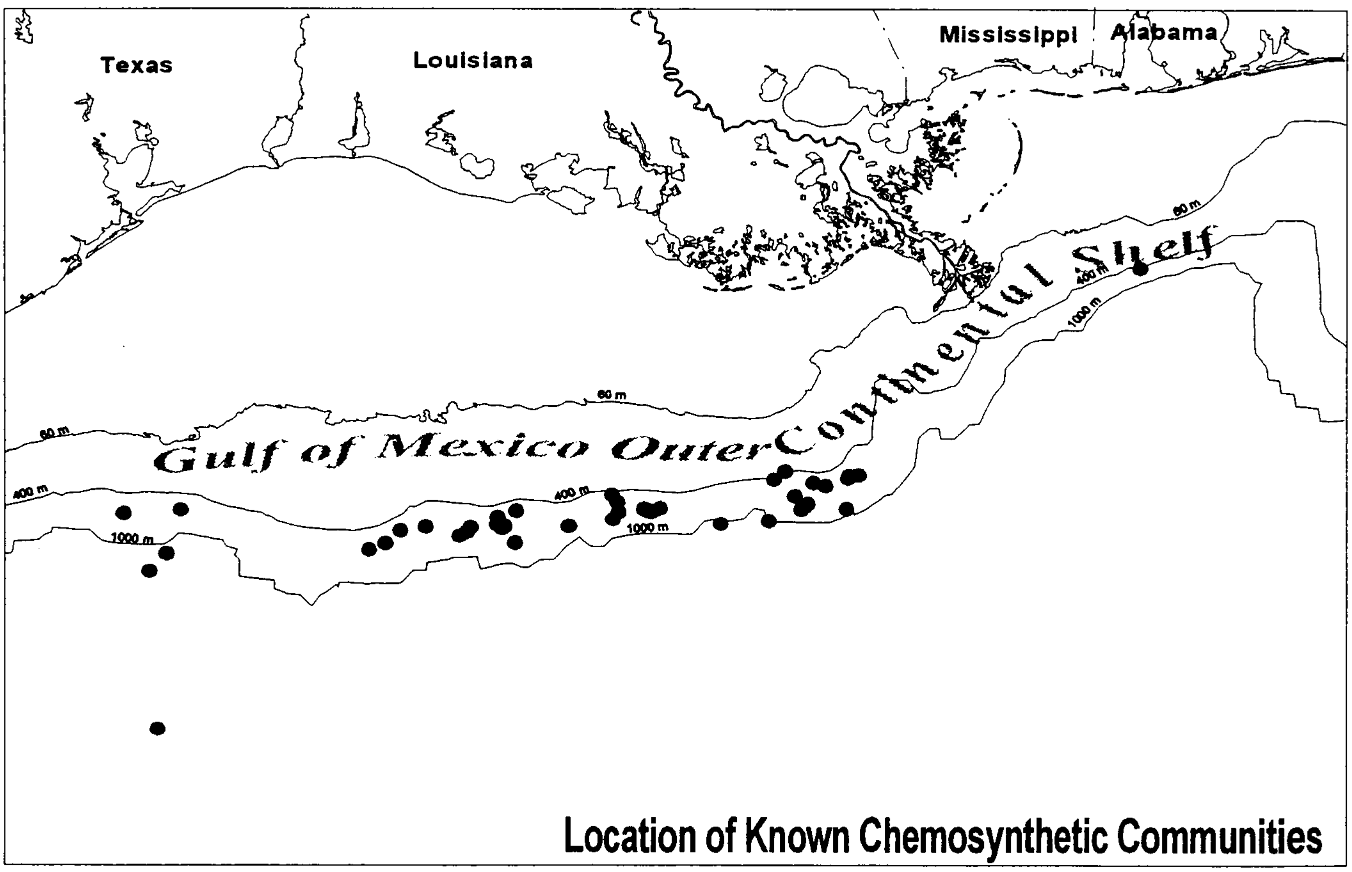
OCS Study
MMS 94-0061

Proceedings: Thirteenth Gulf of Mexico Information Transfer Meeting

December 1993



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

OCS Study
MMS 94-0061

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December 1993

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SUMMARY

The 1993 Information Transfer Meeting (ITM) was by the Gulf of Mexico OCS Region of the Minerals Management Service (MMS) at the Hotel Inter-Continental in New Orleans. The purpose of the ITM is to foster sharing of information among participants about current research, accomplishments, or issues of concern to the MMS. Presentations at the ITM pertained to the MMS Gulf of Mexico Outer Continental Shelf (OCS) oil and gas program, as well as regional environmental, social, or economic concerns, or current OCS industry activities or technologies. This year's ITM also served as an opportunity for the public to comment on the information base available for future oil and gas lease sales, particularly those proposed in the Western and Central Gulf of Mexico. The audience included scientists, managers, and laypersons from government, academia, industry, environmental groups, and the general public.

Technical sessions this year included Legislation and Regulatory Issues, Chemosynthetic Communities, Oil Spill Response, University Research Initiative Progress Reports, GOOMEX and LATEX studies, Geographic Information Systems, Offshore Mitigation Success Stories, Marine Mammals, Socio-Economic Issues, Current and Pending Bonding Requirements, Coastal Zone Management Issues, MMS Environmental Studies Progress Reports, and a session on Bathymetry and Coastline Data.

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ACKNOWLEDGEMENTS

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

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

Particular appreciation is extended to the University of New Orleans, Office of Contract Services, the contractor who handled the logistics for the meeting and compiled the proceedings, and to the Hotel Inter-Continental for its accommodations and service.

OPENING PLENARY

Session: OPENING PLENARY

Chair: Mr. Gary D. Goeke

Date: December 14, 1993

Presentation	Author/Affiliation
Introduction	Mr. Gary D. Goeke Environmental Studies Section Minerals Management Service Gulf of Mexico OCS Region
Agency Welcome	Mr. Chris Oynes Acting Regional Director Minerals Management Service Gulf of Mexico OCS Region
Historical Perspectives of the Oil and Gas Industry	Mr. Paul Kelly Rowan Companies, Inc. Houston, TX
Beyond the Shelf: Future Reserve Growth in the Gulf of Mexico	Mr. Robert H. Peterson Resource Evaluation Minerals Management Service Gulf of Mexico OCS Region

INTRODUCTION

Mr. Gary D. Goeke
Environmental Studies Section
Minerals Management Service
Gulf of Mexico OCS Region

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

ITM INTRODUCTION

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

The ITM agenda is planned and coordinated 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 by invitation through personal contacts between session chairpersons and speakers who have demonstrated knowledge or expertise on the subject. A few presentations are accepted in response to our calls for contributed papers.

Meeting support funding is provided through the MMS Environmental Studies Program. All meeting logistical support is provided by a contractor (Office of Conference Services, University of New Orleans) 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 to revisit some of the basic considerations in OCS operations.

AGENCY WELCOME

Mr. Chris Oynes
Acting Regional Director
Minerals Management Service
Gulf of Mexico OCS Region

Welcome to our Information Transfer Meeting. This is a very important meeting for MMS in the Gulf of Mexico Region, one that focuses on significant developments in the oil and gas industry. We have sessions on a wide variety of issues, including three on the physical oceanography program, one on the GOOMEX study, one on chemo-synthetics, one on deep-water development, and one on bonding. We're glad to have you here, and we hope that you have a good time over the next couple of days.

HISTORICAL PERSPECTIVES OF THE OIL AND GAS INDUSTRY

Mr. Paul Kelly
Rowan Companies, Inc.
Houston, Texas

I want to express my appreciation to the Gulf of Mexico region of MMS for inviting me to participate in the 1993 ITM.

Information sharing among the various stakeholders in the Gulf of Mexico OCS program is one of the factors that makes the Gulf the most successful and important offshore oil and gas province in the United States. It will help sustain its progress and importance in the future.

You're probably asking yourselves why they asked a drilling contractor to come here this morning to talk about historical perspectives on industry in the Gulf and to speculate on trends for the future. But interestingly enough, drilling contractors are probably in as good a position as anyone to project trends because as companies spend money in various regions, we're the first to feel the impact of where the budget dollar is spent and how much is being spent. We do get a better prospective than some of you might think.

Sometimes it is good to take a look backwards in order to better understand where we may be going in the future. As I put together these remarks for this meeting, it occurred to me that next year will mark the 40th anniversary of the federal oil and gas program in the Gulf of Mexico. The program originated offshore Louisiana and Texas in late 1954. The establishment of a federal program followed years of conflicting federal and state claims for offshore jurisdiction that were motivated largely by the interests of both in offshore oil and gas resources.

This federal and state struggle to control offshore lands was known as the Tide Lands Controversy. The history of this controversy helps explain where we are today.

In 1937, at the urging of the Secretary of the Interior, legislation was introduced to Congress that would confirm federal ownership of lands seaward of the low water mark. In 1938, this proposed legislation was being considered and ultimately defeated in Congress.

The first offshore oil in the Gulf of Mexico was produced offshore Louisiana. The State of Louisiana enacted a law asserting its jurisdiction out to 27 miles offshore. Texas and California also made claims to the sea beds off their shores. Then in 1945, President Truman issued a proclamation asserting federal jurisdiction over offshore resources. That same year, the Department of Justice filed a litigation enjoining offshore lease activities from being administered by the State of California. In 1947, the Supreme Court decided the case against California in favor of the federal government stating that California is not the owner of the three-mile marginal belt along its coast. Thus, the federal government, rather than the state, has paramount rights over that belt incident to which is full dominion over the resources of the soil under that water area including oil. In 1950 as we know, the Supreme Court issued similar findings with respect to offshore claims that had been asserted by the states of Louisiana and Texas. As the nation headed for the 1952 presidential election, the issue of jurisdiction over offshore lands became a hotly debated and important issue. In 1952, Congress passed legislation granting state's ownership and jurisdiction over the first three miles off their coast. Citing the Supreme Court's ruling, President Truman vetoed the bill and called for using offshore oil and gas resources for national defense. One year later he issued an executive order to make the continental shelf a naval petroleum reserve. Meanwhile, presidential candidate Dwight Eisenhower campaigned to pledge his support for the measure that had been passed by congress.

Subsequently, in 1953, Eisenhower signed into law the submerged lands act, which established state jurisdiction over the offshore lands within three miles of shore for three marine leagues in the case of Texas and the Gulf Coast of Florida and federal jurisdiction over the offshore lands beyond those state waters. He stated that this measure recognizes the interest of the federal government in the submerged lands outside the historic boundaries of the state. Such lands should be administered by the federal government and income therefrom should go into the federal treasury. The Eisenhower administration was actually opposed to bills proposing to share OCS revenues and decision making regarding the states.

So you can see, for many years we've had this contention between the state and the federal government for both ownership of the land and sharing of the revenues.

Another significant action regarding the resolution of the matters relating to the continental shelf was the enactment of the OCS Lands Act of 1953. The Lands Act authorized the Secretary of the Interior to lease the federal offshore lands for mineral exploration, development and production and provided for very limited state involvement in the federal program. The OCS Lands Act of 1953 also gave the federal government mandate to develop OCS resources and stated outright that there was an urgent need for further exploration and development of oil and gas resources of the submerged lands of the continental shelf.

Now for the first two decades of the program, the primary focus was on the Gulf of Mexico. The management regime that had been established for the OCS worked quite well from 1953 to 1973 while the program was largely focused on the Gulf. At this time, both states and the federal government were able to receive ample benefits associated with developing oil and gas resources in offshore areas.

In places like Louisiana and Texas, those benefits were as they are today, generally perceived as outweighing the costs involved. And, although the federal government had ownership and authority over OCS resources off their coast, Louisiana and Texas had then as they do today, robust state oil and gas programs both onshore and offshore.
The federal OCS program did not expand to areas other than to offshore Louisiana and Texas until the late 1950s and early 1960s. This first phase of expansion took place on a relatively small scale and piecemeal basis. Some leasing and exploration took place off southwest Florida in the early 1960s. Drilling in the areas ceased in 1961. The OCS program expanded to the Pacific coast beginning in 1963 while exploration did take place. Off Washington and Oregon and central and northern California, the exploration at that time had disappointing results, drilling in those areas stopped by 1967. It was only in the Santa Barbara channel that exploration did lead to discoveries and eventually production. As we all know, in 1969, a blow-out oil spill from a production platform on federal lease in the Santa Barbara channel caused significant environmental damage which attracted a good deal of national attention. With it, the first ground swell of opposition of offshore oil and gas development arose. The Santa Barbara oil spill gave impetus for the enactment of the National Environmental Policy Act (NEPA) of 1969 and the Coastal Zone Management Act of 1972, both of which dramatically changed how the federal OCS program was conducted.

During the second two decades of this forty years, there were additional efforts to expand beyond the Gulf. First, we had the Middle East Oil Embargo which occurred in 1973 and early 1974. In 1974, as Americans had their first experience with sharply rising fuel prices and long waiting lines at gas stations, President Nixon set a goal for an even more expanded OCS program and intended to replace petroleum imports. The Department of the Interior responded with a plan for numerous lease sales in frontier areas, including five off Alaska, five off the Atlantic coast, one off central and northern California, one off Washington and Oregon. All during the period of 1974 through 1978.

While the nation experienced an urgent need to develop domestic energy resources and proposed expansion increased concerns about the environmental and socio-economic effects of offshore development, heightened debate resulted. Congress deemed the matter important enough to establish a special OCS committee to develop legislation and after two years of extended congressional deliberations, the OCS Lands Act was amended extensively in 1978. The OCS Lands Act amendments of 1978 were intended to provide more environmental consideration to allow more state and local government involvement in OCS decision making. Section 18 prescribed the process for developing the five-year leasing schedule that we all know today. Section 19 proscribed the now familiar process for coordination and consultation of state and local governments concerning scheduled lease sales under OCS activities. Although the actual purposes and policies set forth in the 1978 amendments recognized environmental principles, they also furthered that same sense of urgency which is continued through the OCS program like a thread of all the legislation by calling for expedited exploration development.

The next landmark followed the Iranian revolution and the resulting oil supply disruption and price increases of 1979. At this time, the sense of urgency in developing the OCS resources received another boost although the five-year OCS leasing program (1980 to 1985 which was developed by Secretary for the Interior, Cecil Andrus of the Carter administration) provided for continuing to pursue the OCS program. The Reagan administration decided the program was an inadequate and inefficient means for developing OCS resources. In 1982, the Secretary of Interior, James Watt, introduced a new five-year program, and announced the policy of area-wide leasing, intended to make available the largest area of the OCS ever, nearly one billion acres of leasing exploration in the Gulf.

Following the action of Secretary Watt, the debate concerning the OCS program turned extremely contentious. Opponents charged that Secretary Watt was indifferent to the views of coastal states and localities and concerns about potential environmental and socio-economic impacts. And, as the OCS program began to expand in 1982, states and environmental groups that did not believe Secretary Watt was being responsive enough in their objections, challenged the Secretary's decisions in court. A great majority of these lawsuits failed. Even those who were successful did not have a significant curtailing effect on the OCS program. Starting with the state of California, interested and affected parties turned to the annual congressional appropriations process as a new means for delaying leases to which they objected. Fiscal year 1982 through fiscal year 1993, the acreage covered by these congressional moratoria grew from 0.7 million acres off California to a total of over 266,000,000 acres off the Pacific and Atlantic coast in the eastern Gulf of Mexico, and in the Bering Sea off Alaska. Over the years, the moratoria also expanded the restricting of issuance of new leases to prohibiting pre-lease activities and exploration and development activities on existing leases.

By 1988, due to prevailing controversy and conflict, the OCS program became a presidential campaign issue. As a consequence of pledges made during that campaign, President Bush, on 26 June 1990, issued directives to cancel all scheduled sales off California, the north Atlantic, Washington and Oregon, to withdraw those areas from leasing, until after the year 2000 except for 87 tracts off southern California that could be considered for leasing in 1996 at the earliest and only if studies satisfactorily addressed those concerns related to those tracts for lease. Then the president directed MMS to begin a process that might lead to buying back existing leases in the eastern Gulf of Mexico off southern Florida. To the degree that President Bush's directives were designed to eliminate motivation for congressional moratoria it did not succeed. Congress continued to enact moratoria for the areas withdrawn by the presidential order and even expanded prohibitions to new areas. The president's announcement did not specifically address the Alaska OCS. The state of Alaska has generally been receptive to the OCS program to opposition limited to certain specific such as Bristol Bay which are sensitive to the standpoint of the issue. Leasing and exploration off of Alaska has declined substantially as elsewhere. This has been due mainly to declining world oil prices and the lack of major discoveries there. However, a recent discovery by ARCO and Phillips and Cook Inlet has sparked a new interest in that area.

The point of this history is to demonstrate once again how we have now come full circle to the federal OCS program that is limited in focus to the Gulf of Mexico just like it was 40 years ago. And it almost seems bound to remain so until the turn of the century.

During the past 20 years, whenever the OCS program has ventured outside the Gulf of Mexico, it has encountered strong political opposition. Moreover, limited exploration drilling, which has occurred in the Atlantic and Pacific coasts with the exception of California, has not been successful from a geological standpoint. We did manage to drill eight wells in Georgia's bank in the north Atlantic in the Baltimore canyon in the mid-Atlantic in the late 1970s and early 80s, with no commercial discoveries. There were indications of natural gas there but no commercial discoveries.

Industry's reaction? The main goal of the five-year program from 1992 to 1997 is a predictable OCS schedule. There has been a lot of opposition and tremendous cost incurred by the companies in trying to develop projects on existing leases such as Point Arguello off southern California, Manteo Natural Gas Prospect offshore North Carolina, and even gas developments off the Florida Panhandle. While each of these projects has impacted a specific group of companies that hold those leases, the rest of the industry has been watching carefully. Even though we may obtain some leases we may not be able to develop them. And even more unsettling to the industry, are the efforts to mandate the cancellation and repurchase of existing leases. These unresolved issues have had a dampening effect on the industry's interest in pursing oil and gas resources outside the central and western Gulf of Mexico. Up to now, industry has generally viewed leases in the United States as reliable relative to contracts with the foreign government. That view has changed given what has happened with respect to reliabilities of some of these leases, and the situation in the U. S. is little better than that of a developing country. At the same time, the acreage leased in the past three years indicates that even industry interest in the central and western Gulf has dropped somewhat. This is largely in response to the persistence of low world oil prices, the economic downturn, and the anticipation of more costly environmental regulations. The decline of the nation's oil and gas industry has been dramatic as 450,000 jobs lost over the last ten years. Any major oil and gas company has redirected their efforts overseas and radically cut back U.S. operations.

A recent study by the American Petroleum Institute shows 64 percent of exploration dollars for 18 U.S. oil companies went overseas in 1992. That represents \$3.4 billion and that makes three consecutive years that foreign expenditures have accounted for more than half of world-wide explorations spent by U.S. majors. Additionally, a May 1992 Arthur Anderson survey found that restrictions and regulations were forcing companies overseas more than costs.

Dramatic changes are now under way in the petroleum sector throughout the world. The winds of private organization are blowing in all regions of the former Soviet Union and Latin America. Economics prevails over politics for a change outside the U.S. We are seeing a tremendous drive for cost-cutting and efficiency. The era of oil nationalism has given way to the economic reality. The national oil companies are selling assets and shares to private investors. Throughout the world, there is a new emphasis on market development. Governments are competing for oil and gas investment capital with tax systems and contract earnings. We all have to understand that international oil company managers in New Orleans, Lafayette, Houston are competing now with their counterparts in London, the Hague, Moscow, Jakarta and Bogatá for limited amounts of exploration and development capital in their countries.

BEYOND THE SHELF: FUTURE RESERVE GROWTH IN THE GULF OF MEXICO

Mr. Robert H. Peterson
Resource Evaluation
Minerals Management Service
Gulf of Mexico OCS Region

Over the last 45+ years the bulk of exploration effort and the resulting field discoveries have come from the Shelf (water depths of less than 600 feet) of the Gulf of Mexico (GOM). Due to these successes, 10 percent of the U.S. oil and 22 percent of the U.S. gas production comes primarily from the GOM Shelf area. The shelf, however, is becoming an increasingly mature exploration area, and a continued expansion in exploration effort is required to find ever smaller fields. New reserve additions are not offsetting production. Certainly, new exploration concepts like the subsalt play (Exxon's Prospect Mickey, MC 211 in deep water, and Phillip's Prospect Mahogany, SS 349, on the shelf), and new technical advances such as 3D seismic techniques will guarantee a long future life for shelf exploration and reserve additions within current field boundaries. However, for significant reserve additions to the GOM to occur, industry will need to discover large new fields in the deep-water areas of the GOM. Fortunately, the geologic conditions are favorable for such accumulations (abundant traps, good reservoirs and widespread hydrocarbon charge), but many engineering challenges exist for the development not only of the largest of these accumulations, but also for the development of the more moderate (though still large by shelf standards) discoveries.

In the GOM today, 835 oil and gas fields (730 active, 105 depleted) have been discovered with proved original recoverable reserves estimated at 11.08 billion barrels of oil and 132.7 trillion cubic feet of gas (34.8 billion barrels of oil equivalent). Figure 1.1 shows the location of these fields. Production at the end of 1992 was 298 million barrels of oil (MMBO) and 4.6 trillion cubic feet of gas (Tcfg). As can be seen from Figure 1.1, almost all of these fields are located on the shelf.

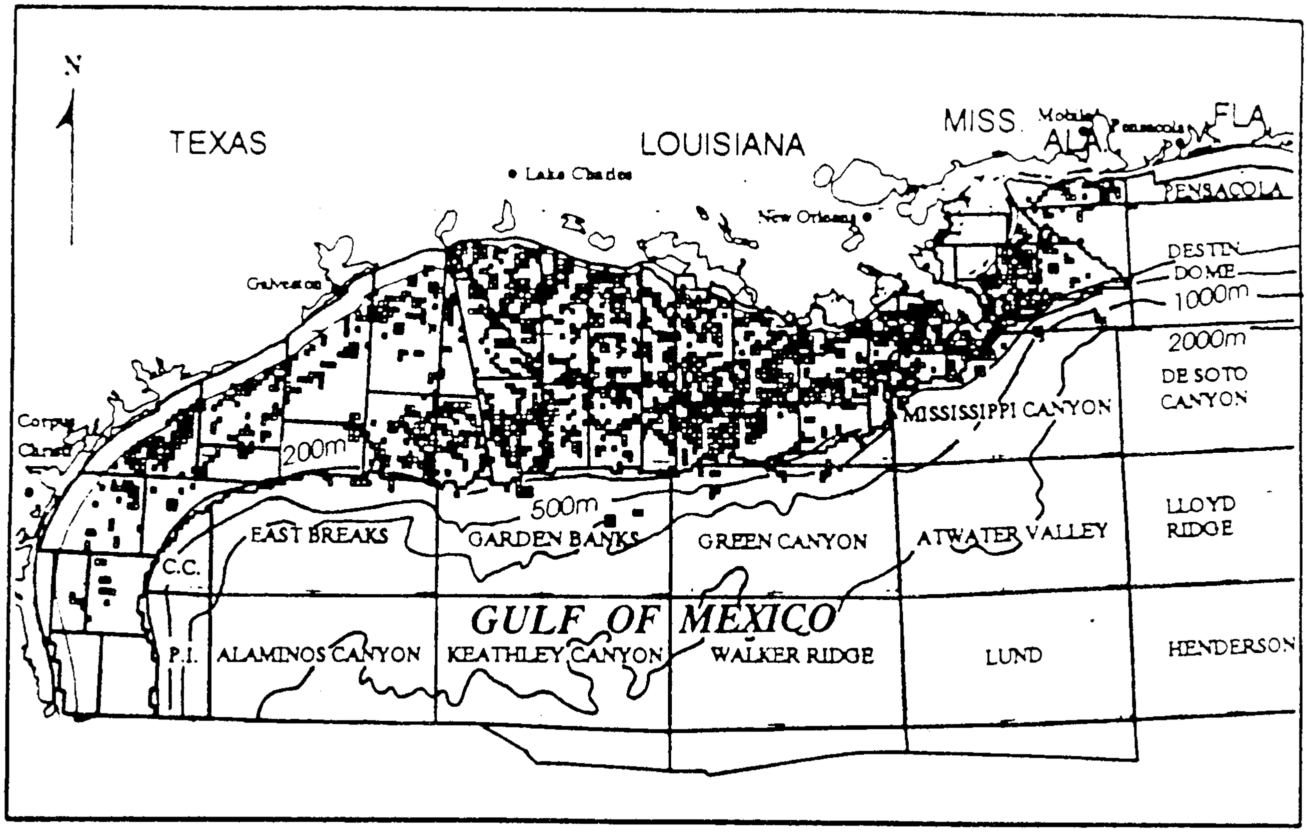

Figure 1.1. Gulf of Mexico, 835 proved fields (730 active and 105 depleted).

When the number of fields and their average size are plotted against the field's discovery year, Figure 1.2, two important trends are evident: (1) more fields are being discovered, but (2) the average size of these fields has been declining dramatically. This same trend can be seen in the data in Table 1.1 which is a summary, by decade, of the exploration effort expended in the GOM and the results of this effort. The number of exploration wells drilled in each decade has increased over the prior decade, and the number of fields discovered has also increased. The discovered hydrocarbon volumes have remained relatively constant, however, at least until the decline in the decade of the 1980s.

Figure 1.3 summarizes the data contained in Table 1.1.

Another demonstration of the increase in exploration effort and its decreasing rewards on the shelf is seen in Figure 1.4, where the amount of hydrocarbons discovered in a given year is divided by the total footage of exploration wells for that year. The result is a declining amount of hydrocarbons discovered for each foot of exploratory drilling, a reflection of the increasing maturity of shelf exploration potential.

It should be noted that the precipitous drop on the graph for the three most recent years (dotted line) is somewhat misleading. The volumes of hydrocarbons used in this graph are proved reserves, reserves that can be estimated with reasonable certainty to be recovered under current economic conditions. Proved reserves must either have facilities that are operational at the time of the estimate to process and transport those reserves to market or a commitment or reasonable expectation to install such facilities in the future. Obviously, many hydrocarbon discoveries (especially in high-cost areas like the deep water) may take several years of evaluation before there is enough certainty in their economic viability to commit to develop and move these discovered reserves into the proved reserve category. This delay causes an under-reporting of reserve addition for the most recent years exploratory drilling. Another factor that has a similar effect is the normal growth in field size after the initial estimate is made and further development drilling takes place.

Figure 1.5 is a map showing such unproved field discoveries where a well has drilled producible hydrocarbon pay, but where no commitment to develop has yet occurred. As the decision to develop these unproved fields occurs, the curve on Figure 1.4 for the most recent year's drilling will rise to the approximate level seen in the mid 1980s.

Large fields are extremely important in the overall reserve picture of the GOM. The 100 largest fields (approximately 100 MMBOE and greater in size) represent just 14 percent of all fields discovered, but contain 62 percent of total reserves in the GOM. Equally important is the fact that the large fields tend to be found early in the exploration effort. Figure 1.6 plots Reserves by Discovery Year in the GOM and indicates two important facts about the GOM shelf:

1) By comparing remaining reserves to original reserves it can be seen that much of the reserves discovered over the last 30 years have already been produced, and, in fact, since 1984 new reserve discoveries are no longer offsetting annual production. Remember the most recent year's data are not yet adequate for final assessment.

2) Large fields tend to be discovered early. Only one of the 10 largest fields on the shelf was discovered after 1962 (EI 330), and only six of the top 20 fields were discovered after 1962. Equally important, since 1980, only one field containing more than 200 MMBOE was discovered on the shelf (MI 668). However, in contrast to the shelf, the deep-water area of the GOM, where only limited exploration and development drilling have occurred, there have already been three 200 MMBOE and larger field discoveries.

It can be expected that there will be some additional large discoveries made on the shelf, but it is in the deeper water areas of the GOM where we must look to find the new large field discoveries so important for reserve growth in the GOM.

Fortunately the deep-water GOM is still a lightly drilled frontier area.

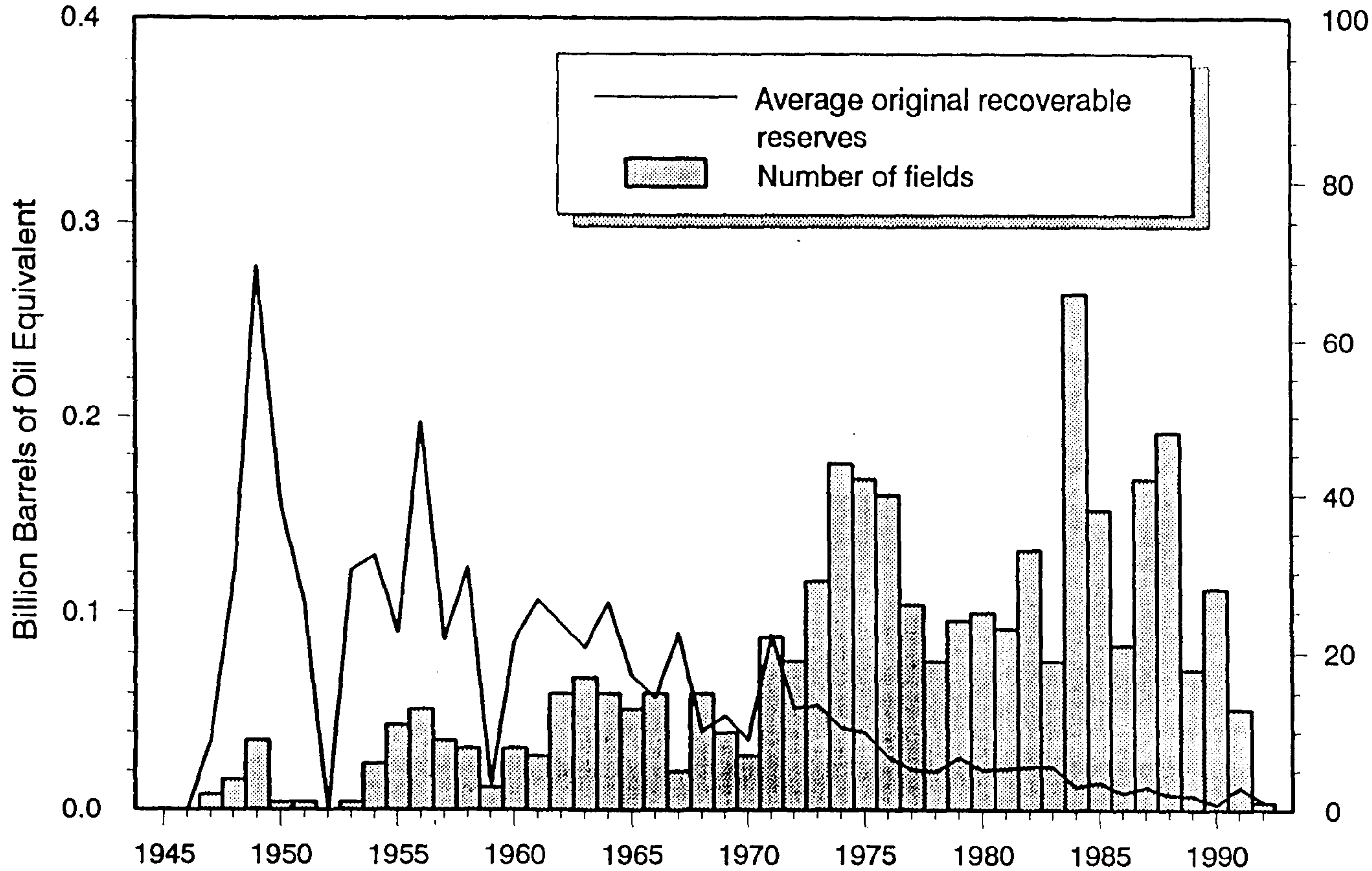

Figure 1.2. Number of proved fields and average size by field discovery year.

Table 1.1. Exploration Effort and Reward in the Gulf of Mexico.

YEARS 19-	EXPL. WELLS DRILLED	DISC. FIELDS	AVG. FIELD MMBOE	EXPL. WELLS/ FIELD	CUMMUL-ATIVE % DISC.	VOL. DISC. BBOE
47-59	442	69	139	6.5	28	9.6
60-69	2,377	117	77	20	55	9.0
70-79	3,356	262	42	13	88	11.1
80-89	4,356	296	14	15	100	4.2

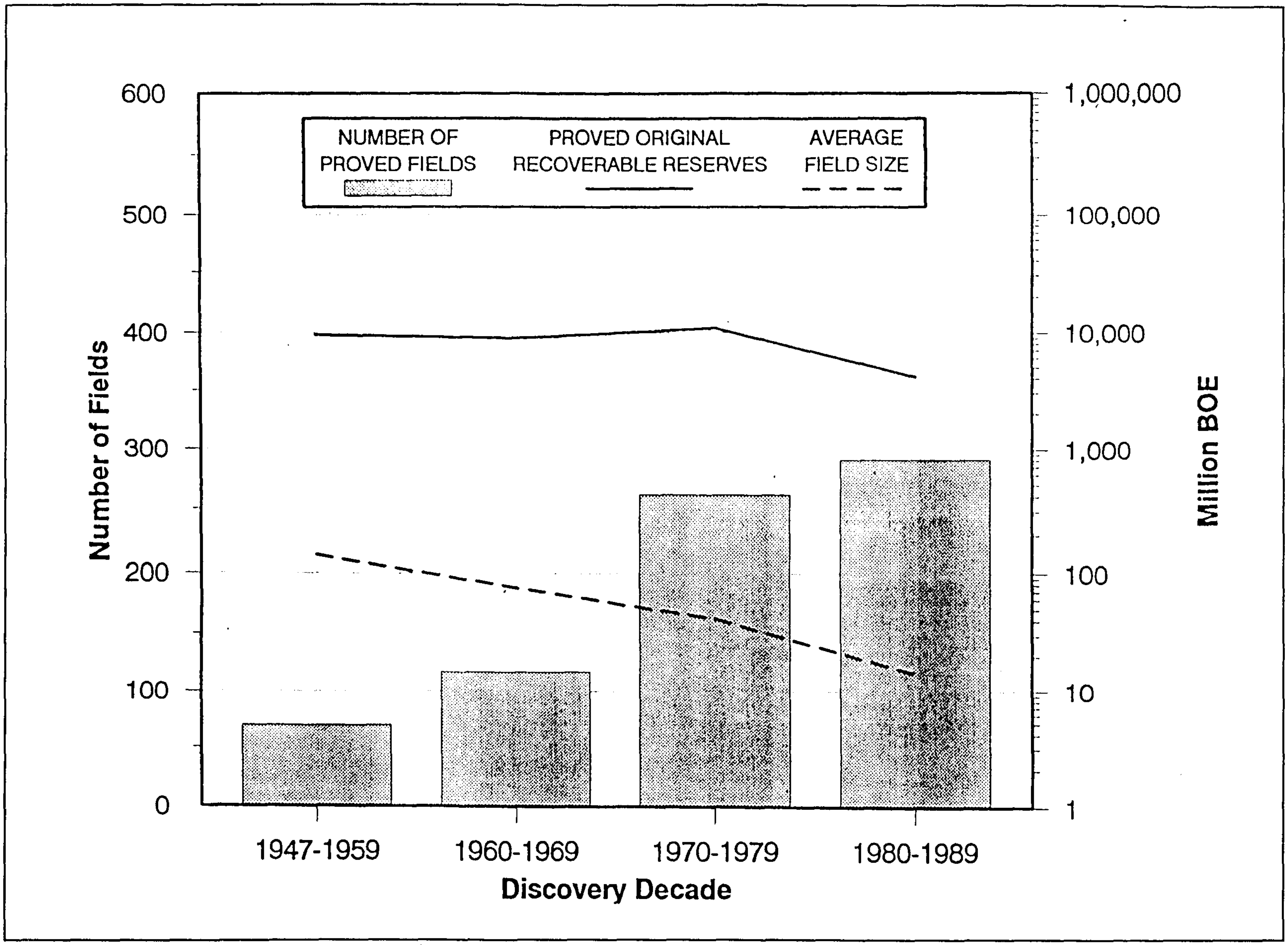

Figure 1.3. Number of proved fields, proved original recoverable reserves and average field size by discovery decade.

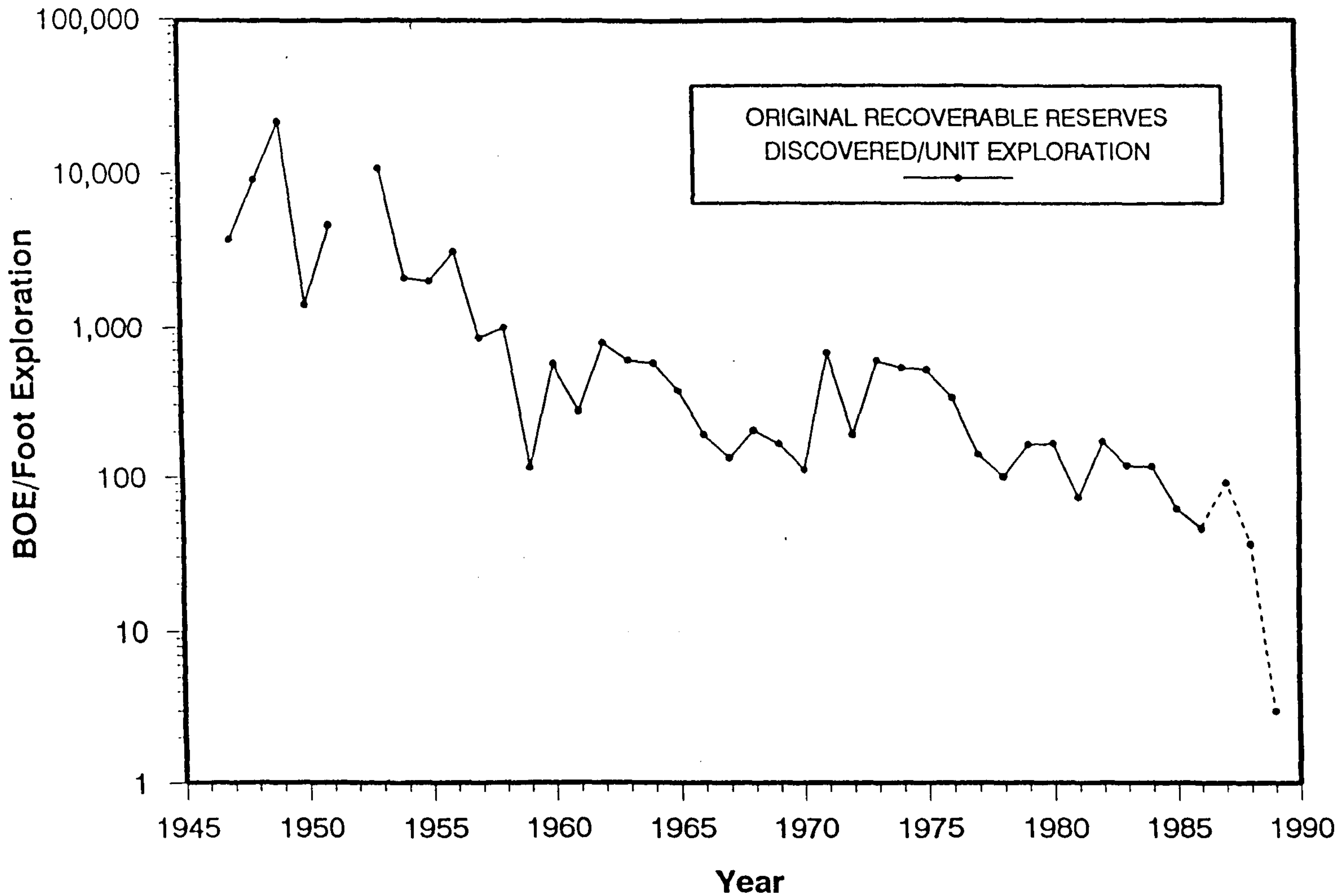

Figure 1.4. Proved original recoverable reserved (BOE) discovered per foot of exploratory drilling by year.

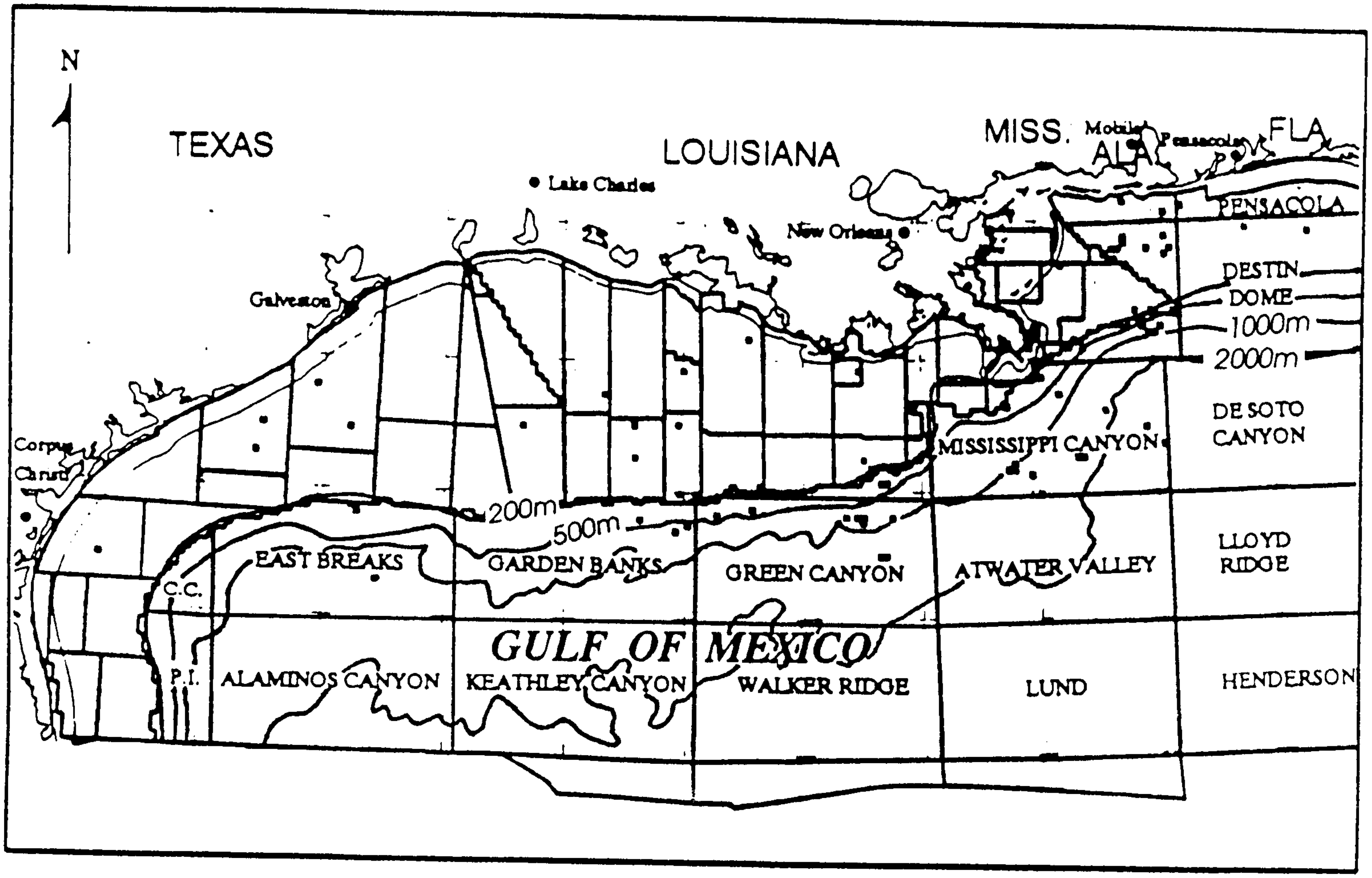

Figure 1.5. Location of 67 unproved active fields.

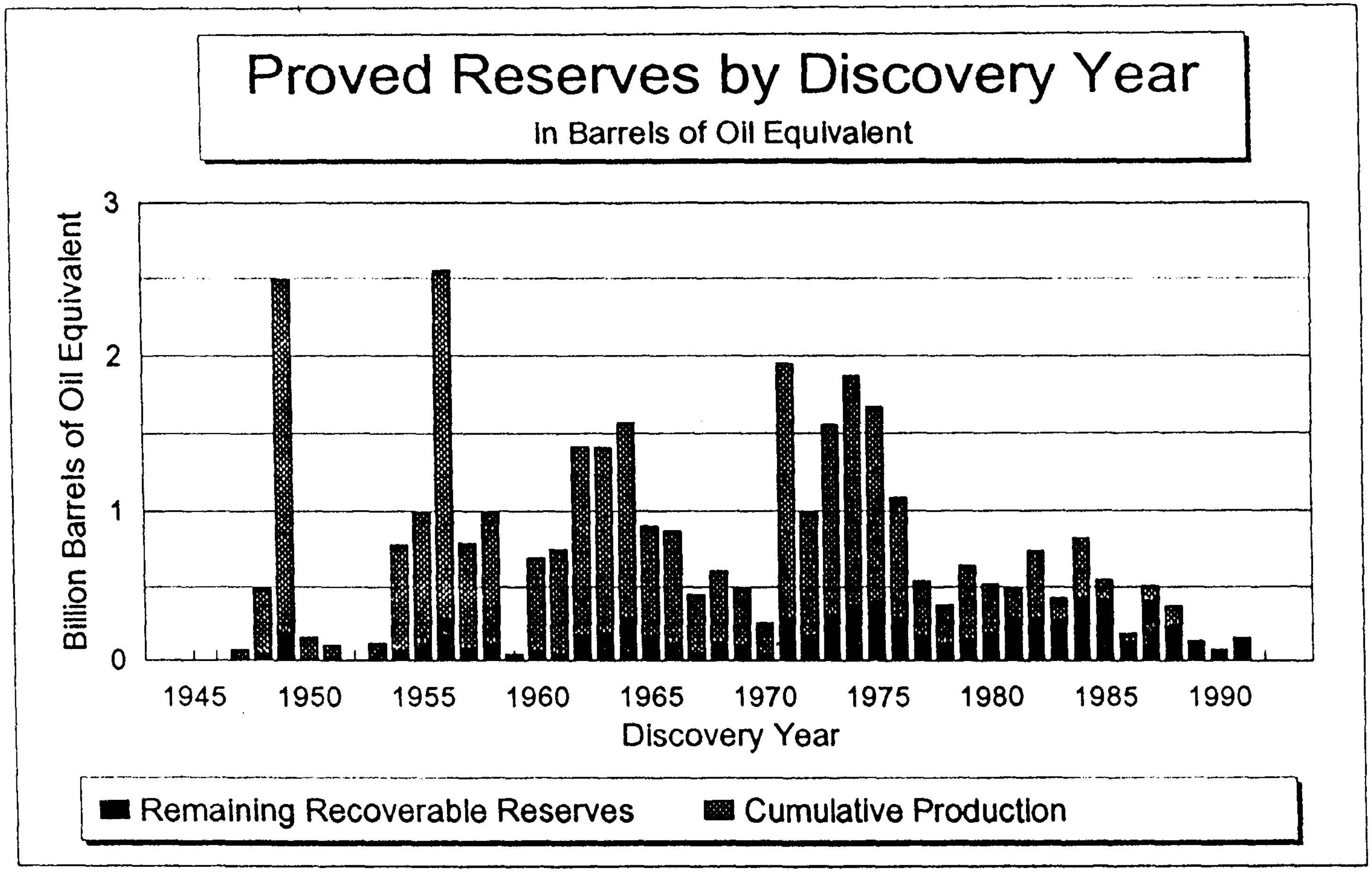

Figure 1.6. Proved reserve additions by discovery year.

BLOCKS TESTED IN THE CENTRAL AND WESTERN GOM 5/93

OF THE 7,505 SHALLOW WATER BLOCKS (<1,500 FT. WATER), 4,700 HAVE A WELL DRILLED SOMEWHERE ON THE BLOCK (63 PERCENT).

OF THE 7,710 BLOCKS IN DEEP WATER (>1,500 FT. WATER), ONLY 172 HAVE A WELL DRILLED ON THE BLOCK (2 PERCENT).

Of course, any optimism for the deep-water GOM depends on the assumption that the deep water will be at least partly as prolific as the shallow water. Fortunately, the geologic elements (abundant traps, good reservoir and widespread charge) that are present in the shallow-water area and are responsible for its hydrocarbon productivity are also present in the deep water.

THERE EXISTS A STRONG GEOLOGIC BASIS FOR CONTINUED DEEP WATER SUCCESSES.

SHALLOW WATER (0-1,200 feet)	DEEP WATER (>-1,200)
SALT MOVEMENT, WHICH PRODUCES ABUNDANT TRAPS	SAME
DELTAIC AND SHELF RESERVOIRS	TURBIDITE RESERVOIRS
UNDERLYING MESOZOIC SOURCE ROCKS	SAME
33.8 BBOE PROVED RESERVES	TO BE DETERMINED (already 1 BBOE PROVED RESERVES)

TRAP: Numerous studies, seismic data, and well penetrations indicate that allochthonous salt underlies the entire OCS deep-water GOM area, out to and even beyond the Sigsbee escarpment. This salt provides the tectonic force that generates hydrocarbon trapping elements such as anticlinal closures over salt, pinchouts against salt, radial fault traps, sediment truncations against salt, and faults. These salt piercements also provide a conduit for both Jurassic and Upper Cretaceous source rock derived hydrocarbons to migrate into the reservoir section. The salt also provides topographic relief on the water bottom that can localize turbidite sand deposition and that aids in the creation of stratigraphic traps when these turbidite sands pinchout against topographic salt highs.

RESERVOIR: Twenty years ago, few believed that thick, productive and widespread reservoirs existed in the deep-water area. We now recognize that tremendous amounts of sand have been carried out into the deep marine during lowstands of sea level. Well control indicates widespread deposition of turbidite sands from East Breaks to Mississippi Canyon. In fact, a recent test in Keathley Canyon Block 255 located in over 5,800 feet of water, encountered massive amounts of turbidite sands throughout most of the well's 21,472 depth. Although thick reservoir sands appear common in the deep-water GOM, the important question of reservoir productivity is harder to assess. One important example of high productivity reservoirs is at Shell's Bullwinkle field. At Bullwinkle field (Green Canyon Block 65), the turbidite reservoir "J" sand has a production rate of 58,500 Barrels of Oil per Day (bopd) and 90 Million Cubic Feet of Gas per Day (Mcfgd) from only 20 wells. Nine conventionally completed wells have consistently produced at rates above 4,000 bopd (from AAPG abst., 1993, Holman and Kohli). Such productivity will be necessary to justify the high expenses necessary to develop these deep-water accumulations.

CHARGE: Charge is the result of the presence of a source rock, matured and migrated through the reservoir section. N. Terence Edgar and Jerry Clayton (Edgar and Clayton 1992) suggest an oil source rock under the entire GOM, and there is ample physical evidence to support a widespread mature source rock across the entire deep-water area. The presence of discoveries across the deep-water GOM is certainly encouraging. Even more widespread is the occurrence of hydrocarbon seeps on the ocean floor. These seeps tell us that mature source rocks are present and that these hydrocarbons are migrating through the objective reservoir section to the ocean floor. Although seeps indicate failed traps or a lack of a trap, there is a good association of seeps and field discoveries. Seeps have been examined from the shelf and out to Alaminos Canyon in 2,200 meters of water (7,150 feet) (Sassen 1993). Satellite imagery also reveals natural oil slicks on the ocean surface across much of the deep-water GOM region (Amos *et al.* 1993).

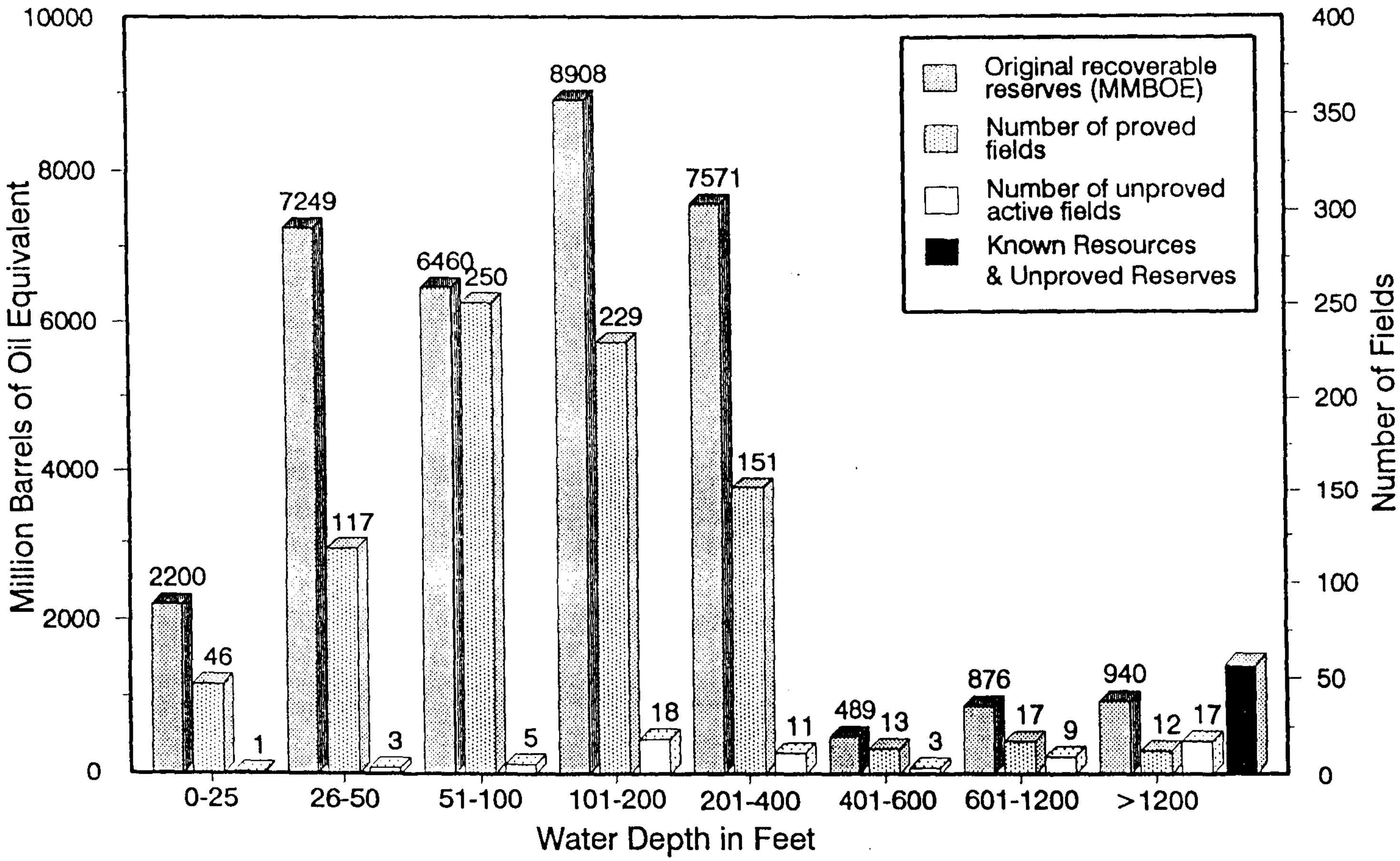

Figure 1.7. Field and reserves distribution by water depth.

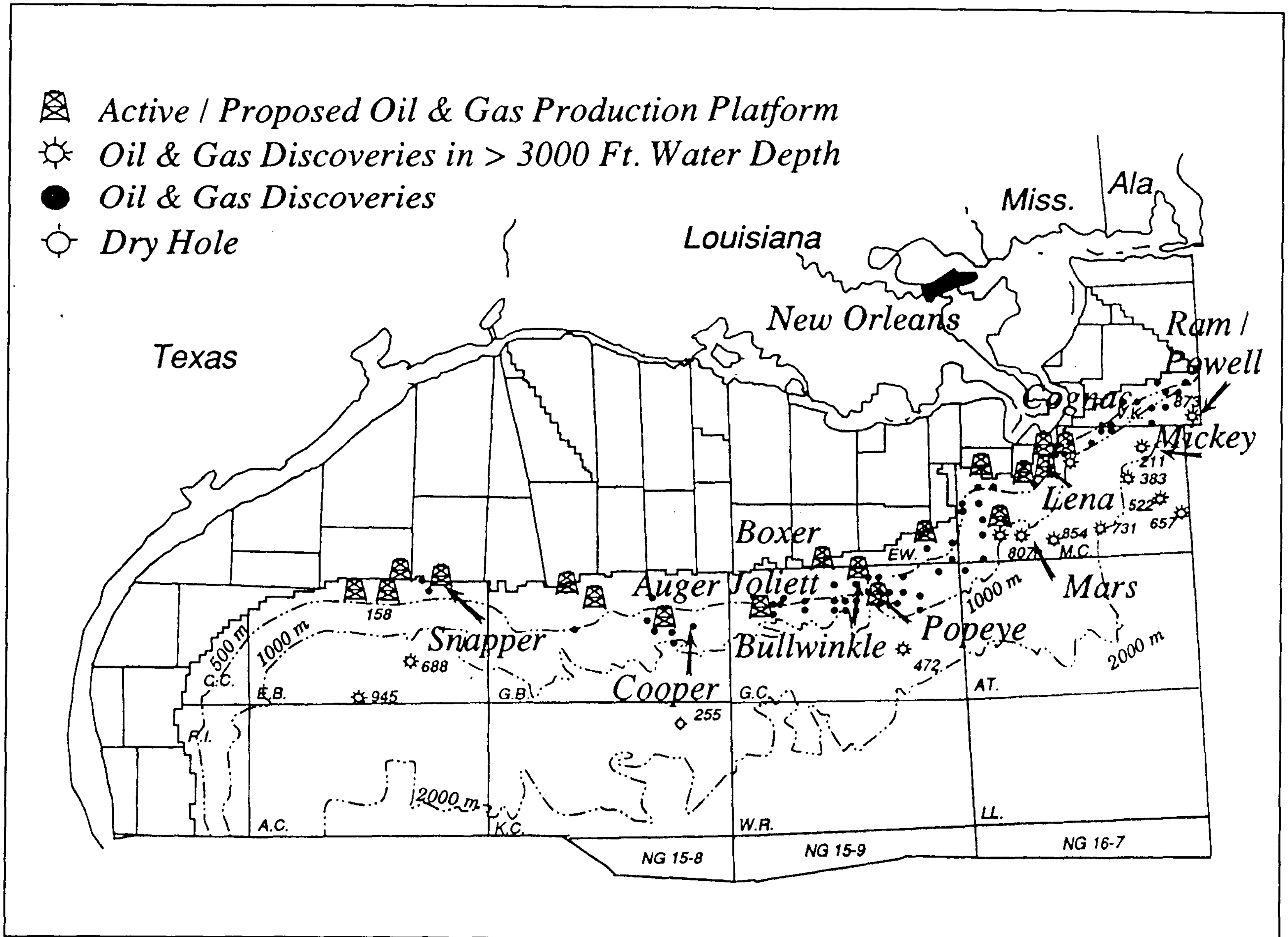

Figure 1.8. Deep-water and Flexure Trend oil and gas fields, Texas-Louisiana.

Table 1.2. Likelihood of a Field Discovery reaching production status. Fields in greater than 600 feet of water, 12/93.

74 field discoveries
- 30 expired
  - 2 abandoned
    - 22 are active unproved (waiting decision)
      - 20 are proved
        - 14 are producing

This geologic optimism is being justified by a number of recent deep-water discoveries. Figure 1.7 shows the number of fields and their reserves by water depth. As already mentioned, the bulk of fields and reserves have been developed on the shelf, but the deep-water areas are already making an impact. Only 3.5 percent of the fields in the GOM are in greater than 600 feet of water but represent 5.2 percent of the reserves; this percentage will certainly grow when large new discoveries like Mars, MC 807 and GB 260 are added to the proved reserve figures. Of particular interest are the discoveries occurring in greater than 1,200 feet of water, where proved reserves are approaching 1 billion barrels of oil equivalent. Several other discoveries have been drilled that suggest an additional 1.5 billion barrels of oil equivalent that may be added to GOM reserves. Figure 1.8 shows the distribution of some significant deep-water and flex trend discoveries in the GOM. It is worth noting that these discoveries reach from East Breaks west to Viosca Knoll and Mississippi Canyon an—area some 572 miles wide—and from the shelf edge to 1,425 meters (4,700 feet) water depth.

Already there are 10 deep-water accumulations that, if developed, will rank in the top 100 fields in the Gulf of Mexico.

In the deep-water, field sizes range from a few tens of millions of barrels up to several hundreds of millions of barrels. Certainly the largest fields will be developed, but the moderate accumulations will be the ones to benefit most from advancing technology. The development challenge is great, and the mere presence of a hydrocarbon accumulation is no guarantee that development will take place. Table 1.2 shows the history of field discoveries beyond the shelf and how many have resulted in production.

The shelf is where the bulk of reserves have been discovered in the GOM, but new reserve additions have begun to decline due to decreasing field size. Large field discoveries hold the key to future reserve growth in the GOM, and these new large fields must come from the deep-water areas of the GOM. Fortunately, the key elements of abundant salt-generated structures and associated traps, mature source rocks and widespread thick and productive reservoirs are present throughout the deep-water areas of the GOM. Already several large discoveries are due to begin production in the deep-water GOM, and the likelihood of many additional significant discoveries is good.

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SESSION 1A

CURRENT LEGISLATIVE AND REGULATORY ISSUES

Session: CURRENT LEGISLATIVE AND REGULATORY ISSUES

Chair: Ms. Carla M. Langley

Date: December 14, 1993

Presentation	Author/Affiliation
Current Legislative & Current Regulatory Issues	Ms. Carla M. Langley Minerals Management Service Gulf of Mexico OCS Region
Legislative Perspective and Outlook	Ms. Jill Stivers Martin Minerals Management Service Office of Congressional and Legislative Affairs Washington, D.C.
Environmental Regulations: MMS Perspective	Mr. John Goll Minerals Management Service Headquarters Herndon, Virginia
Regulations for the GOM OCS	Mr. Scott Wilson U.S. Environmental Protection Agency Region VI Dallas, Texas
Air Quality Regulations for the Eastern Gulf of Mexico	Mr. Scott Davis U.S. Environmental Protection Agency Region IV Atlanta, Georgia
Summary: Current Legislative and Policy Issues	Mr. Harold Cargol Division Landman on behalf of the American Petroleum Institute Offshore Division Texaco Exploration and Production Company
Offshore Operators Committee (OOC)	Mr. Ron E. Rutherford Division Manager of CONOCO

CURRENT LEGISLATIVE AND REGULATORY ISSUES

Ms. Carla M. Langley
U.S. Minerals Management Service
Gulf of Mexico OCS Region

CHAIR OPENING REMARKS

The six speakers in the Regulatory Issues Session discuss current legislative and regulatory issues within their respective areas of expertise. The session primarily addresses current legislative and regulatory issues for the offshore oil and gas industry operating in the Gulf of Mexico.

Briefly, the session structure includes two speakers with the Minerals Management Service (MMS), two speakers with the U.S. Environmental Protection Agency (EPA), and two spokespersons each representing an oil and gas industry group. The MMS speakers are both based at the Headquarters office. The EPA speakers are representatives of the two regional offices responsible for oil and gas operations in the Gulf of Mexico based in Atlanta and Dallas. The American Petroleum Institute and the Offshore Operator's Committee spokesperson address legislative and regulatory issues, respectively.

Ms. Carla Langley is an Environmental Scientist in the Office of Leasing and Environment in the Gulf of Mexico Region (GOMR). Ms. Langley oversees publications coordination and information transfer for the GOMR Environmental Studies Section. She is a graduate of the University of New Orleans in Louisiana.

LEGISLATIVE PERSPECTIVE AND OUTLOOK

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BRIEF RECAP OF THE 101ST CONGRESS

The 101st Congress was productive, especially at the close of the session: nine laws were passed which were of interest to the Minerals Management Service's Offshore program. Of note, the 1990 Budget Summit and agreement, which set strict spending caps on discretionary spending, also set the tone for what future Congresses could and could not do. The results of that agreement can be seen both in legislation that **was not** passed (for example, in the OCS provisions of the Energy Policy Act of 1992 due to "pay-go" implications) and in legislation that became a high priority for passage (103rd Congress appropriations bills, budget bill, second round of budget cuts, emergency supplemental bill).

When I appeared before this group in December 1990, I predicted the following for the 102nd Congress with respect to issues of interest to the Offshore program:

1. the focus of moratoria will shift primarily to areas offshore Alaska (particularly the Chukchi and Beaufort) and to some extent, to certain traditional areas in the central and western Gulf;

2. marine sanctuary status will be sought for several areas legislatively since the administrative process is so slow. Legislative designations will carry permanent oil/gas/mineral prohibitions; and

3. Congress will focus on OCS revenue sharing as well as various amendments to the OCSLA.

ACCOMPLISHMENTS OF THE 102ND CONGRESS

Was I correct in my assessment? The simple answer is that I was close. But before I recap what legislation passed the 102nd Congress of interest to the Offshore program, especially the Gulf of Mexico region, I would like to put the work of the 102nd Congress into a context that helps explain not just what happened but why it happened as well.

- Unlike the 101st Congress (or, as we will see, the 103rd) the 102nd Congress was not a very productive one.
- This Congress could be characterized by internal problems and charges of gridlock (in the last two years of the Bush Administration, the president vetoed 21 bills in 1992).
- Its internal problems included the Clarence Thomas confirmation, the House Bank and Post Office scandals, and the Keating Five investigation.
- Possibly the lack of a clear and forceful legislative agenda by the Administration helped focus the spotlight on these internal problems.
- In fact, most agree that the high point of the 102nd Congress was in the opening days of the session when a thoughtful and nonpartisan debate on a resolution to go to war in the Persian Gulf was debated.
- After that, it was downhill; a combination of partisan politics and the 1990 budget agreement made domestic progress next to impossible.
- The 102nd Congress did set some records, in terms of retirements and primary defeats by incumbent members (72 Representatives and nine Senators). Also, by adjournment, those campaigning faced the most "anti-incumbent year in decades." It was also a presidential election year.

LEGISLATION PASSED BY THE 102ND CONGRESS

But before Congress adjourned, what did they do of interest to the Offshore program? In terms of environmental legislation, they began work on the Clean Water Act and Endangered Species Act reauthorizations, and they begin work on legislation to elevate EPA to a Cabinet-level department.

Towards the end of the session, some in Congress begin to focus their attention on both the Gulf of Mexico and the domestic oil and gas industry: S.3127 (Johnston)—deep water incentives and S. 2627 (Gramm) and S. 3122 (Bentsen)—Gulf of Mexico protection. None of the Gulf of Mexico bills received a hearing; however, the deepwater incentives bill did, and as we will see later, almost became a part of comprehensive energy legislation that was passed at the end of the 102nd Congress.

1) Title II of P.L. 102-587: National Marine Sanctuary Act Reauthorization

- reauthorizes the program through FY 1996;
- requires federal agencies to consult with NOAA on proposed actions likely to harm sanctuary resources;
- streamlines the designation process;
- strengthens enforcement and civil penalties for violations;
- designates two new marine sanctuaries: Stellwagon Banks (Mass.) and Hawaiian Islands Humpback Whale sanctuary; and
- prohibits oil/gas/mineral activities permanently in three sanctuaries: Stellwagon Banks, Monterey Bay and Olympic Coast.

2) Pipeline Safety Act (P.L. 102-508)

- reauthorizes the program through FY 1995;
- reauthorizes the Natural Gas Pipeline Safety Act and the Hazardous Liquid Pipeline Safety Act;

- provides that pipeline safety responsibilities will now include environmental protection in addition to safety of life and property;
- mandates industry-wide guidelines on internal inspection devices (smart pigs), etc.;
- requires minimum pipeline operator training;
- requires data collection, analysis and corrective action regarding abandoned underwater pipelines; and
- institutes a national program to inspect underwater pipelines to ensure proper burial (done in 1990 for Gulf of Mexico).

3) FY 92 and FY 93 Department of the Interior Appropriations Acts (P.L. 102-154 and P.L. 102-381)

- The acts continued the same moratoria as enacted in FY 1991: areas in the president's 1990 decision; leasing/drilling ban for North Aleutian Basin; prelease/leasing ban on the Eastern Gulf area above 26 degrees; and a prelease/leasing ban on the entire Mid/South Atlantic area.
- Approximately 463 million acres were affected.
- In FY 92 environmental groups requested a broad array of moratoria: all Alaska sale areas; certain C and W GOM areas; and drilling bans expanded to the Florida Panhandle and North Carolina areas.
- In FY 93 environmental groups continued to request significant moratoria offshore Alaska plus drilling bans in the Florida Panhandle and offshore North Carolina.
- Of note, the Committee also seemed unwilling to expand moratoria, particularly drilling bans.

4) National Energy Policy Act (P.L. 102-486)

Perhaps the most interesting debate of the 102nd Congress was the debate on a comprehensive energy bill. When it finally passed, it was notable (from an MMS perspective) for what it almost contained.

Oil jitters surrounding the Persian Gulf war set the stage for sweeping energy legislation. Other factors also set the stage: 1990 Clean Air Act amendments that focused on the need for natural gas; the continuing decline of domestic energy production; and the fact that the Administration was working on a national energy strategy. The Gulf War was called "the flame that made the kernels explode into legislation." On the Senate side, S. 1220 (Johnston) was the operative energy bill, but it was controversial (ANWR drilling and CAFE). By the time it finally passed the Senate, ANWR and CAFE had been dropped out, and the bill was now S. 2166. It contained the following OCS provisions:

- No prelease/leasing until the year 2000 for areas in the president's 1990 decision plus the area offshore New Jersey (200 million acres);
- Seventy-three leases in southwest Florida to be cancelled subject to the availability of appropriated funds to buy them back; and
- OCS Impact Assistance Fund created and a larger fund to be allocated based on OCS production; smaller fund to be shared with all coastal states regardless of OCS activities.

In the process, the Senate defeated two amendments proposed by Senator Graham (FLA.): 1) leasing ban off the entire Florida coast; and 2) changes to sections five and 20 of the OCSLA. On the House side, energy legislation was proceeding more deliberately and with less controversy. However, both the Merchant Marine and Fisheries and the Interior and Insular Affairs Committees added OCS provisions to the energy bill that were more sweeping than those proposed by the Senate. They were as follows:

- prelease/leasing moratoria until 2002 on all areas included in the Senate bill plus the entire Mid/South Atlantic, Straits of Florida, and Eastern Gulf above 26 degrees (500 million acres);
- cancellation requirements for three areas (southwest Florida, North Aleutian Basin and certain leases offshore North Carolina);

- coastal Impact Assistance Fund, one fund to be administered by Commerce and based primarily on a revenue sharing approach (only 11 percent based on OCS production); and

- various amendments to the OCSLA establishment of ESRP's for moratoria areas; amendments to lease cancellation and compensation process; and requirement for Alaska leases to comply with ANILCA section 810.

Conference on the bill started on 10 September and concluded on 1 October. The OCS provisions were the last item taken up by the conferees due to the controversial nature of the OCS buyback provisions. The 1990 Budget Enforcement Act presented "pay-go" problems for any buyback scenario and were a major stumbling block to proponents of buyback. Simply stated, there was no way to pay for the buyback. In addition, Senator Johnston wanted to add his deepwater incentives legislation to the energy bill. The House conferees rejected this offer. In the end, the House conferees finally withdrew their OCS provisions and decided to "revisit the issue next year." So despite the fact that both the House and Senate versions of the energy bill contained OCS provisions, No OCS Provisions were incorporated into the final legislation.

OUTLOOK FOR THE 103RD CONGRESS

If the 102nd Congress was characterized by the term "gridlock," the catchword for the 103rd Congress so far would have to be "fast forward." Half way through the session, this Congress has been one of the most productive in generations. If they continue at their current pace, the term "historic" may ultimately be applicable.

This Congress is already notable in one respect: it has 110 new members, which is the largest new class since the Watergate years. In many ways they were elected because they represented change and because of their emphasis on fiscal issues. Certainly, it can be argued at this point that they are fulfilling their mandate.

For example, the 103rd Congress has already hammered out a budget agreement (which will reduce the federal deficit by $496 billion through 1998 and put into place even more severe limitations on discretionary spending than the 1990 agreement), and is also working on an unheard-of second round of budget cuts (the House recently passed an additional $37 billion in cuts, and the Senate is scheduled to take up the issue early in 1994).

In addition, Congress has killed funding for the superconducting super collider and almost killed funding for the NASA space station; tackled the issue of how to pay for "emergency" spending; significantly scaled back the economic "stimulus" package; and will probably take up issues such as a balanced budget amendment and a review of entitlement spending.

With so much focus on budget issues, it is somewhat amazing that Congress has found time to work on other issues. However, a quick review of legislation passed by both houses of Congress or enacted into law shows just how productive they have been so far:

NAFTA
Family Leave
Voter Registration (motor voter)
Aid to Russia
National Service
Brady bill
Hatch Act modifications
Military base closings
Campaign fiance reform
Crime bill
Mining law reform

Next year Congress will continue to work on several of the issues listed above as well as focus its attention on new issues, including health care reform, welfare reform, immigration reform, job training and Congressional reform. With all that on their plate, will they also find the time to pass legislation of interest to the Offshore program? In all likelihood, the answer is "yes," since several major environmental laws or pending pieces of legislation are already under review by Congress. For example:

1. Endangered Species Act reauthorization (H.R. 2043 and S. 921)

There have been numerous hearings on reauthorization at this point, but no bill has moved to markup as yet. There seems to be a focus on "ecosystem management," creating incentives for private landowners to conserve species and requiring greater efforts to restore species while trying to reduce the economic impacts. Congress has indicated its willingness to work with the Administration in fashioning a reauthorization bill.

2. National Biological Survey Organic Act (H.R. 1845 and S. 1008)

The bill has passed the House, but not without rancorous debate and amendment: 1) no volunteers can help collect information; 2) NBS must obtain permission before going onto private property; and 3) a landowner must have access to the information collected on his land. There is no Senate action yet, but this is a priority item for the Department. However, the issues raised by amendments to H.R. 1845 (private property rights and possible "takings") could crop up when the Senate considers an NBS bill and possibly foreshadow future debate on reauthorization of the Endangered Species Act and the Clean Water Act.

3. EPA Cabinet Elevation legislation (S. 171 and H.R. 3425)

A bill has passed the Senate that would create a Department of the Environment and abolish the CEQ. But the House postponed Floor action on a bill until 1994 due to conflicts over possible amendments.

Several House members support an amendment to require EPA to conduct a cost/benefit analysis of any new environmental regulations. The Senate bill already has a similar amendment, and this amendment is also supported by the National Governor's Association and the National Association of Counties.

In related action, the House passed H.R. 3512, a bill to abolish CEQ and put NEPA functions in a new White House office. The Senate EPA bill proposes to abolish CEQ and house NEPA functions in EPA. CEQ abolishment has been and will continue to be a visible issue as the bills move through Congress.

4. Marine Mammal Protection Act reauthorization (S. 1636 and H.R. 2760)

The Act was authorized through FY 93. S. 1636 has been marked up by the Senate Commerce Committee, but no markup has occurred in the House as yet. S. 1636 extends the program through FY 98 and focuses primarily on fishery operations and marine mammal interactions.

In related action, H.R. 3049 was passed by Congress and signed into law (P.L. 103-86). It extends for 6 months (until 1 April 1994) the exemption for commercial fishing activities to comply with the "incidental taking" provisions of the Act.

5. Clean Water Act reauthorization (S. 1114)

Both the House and Senate have held hearings, but no markup has occurred by either (the House has not yet introduced its primary bill). The focus of reauthorization efforts appear to be on "watershed management"; sewer overflow problems; non-point source pollution control; and funding mechanisms for sewage treatment plant construction. The issue of section 404 (wetlands) continues to make any reauthorization effort controversial.

103RD CONGRESS
LEGISLATIVE OUTLOOK
ISSUES OF PARTICULAR INTEREST TO THE GULF OF MEXICO REGION

I have tried to highlight some of the **major** environmental legislation currently before the 103rd Congress; however, Congress is considering other bills that, although not classified as "major," could have a significant impact on the Offshore program in the Gulf of Mexico. These include

1. OCS Deepwater Incentives legislation (S. 318 and H.R. 1282)

The House and Senate have both held hearings on the bills listed above. In general, the legislation is intended to spur exploration and development of deepwater Gulf of Mexico areas by 1) clarifying the Secretary's current discretionary authority to reduce or suspend royalties on non-producing leases; and 2) mandating a royalty holiday on "new production" located in 200 meters of water or greater until capital costs are recovered. The Senate bill is limited to the Central and Western Gulf of Mexico, while the House bill pertains to any deepwater OCS areas.

The Administration testified on both bills, and while it did not take a position on the specifics of either bill, it did support the objectives of the bills. The Administration also noted the following:

- The mandatory royalty suspension is estimated to have a net loss of $1.9 billion in foregone royalties (in 1993 dollars) since it would provide a windfall to several fields which could be produced even in the absence of the incentive.

- Only two fields (both located in water depths greater than 400 meters) would be positively impacted by the incentive (with estimated reserves of 150 mboe).

- The mandatory suspension should be limited to new leases only; to tracts located in 400 meters of water or greater; and to the Central and Western Gulf of Mexico.

The Senate is expected to take the lead on this legislation. It is speculative as to whether the legislation can move through both sides of Congress, and if so, how. But Senator Johnston has stated that this legislation is one of his priorities.

2. Gulf of Mexico Protection/Enhancement (H.R. 1899, H.R. 1566, S. 83 and S. 686)

Although this legislation got little attention in the 102nd Congress, there is general agreement from members from Gulf coast states that the Gulf of Mexico region should have a "formal" program to promote the environmental and economic interests of the Gulf region by better coordinating various federal, state and local activities. Both the Chesapeake Bay and the Great Lakes have formalized programs; the Gulf program has been operating on an "informal" basis since 1988.

Therefore, there should be more impetus in 1994 to pass such legislation than in the past. Although efforts have currently stalled on the House side at this point, there is a good chance that legislation can still be enacted in 1994. The Administration has testified on the House bills but did not specifically endorse either bill. Instead, it focused on elements which should be incorporated into any Gulf of Mexico legislation, providing that

- the program must address region-wide, interjurisdictional issues that can not be addressed by just one federal or state agency.

- the federal part of the program must be a full and shared partnership among the various agencies.

- the program must allow participating agencies to work within existing authorities.

- the emphasis of the program should be on implementation and light on organizational bureaucracy.

It is possible that any Gulf of Mexico legislation finally agreed to could be incorporated in the Clean Water Act as it proceeds through the reauthorization process.

3. Clean Water Act—Technical Amendment to section 311

Section 311 of the Clean Water Act deals, in part, with oilspill prevention and response requirements for activities in federal and state waters. MMS has been delegated that responsibility for "offshore facilities" by Executive Order 12777. Unfortunately, while MMS has the responsibility to ensure that offshore facilities have oilspill prevention and response plans in place and performs inspection on these facilities, the Bureau cannot issue civil penalties for any violations found under section 311. Instead, they must rely on either the Coast Guard or EPA to cite violators.

Therefore, during the reauthorization process for the Clean Water Act, there may be an opportunity to amend section 311 to give the Department of the Interior explicit authority to issue civil penalties. This amendment is strictly technical in nature and appears, so far, to be non-controversial.

OTHER ISSUES OF INTEREST DURING THE 103RD CONGRESS

Although no legislation is currently pending, Congress can also be expected to address the following issues in 1994, most probably through oversight hearings or the appropriations process:

1. Fiscal Year 1995 Appropriations

In FY 1994 OCS moratoria provisions which had been in effect since FY 1991 were again rolled into the DOI Appropriations Act (P.L. 103-138). In fact, the Administration supported these provisions.

Environmental groups focused their moratoria requests on many of the same areas as in the past (Alaska sales and drilling bans for areas offshore the Florida Panhandle and offshore North Carolina). The area which received the most attention was the Cook Inlet/Shelikof Straits area. However, of note, the Appropriations Committees again refused to expand moratoria and continued to express reservations about additional drilling bans.

In FY 1995, the Cook Inlet/Shelikof Straits area will probably continue to be the area of most interest in terms of moratoria requests. It is also likely that there will be requests to continue the moratoria on areas currently under prohibition.

2. Review of the Offshore program and the OCSLA

Already the House Merchant Marine and Fisheries Committee and the Senate Energy Committee have held hearings on various OCS issues, including OCS buybacks, site clearance procedures and the rigs-to-reefs program, OCS deepwater incentives, leasing in gas-prone areas, and OCS moratoria.

In 1994, the Merchant Marine and Fisheries Committee (Subcommittee on Oceanography, Gulf of Mexico and OCS) has indicated that it will continue oversight hearings on the following issues: OPA 90 implementation of financial certification responsibilities for "offshore facilities," OCS impact assistance, access to and use of OCS sand and gravel resources, and various proposals related to leasing and drilling bans on the OCS.

3. Implementation of the Oil Pollution Act

MMS is responsible for implementing certain sections of OPA 90. The issue which has been of greatest interest to Congress is how the Bureau will implement section 1016—financial responsibility for "offshore facilities." MMS has testified on the status of our rulemaking and emphasized that we are interested in hearing from all potentially affected parties on the impact of any regulations. Congress will maintain a high level of interest in 1994 in the status of OPA section 1016 implementation.

4. Review of Implementation of the Clean Air Act Amendments of 1990

The Senate Environment and Public Works Committee has indicated that they will begin oversight hearings on the progress of implementing the various provisions of the CAA. While the emphasis will be on EPA issues, a possible item of interest is the effects of OCS development in the Gulf of Mexico on air quality in adjacent ozone nonattainment areas. MMS was required to do a study on this issue and report to the Committees within three years.

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ENVIRONMENTAL REGULATIONS: MMS PERSPECTIVE

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INTRODUCTION

This presentation is an overview of several rulemaking actions, representing both MMS and EPA rules, which will be affecting Gulf of Mexico operators. They include a current MMS rulemaking on archaeology, two issues related to EPA waste disposal rules with current and future implications, and a potential MMS air quality rulemaking.

ARCHAEOLOGY

Since 1973, MMS has had a lease stipulation to handle archaeological resources. Because this has really become a standard stipulation, MMS decided to propose converting the stipulation into a rule. The rule was proposed in the 12 October 1993 Federal Register.

The rulemaking will not cause new requirements on operators but will simply maintain the status quo of the stipulation. MMS will still inform operators which areas will need archaeological reports. The reports will be based on remote sensing, the type depending on whether shipwreck or habitation sites, etc. are possible. For many, existing geohazards surveys can be used. If the report concludes an archaeological site is possible in an area, avoidance of the site remains the simplest mitigation.

The comment period closed 13 December and MMS will evaluate the comments for a decision on the rule.

PRODUCED SANDS

The next two topics are related and deal with disposal of produced sands (well solids, etc.). The issue concerns the methods of disposal that may or may not be available in the future. They involve the EPA NPDES new source performance rules and the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (also known as the London Convention). In some ways the issue is very simple, but in others it is quite convoluted, especially considering the London Convention.

Present domestic and international direction seems to imply that disposal of produced sands should be done in onshore waste sites. The issue is whether we should retain other options for disposal (such as reinjection or encapsulation into the seabed, or ocean discharge), especially if onshore landfills become limited in the future? If we want to try to retain such options, we need to ensure that we have good data to support decisions. Some questions can be asked. Is onshore disposal of OCS well solids the wisest use of onshore disposal sites? Is it environmentally the best choice? Will onshore disposal be available in the future?

New Source Performance Standards

In its March 1993 final rule, EPA set the new standard for produced sand from new sources as zero discharge. They believed this was technologically and economically achievable; rather than discharging into the ocean, the prime disposal method would be to barge the material to shore.

At the request of MMS and the Department of Energy during the rulemaking, EPA did keep the door open for ocean discharge at some point in the future, if good technology is developed. MMS and DOE were concerned about availability of onshore disposal in the future, environmental issues associated with barging and onshore disposal, and possible disincentive to improve disposal technology. In the preamble to the March 1993 rule, EPA listed information it would need to revisit the issue: information on new technologies and their efficiency, the fate of solvents in washing sands, the availability of disposal sites, appropriate disposal methods for sand containing NORM—naturally occurring radioactive materials. This last item may be the controlling one regarding disposal and leads to the second topic connected with the London Convention.

The London Convention

The London Convention (LC) potentially affects the disposal of produced solids. Internationally, the LC limits the disposal of waste into the ocean. In November 1993, the international community expanded the LC to ban dumping low level radioactive waste (LLW) into the sea. It also passed a voluntary moratorium on sub-seabed disposal of LLW. Strictly following these words infers another strong push to dispose onshore any produced sands that may contain NORM. Limited disposal by reinjection and encapsulation has been done offshore but potentially also could be limited.

But other sections of the LC come into play, which regrettably involve some ambiguities. Under the LC, normal operations from offshore platforms are exempt from the disposal prohibitions, but the exemption may or may not include situations in which material is transported for the express purpose of disposal (as it often is offshore). Are all activities including transportation exempt? If yes, offshore produced sand disposal may be exempt from the LC but would still be subject to domestic regulation (allowing the United States the option of disposal into the ocean or into the seabed.) If such activities are not exempt, then defining LLW becomes important. The LC does not define LLW. Rather, the participants proposed that the International Atomic Energy Agency develop guidance over the next few years. In the meantime, each country would define what it considered LLW.

To assist in developing guidance for either scenario (the domestic-controlling or LC-controlling), good information will be needed on the quantities of waste with NORM, associated activity levels, disposal locations. Other issues should be reviewed: can the "dirtier" portions of the waste be segregated from "cleaner" portions? What NORM levels are acceptable for what type of land disposal sites? Is reinjection or encapsulation into the seabed environmentally preferable?

A goal to work toward is to keep options open, especially regarding reinjection and encapsulation, and to make sure the solutions are economically and environmentally wise.

OCS AIR QUALITY REGULATIONS

In 1980, the Department of the Interior published air quality rules for operators on the OCS. Much of the 1980s was spent in litigation and negotiation with state and local governments in California over the rules. This included several years of a negotiated rulemaking process. Ultimately, the Clean Air Act Amendments of 1990 transferred the air quality jurisdiction for most of the OCS to EPA. However MMS retained the Western and Central Gulf of Mexico, the area with the vast majority of OCS sources. The CAAA also directed MMS to do a study of the effects offshore sources have on the nonattainment areas in the Gulf of Mexico and to review whether changes may be needed to its air quality regulation.

Because much has transpired in the decade since the original DOI rules were published, MMS has formed an internal workgroup (including an EPA representative) to review its GOM rules to see if modifications may be needed.

The group is considering whether the overall approach still makes sense. (The original rules were developed in the late 1970s and much has changed in air quality regulatory theory since then, clearing up ambiguities in the rules) and whether the exemption level approach should be retained. The group is developing specific wording on upsets and equipment failure, both in defining the terms and setting procedures to handle them in real-time, including specific words on pipeline laying and other temporary sources, as well as flaring and short-term emissions. A special look is being taken for Class I areas, and MMS will be working with the Fish and Wildlife Service and the National Park Service concerning activity in the vicinity of the Breton National Wildlife Refuge. (One special emphasis of Secretary Babbitt is for Interior Agencies to work together as a team, rather than in conflict as has occurred in the past. Having MMS, FWS, and NPS work together should end up with better and more consistent solutions.)

We likely will go forward with those items that need immediate attention, such as for the Class I areas. We may initially develop a regulatory approach through Letters or Notices to Lessees and follow on later with rule amendments. The group will not be proposing changes that may be influenced by the results of the ozone study until after that report has been completed and assessed.

We are aware of costs that lessees face with each new regulation. We will attempt to limit costs as we can. We in the federal and state governments are also faced with reduced staffs and funding. So special emphasis will be made to keep solutions simple but meaningful. We want to work with industry, the states, other federal agencies, and interested parties in developing these solutions.

John Goll is the Chief of the Environmental Policy and Programs Division at the headquarters of the Minerals Management Service. He oversees MMS's environmental activities, including the Environmental Studies Program, the National Environmental Policy Act analyses performed by MMS to evaluate lease sales and industry proposals, and MMS's and other Agencies' environmental regulations. John earned a bachelor's degree in Meteorology and Oceanography and a master's degree in Meteorology, both from the University of Michigan.

REGULATIONS FOR THE GOM OCS

Mr. Scott Wilson
U.S. Environmental Protection Agency
Region VI
Dallas, Texas

On 19 November 1992 EPA reissued the Outer Continental Shelf General Permit for the western Gulf of Mexico. That permit only covered facilities located in and discharging to the Outer Continental Shelf offshore of Louisiana and Texas. Due to administrative constraints, areas offshore of Mississippi, Alabama, and Florida, which were covered by the permit when it was issued in 1986 were not covered by the reissued permit in 1992.

Ocean Discharge Criteria in Section 403(c) of the Clean Water Act and in 40 C.F.R. Part 125, Subpart M prohibit issuance of a National Pollutant Discharge Elimination Systems permit for discharge into the territorial seas, contiguous zone, or the oceans which will cause unreasonable degradation of the marine environment. In order to ensure that discharges allowed under the western Gulf of Mexico general permit do not cause unreasonable degradation of the marine environment, new water quality based limitations and monitoring requirements were added to the permit when it was reissued. The new water quality based requirements include produced water toxicity limits and monitoring for bioaccumulation and Naturally Occurring Radionuclides.

Compliance monitoring for the produced water toxicity limits was required to be accomplished using seven-day chronic toxicity tests with the Mysid Shrimp and Sheepshead Minnow. The permit required that produced water discharges were not chronically toxic at the edge of the 100 meter mixing zone. Dilutions at the edge of the mixing zone were calculated for all of the ranges of discharges expected under the permit using the CORMIX1 model and were listed in table 1 of the permit. Permittees were to determine their critical dilution from that table based on the discharge rate and the pipe diameter of their produced water discharge. The frequency of monitoring was based on the potential to cause toxicity, which was deemed to be greater with larger volume produced water discharges than with smaller ones. As a result, the required monitoring frequencies were once per month for discharges over 4,600 barrels per day; once per quarter for discharges from 500 barrels per day to 4,600 barrels per day, and annually for discharges under 500 barrels per day. Permittees were given one year to begin monitoring for produced water toxicity.

The bioaccumulation monitoring requirements in the permit were intended to apply to the 10 percent of dischargers with the largest produced water discharge rates; these were expected to exhibit the greatest potential to cause bioaccumulation. The permit requires that all operators with discharges over 4,600 barrels per day collect and monitor marine organism tissue for various organic chemicals and metals expected to be present in produced water. The permit also allows permittees the option of conducting a group study where the participants would conduct bioaccumulation monitoring at fewer platforms but in return the monitoring would be much more extensive and the results potentially more conclusive. The permit gave operators two years before they were required to commence bioaccumulation monitoring.

Monitoring for Radium 226, Radium 228, Gross Alpha Particles, and Gross Beta Particles was also required by the reissued western Gulf of Mexico OCS general permit. Like monitoring for the produced water toxicity limit, the monitoring frequency was based on the produced water discharge rate. Operators discharging 4,600 barrels per day and greater are required to monitor monthly, from 500 to 4,600 barrels per day quarterly, and less than 500 barrels per day annually. Permittees were given one year to commence monitoring, and monitoring was to be done only for a period of one year.

Due to modeling problems which resulted in unnecessarily stringent critical dilutions for the produced water toxicity limits, the permit was proposed to be modified on 4 August of this year. The proposed modification also included new, more stringent technology based limits derived from national effluent guidelines, which were published on 4 March and effective on 4 April. The final modified permit was published in the Federal Register on 3 December 1993 at page number 63964.

Produced water critical dilutions which are required to be met for the toxicity limits were recalculated and included in the permit in a manner which more closely represents the wide variety of conditions affecting discharges covered under this permit. A modified version of the CORMIX1 model was used to calculate the critical dilutions. Through extensive examinations, the CORMIX1 model was found to be accurate in the near field phase of dilution calculations, but in the far field phase of calculations it was found to under-predict dilution. An equation was developed which was applied to the CORMIX1 results from the near-field calculations to calculate more accurately the dilution at 100 meters. The final modified permit contains the new critical dilutions on several tables which account not only for the discharge rate and pipe diameter but also for the water depth between the discharge pipe and the seafloor. To determine their critical dilution, permittees will find the table which applies to the appropriate water depth and from that table find the dilution corresponding to the discharge rate and pipe diameter of their platform. The new critical dilutions were effective upon publication in the Federal Register on 3 December, and permittees were required to start produced water toxicity monitoring, at the appropriate frequency, beginning 3 December. The modified permit also allows permittees to add diffusers or multiple port discharges to obtain more dilution to meet the toxicity limits.

The radionuclide monitoring was changed slightly in the modification. Gross alpha and gross beta particles no longer must be monitored since it has been determined that the dissolved solids in produced water interfere with testing. The frequency of monitoring is still based on the produced water discharge rate, as previously stated.

The modified permit still requires bioaccumulation monitoring for all produced water discharges over 4,600 barrels per day. Monitoring is required to commence in November of 1994.

Effluent guidelines for the offshore subcategory were issued on 4 March 1993. The modified permit contains several changes in technology based limits and monitoring requirements resulting from the new effluent guidelines. The oil and grease limits for produced water were decreased from a maximum of 72 mg/l and an average of 48 mg/l to a maximum of 42 mg/l and an average of 29 mg/l. The new oil and grease limits also apply to well treatment, completion, and workover fluids discharged in the produced water waste stream. The static sheen test method is now required for monitoring free oil in discharges of drilling fluids and drill cuttings and in well treatment, completion, and workover fluids which are discharged as a separate waste stream. The modified permit also allows the use of a partial test for monitoring the toxicity of drilling fluids. The partial test is a pass/fail test run on a single drilling fluids dilution of 30,000 ppm and a control, along with the reference toxicant test.

The final major change to the Western Gulf of Mexico general permit was a change in the area of coverage. Permittees commenting on the modification requested that facilities in the territorial seas be able to discharge produced water to the Outer Continental Shelf. Since treatment technology has been prescribed by the issuance of guidelines for produced water discharges in the offshore subcategory, and the permit is felt to contain sufficient limits to protect water quality, the final modified permit allows discharges of produced water from the territorial seas to the Outer Continental Shelf. The corresponding change made in the permit is that the discharge rate was limited to 25,000 barrels per day. This new limit was added to ensure compliance with Ocean Discharge Criteria and thus enable EPA to issue the final modified permit.

New source performance standards were issued on 15 January 1993, defining and establishing new sources in the offshore subcategory. A new source is defined as any development or production facility for which significant site preparation is begun after 15 January 1993. Due to time constraints with the modification of the existing Western Gulf of Mexico general permit EPA Region six proposed a separate permit covering new sources. That proposal can be found in the Federal Register for 14 October 1993 on page number 53200. Since the requirements of that permit are expected to be nearly identical to those of the existing permit, as it was modified, EPA plans to combine the existing source and new source permits in the near future.

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AIR QUALITY REGULATIONS FOR THE EASTERN GULF OF MEXICO

Mr. Scott Davis
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The basis for air regulations for the Eastern Gulf of Mexico are the Clean Air Act, Title 40 of the Code of Federal Regulations, and the Florida Administrative Code. The specific regulations to apply to an offshore source are dependent on the location of the source offshore the state of Florida. For sources located from the coastline to three leagues offshore, approximately nine statute miles, this area falls within the state boundary of Florida, and the state retains regulatory authority. For sources located from the seaward boundary to within 25 miles of the state's seaward boundary, regulatory authority is maintained by the U.S. Environmental Protection Agency (EPA), but it may be delegated to the State of Florida on the basis of certain conditions. For sources outside of 25 miles of the state's seaward boundary, EPA retains regulatory authority.

SECTION 328 OF THE CLEAN AIR ACT

The basis for the Outer Continental Shelf (OCS) air regulations is Section 328 of the Clean Air Act Amendments of 1990, Air Pollution from Outer Continental Shelf Activities. Section 328 mandated the establishment of requirements to control air pollution from OCS sources located offshore of the states along the Pacific, Arctic, and Atlantic coasts, and along the United States Gulf Coast off the State of Florida eastward of 87 degrees 30 minutes longitude, to attain and maintain federal and state ambient air quality standards and to comply with the provisions of Part C of Title I of the Act. Authority for the Gulf of Mexico was divided. The eastern Gulf is under the authority of EPA. The central and western Gulf are under the authority of the Minerals Management Service (MMS).

OUTER CONTINENTAL SHELF AIR REGULATIONS SUMMARY

On 4 September 1992, EPA promulgated a new Part 55 of Chapter I of Title 40 of the Code of Federal Regulations (40 C.F.R. Part 55). These regulations established requirements to control air pollution from OCS sources. New sources must comply with the requirements of this part on the date of promulgation (4 September 1992) and existing sources must comply within 24 months from promulgation (4 September 1994). The requirements apply to all OCS sources located in the Gulf of Mexico east of 87.5 degrees longitude (near the border of Florida and Alabama). Those sources located west of 87.5 degrees longitude in the Gulf of Mexico fall entirely under the jurisdiction of MMS.

For OCS sources located within 25 miles of states' seaward boundaries, the requirements are the same as the requirements that would be applicable if the source were located in the corresponding onshore area (COA). In states affected by this rule, state boundaries extend three miles from the coastline, except off the coast of the Florida Panhandle, where the state's boundary extends three leagues (approximately 9 statute miles) from the coastline. Sources located beyond 25 miles of states' boundaries are subject only to federal requirements for Prevention of Significant Deterioration, New Source Performance Standards, and National Emissions Standards for Hazardous Air Pollutants, if applicable. Beyond 25 miles of states' seaward boundaries, the OCS program requirements will be implemented and enforced solely by EPA. These regulations also established procedures to allow the Administrator to exempt any OCS sources from a control technology requirement if it is technically infeasible or poses an unreasonable threat to health or safety. This rule establishes procedures for EPA to delegate implementation and enforcement of the requirements of this rule to state and local agencies. EPA will amend these new OCS regulations to incorporate the federal operating permit program (40 C.F.R. Part 71) and enhanced compliance and monitoring regulations when they are finalized.

The Outer Continental Shelf Air Regulations, 40 C.F.R. Part 55, include the following sections:

Section 55.1 — Statutory authority and scope
Section 55.2 — Definitions
Section 55.3 — Applicability
Section 55.4 — Requirements to submit a notice of intent
Section 55.5 — Designation of corresponding onshore area

Section 55.6 — Permit requirements
Section 55.7 — Exemptions
Section 55.8 — Monitoring, reporting, inspections, and compliance
Section 55.9 — Enforcement
Section 55.10— Fees
Section 55.11— Delegation
Section 55.12— Consistency updates
Section 55.13— Applicable federal requirements
Section 55.14— Applicable requirements of the COA

Highlights of the OCS air regulations include the following:

- Pursuant to § 55.1, there is to be a rational relationship to the attainment and maintenance of federal and state ambient air quality standards and the requirements of Part C of Title I of the Clean Air Act. Furthermore, the rule is not to be used for the purpose of preventing exploration and development of the OCS.

- Onshore area is defined in § 55.2 as a coastal area designated as an attainment, nonattainment, or unclassifiable area by EPA in accordance with Section 107 of the Clean Air Act.

- Corresponding onshore area is defined in § 55.2 as meaning, with respect to any existing or proposed OCS source located within 25 miles of a state's seaward boundary, the onshore area that is geographically closest to the source or another onshore area that the Administrator designates the COA pursuant to 40 C.F.R. Section 55.5.

- Potential emissions are defined in § 55.2 to mean the maximum emissions of a pollutant from an OCS source operating at its design capacity. Any physical or operational limitation on the capacity of a source to emit a pollutant, including air pollution control equipment and restriction on hours of operation or the type or amount of material combusted, stored or processed, shall be treated as a limit on the design capacity of the source if the limitation is federally enforceable. Pursuant to Section 328 of the Clean Air Act, emissions from vessels servicing or associated with an OCS source shall be considered direct emissions from such a source while at the source, and while enroute to or from the source when within 25 miles of the source and shall be included in the "potential to emit" for an OCS source.

- Pursuant to § 55.4, prior to performing any physical change or change in method of operation that results in an increase in emissions, the applicant shall submit a Notice of Intent (NOI) to the Administrator through the EPA Regional Office and at the same time shall submit copies of the NOI to the air pollution control agencies of the nearest onshore area and onshore areas adjacent to the nearest onshore area.

- The requirements to obtain an OCS air permit are outlined in § 55.6. These include the permit application, administrative procedures and public participation, preconstruction requirements, operating permit requirements, notification requirements for other reviewing agencies, modifications, and compliance plans.

- Pursuant to § 55.7, the Administrator or the delegated agency may exempt a source from a control technology requirement of 40 C.F.R. Part 55 if the Administrator or the delegated agency finds that compliance with the control technology requirement is technically infeasible or will cause an unreasonable threat to health and safety.

- EPA may require monitoring or reporting and may authorize inspections pursuant to Section 114 of the Clean Air Act and the regulations thereunder. Sources shall also be subject to the requirements set forth in Sections 55.13 and 55.14. The Administrator or the delegated agency shall consult with MMS and the U.S. Coast Guard prior to inspections. This shall in no way interfere with the ability of EPA or the delegated agency to conduct unannounced inspections.

- Pursuant to § 55.9, if an OCS source is ordered to cease operation of any piece of equipment due to enforcement action taken by EPA, the shutdown will be coordinated by the enforcing agency with MMS and the U.S. Coast Guard to assure that the shutdown will proceed in a safe manner. No shutdown action will occur until after consultation with these agencies, but in no case will initiation of the shutdown be delayed by more than 24 hours.

- Pursuant to § 55.10, for OCS sources located within 25 miles of states' seaward boundaries, EPA can collect operating fees from OCS sources calculated in accordance with the fee requirements imposed in the corresponding onshore area if the fees are based on regulatory objectives, such as discouraging emissions. If the fee requirements are based on cost recovery objectives, however, EPA will adjust the fees to reflect the costs to EPA to issue permits and administer the permit program.

- The delegation of the authority to implement and enforce the requirements of this OCS program within 25 miles of the state seaward boundary is outlined in § 55.11. The Administrator will delegate implementation and enforcement authority to a state if the state has an adjacent OCS source and the Administrator determines that the state has adequate regulations and adequate resources and administrative procedures to implement and enforce the requirements of the program.

- Pursuant to § 55.12, EPA will complete consistency updates as necessary to update 40 C.F.R. Part 55 to maintain consistency with regulations of onshore areas. Where an OCS activity is occurring within 25 miles of a state's seaward boundary, consistency reviews will occur at least annually. In addition, consistency reviews will occur upon receipt of a Notice of Intent and when a state or local agency submits a rule to EPA to be considered for incorporation by reference into 40 C.F.R. 55. State and local rules submitted for inclusion into 40 C.F.R. Part 55 must be rationally related to the attainment and maintenance of federal or state ambient air quality standards or to the requirements of Part C of Title I of the Clean Air Act. No rule or regulation that EPA finds to be arbitrary or capricious will be incorporated into this part. Rules concerning administrative or procedural requirements, including public participation procedures, will not be incorporated into this part.

- The applicable federal requirements for OCS air permits are outlined in § 55.13. For 40 C.F.R. these include: Section 51.165—New Source Review; Section 52.21—Prevention of Significant Deterioration; Part 60—Standards of Performance for New Stationary Sources; Part 61—National Emissions Standards for Hazardous Air Pollutants; and Part 124—Procedures for Decisionmaking.

- The requirements that apply to OCS sources located within 25 miles of states' seaward boundaries are listed, by state, in § 55.14. The documents which EPA has reviewed and promulgated as applicable to OCS sources located within 25 miles of states' seaward boundaries have been incorporated by reference and are listed in this section.

EPA REGION IV PERMITTING UNDER 40 C.F.R. PART 55

EPA Region IV is currently processing an Outer Continental Shelf air permit application submitted by the Chevron U.S.A. Production Company, Inc. for an exploratory, offshore, natural gas drilling operation for Destin Dome Block 97, to be located approximately 29 miles offshore of Pensacola, Florida. EPA will be the permitting authority for this source under the provisions of the OCS air regulations. This proposed source is the first facility to be processed by EPA Region IV under the permitting requirements of the OCS air regulations. For OCS air permitting purposes, the proposed project must comply with state emission regulations which are in effect on the mainland under the applicable provisions of the Florida Administrative Code.

The final permit decision will be upcoming. The State of Florida will have the option of requesting delegation of the OCS permitting program once there is an adjacent OCS source. EPA Region IV retains authority if the State of Florida does not request delegation.

Mr. Scott Davis is an Environmental Engineer in the Air, Pesticides, and Toxics Management Division of the Region IV offices of the U.S. Environmental Protection Agency in Atlanta, Georgia. He received his bachelor's degree in industrial and systems engineering from the Georgia Institute of Technology in 1983. He is currently with the Source Evaluation Unit, which processes federal PSD/NSR, Acid Rain, and Outer Continental Shelf air permits.

SUMMARY: CURRENT LEGISLATIVE AND POLICY ISSUES

Mr. Harold Cargol
Division Landman on behalf of the American Petroleum Institute Offshore Division
Texaco Exploration and Production Company

This presentation will outline the American Petroleum Institute's (API) perspective on a number of government policies and legislation that affect the oil and gas industry. API is a trade association representing approximately 300 member companies engaged in petroleum exploration, production, refining, transportation, and marketing in the United States. Many API members conduct exploration and production activities in offshore, as well as onshore areas. Accordingly, API has a great interest in legislation and policies affecting those activities.

Unfortunately, today, it almost seems politically incorrect to speak about the need for fossil fuels, especially oil, in the country's energy mix. However, fossil fuels — oil as well as gas — will be a critical part of this country's energy equation for many more years. Attempts to reduce the role of oil and gas, especially through government mandates and restrictions, will hurt this country's economy.

The fact is that oil and gas products are convenient, affordable, and have become more and more environmentally friendly. They make a vital contribution to the U.S. economy and to American society. If anything, government should encourage development of domestic oil and gas reserves both offshore and onshore. This will help ensure that consumers get the products they want and need and that we keep the jobs that produce them in the United States.

This encouragement is all the more important considering that domestic oil production has been declining and is at its lowest point in 35 years — at 6.8 million barrels per day now, down from 9.2 million barrels per day in 1973. And this encouragement would also help government boost declining revenues. For example, in the last decade federal OCS annual revenues have gone from $10 billion to $2 billion partly as a result of declining production. Since inception of the OCS leasing program in 1954, payments to the U.S. Treasury have totalled more than $100 billion, an amount only exceeded by federal income tax revenue. This major source of revenue should be protected.

Much can be done to ensure production and delivery of needed oil and gas products. First, this Administration and the oil and gas industry can work together to change the public's perception of oil and gas exploration and production — particularly in the offshore areas. This positive change is vital if we are to meet the nation's energy needs in an economic and environmentally responsible manner.

Gaining the public's confidence is key to ending offshore moratoria as well as to tempering regulatory and legislative proposals that block or delay exploration and production. Together, industry and government can demonstrate to the public that oil and gas activities are being conducted in an environmentally sensitive and safe manner.
Unfortunately, government policies now deny industry access to promising new domestic opportunities to explore for oil and gas. For example, the recently passed Interior Department fiscal year 1994 appropriations bill continues for yet another year the leasing moratoria on vast areas of the federal OCS.

In addition to restricting domestic oil and gas production, these government policies, together with low prices and increasing environmental expenditures, have contributed to the loss of more than 375,000 workers in the oil and gas extraction industry in the last 10 years, more than those lost by the steel, textiles, and electronics industries combined. In addition to the job losses, these trends have caused our nation to import more and more oil. The United States currently imports $43 billion worth of oil, and we do not expect much improvement for the foreseeable future.

The government could act to improve access in several ways. Improving access to federal lands is critical because many of the highest potential oil and gas prospects are now off limits. Improved access means

- not imposing new OCS moratoria and not expanding the current moratoria;

- allowing environmentally sound exploration of the oil-rich coastal plain of the Arctic National Wildlife Refuge in northeastern Alaska;

- supporting balanced wetlands policies and flexible regulation to balance economic and social considerations with wetlands protection;

- ending the administrative moratoria on oil and gas leasing in national forests; and,

- ensuring that E & P restrictions are necessary and scientifically based and that performance standards for sensitive areas permit access.

In addition to access, the presenter addressed the following issues:

- The Department of Energy's "Domestic Natural Gas and Oil Initiative"
- OCS Lease Cancellation
- Gulf of Mexico Program Legislation
- Endangered Species Act and Wetlands Legislation
- OCS Policy Committee
- Risk Assessment

Mr. Harold Cargol is Division Landman, Offshore Division, Texaco Exploration and Production Company. Mr. Cargol has worked for Texaco over 22 years. During the last 10 of those years, Mr. Cargol has exclusively focused on the Outer Continental Shelf (OCS). He administers Texaco's land and regulatory program pertaining to the OCS. Mr. Cargol received his M.B.A. from Loyola University and a B.S. in Business Administration from Nicholls State University in Louisiana.

OFFSHORE OPERATORS COMMITTEE (OOC)

Mr. Ron E. Rutherford
Division Manger of CONOCO

The Offshore Operators Committee (OOC) is a trade association of oil and gas operating companies in the Gulf of Mexico. We have an associated membership of service companies, contractors, and consultants. The OOC was formed over 40 years ago. Our operating membership currently includes 97 companies who collectively represent about 95 percent of the oil and gas production in the Gulf of Mexico. Our primary purpose is to consult with and advise government agencies concerning matters affecting our industry. The OOC does not lobby and we do not litigate; this gives us a unique opportunity to discuss operating issues and regulations in a non-adversarial atmosphere with the various agencies who regulate our activities.

OOC believes that several quality characteristics lead to good regulations:

First, the regulation must be consistent with the scope of its enabling legislation. There has been a trend in the last several years for legislation to be more specific and prescriptive in scope. Although this limits the agencies' flexibility in drafting regulations, agencies must not go beyond the legislative scope.

Next, regulations must be approached using sound scientific processes and good cost-benefit analysis. Society has a right to know how much proposed regulations will cost, what the choices are, and just how much benefit they really will provide. Unfortunately, those questions are seldom answered before we are faced with costly regulations based on opinions and perceptions.

Next, we prefer performance based-regulations to prescriptive requirements. Technology is evolving rapidly in the oil and gas industry and elsewhere. We must be able to take advantage of these technological changes to improve safety and environmental performance instead of being limited by overly prescriptive requirements.

Finally, the regulation should not duplicate existing regulations of other agencies. Multiple agency jurisdiction is difficult and time consuming to comply with, and it creates a great deal of uncertainty on the part of both industry and agencies.

Three regulations are of some concern to the OOC:

The first is the EPA National Pollution Discharge Elimination System or NPDES. OCS discharge effluent parameters were revised last month, and technology is simply not available to allow much further reductions and still be able to discharge. The revised produced water, oil, and grease limits of 29 mg/l monthly and 42 mg/l daily are difficult to meet. Industry is installing costly new equipment, and making major investments that stretches current technology with no assurance that the equipment will be able to meet these limits to allow discharging.

Toxicity testing is a new requirement for produced water effluents. Expensive testing requirements and equipment modifications are needed to meet the permit limits, again with no assurance that the equipment will result in the capability to continue discharging.

Drilling muds and cuttings toxicity limits have not been revised on the OCS, and we have been complying with them for the last several years.

At this point, we are not sure if "current technology" can consistently meet the requirements for produced water, oil, grease, and toxicity to allow industry to continue to discharge, but we are certain that further tightening of discharge limits will force reinjection of produced water and hauling drilling muds and cuttings to shore for disposal.

Current scientific evidence does not indicate that discharging produced water and drill muds and cuttings causes environmental harm, even at the previous, more relaxed limits. The cost to industry for tightening effluent limits beyond today's levels is huge. EPA has estimated that it would cost industry 5 billion dollars for new equipment and 450 million dollars per year to operate it if we are required to reinject all produced water. Hauling all drilling muds and cuttings to shore will cost about 233 thousand dollars per well or about 160 million dollars per year, assuming drilling remains at the current number of wells per year.

These cost estimates assume that all producing properties and drill wells would be able to support that level of increased spending; thus assumption is unrealistic. Planned wells would not be drilled; and currently producing properties would be shut-in and abandoned prematurely because they could not support the significant cost increases. Those activity reductions translate into fewer jobs, reduced revenue to the federal government, loss of reserves, and increased dependence on foreign crude oil, a high price to pay for virtually no incremental environmental benefit.

We are also concerned with MMS regulations required by the Oil Pollution Act of 1990 or OPA 90. We fear that the $150 million financial responsibility requirements would force premature abandonment of many existing facilities. Absent the asset base required for self-insurance at this level, bonds and insurance premiums can range from $1 million per year up to $15 million per year even if they can be obtained, and most believe they cannot be. These amounts exceed the annual profit of many independent operating companies.

If this regulation is promulgated as the enabling legislation is conservatively and strictly interpreted, the results will be loss of jobs, reduced federal government revenue, loss of reserves, and increased dependence on imported oil. Some estimates predict 1/3 of the current Gulf of Mexico oil and gas production would be shut-in if this financial responsibility requirement were promulgated.

This financial responsibility requirement does not meet logical or scientific tests. The history of actual oil spills in the Gulf of Mexico coupled with the "worst case" spill scenario does not support a $150 million clean-up cost per facility.

The benefit of this requirement simply does not justify its cost.

The final regulatory concern is with the MMS air regulations for the Gulf of Mexico OCS. In the Clean Air Act Amendment of 1990, Congress mandated that MMS study the onshore air quality impact from OCS emissions. This study focuses on ozone non-attainment areas at Houston, Baton Rouge, and Lake Charles, and it should be complete in 1995. Additionally, OOC and API are sponsoring a study that will estimate industry cost for various air emission control applications. We understand that MMS is currently considering Gulf of Mexico OCS air regulations before the scientific study is complete.

OOC and API are uncertain of the scope of the MMS air regulations being considered. We are concerned that unnecessary regulations may be promulgated before the scientific study is completed and that the cost-benefit may not be appropriately considered.

Any one of these three regulations has the potential for a significant adverse effect on the Gulf of Mexico oil and gas operations. The combined effect of all three could be devastating. We urge the agencies to carefully consider the quality characteristics of good regulations they proceed with NPDES, OPA 90 financial responsibility, and OCS air regulations.

Let us turn to some of the regulatory initiatives that the oil and gas industry is pursuing. We try hard not simply to oppose proposed regulations, but to offer compromises in a cooperative atmosphere, moving closer to the quality characteristics of good regulations that I mentioned earlier. Our initiatives in the safety and environmental management planning (SEMP) illustrate a positive cooperative effort between MMS and industry to improve safety and environmental performance.

Almost two years ago MMS expressed an interest in achieving improved safety and environmental performance by moving away from the prescriptive control paradigm to an industry management and expectation process. At that time, the refining and chemical industry had a system like this, and several producing companies were developing similar systems.

After some communication with MMS, industry decided to prepare an API recommended practice for development of a safety and environmental program for OCS operations and facilities. This became known as RP 75, and it was published in May 1993. MMS participated with industry in preparation of this recommended practice. Additionally, MMS agreed not to promulgate SEMP regulations as long as voluntary industry implementation was progressing sufficiently.

This prompted industry to encourage broad implementation of the RP and so far API and OOC have sponsored three training workshops during 1993 with a total of 555 attendees from 147 companies.

Additionally, API and OOC drafted a process to assess RP 75 implementation, which we are discussing with MMS now. The purpose of the implementation assessment process is to give individual companies a scorecard of their implementation progress and to allow periodic company assessments to be combined into an overall industry implementation assessment; MMS can thus determine if voluntary implementation is progressing sufficiently to preclude formal SEMP regulations.

In 1992, the MMS director visited with New Orleans oil and gas executives and asked what could be changed to improve oil and gas profitability in the Gulf of Mexico. The OOC decided to take a close look at existing regulations and determine major items that could be changed without reducing safety or environmental protection. We came up with a list of nine major items.

The major items included relaxing requirements for suspension of production, allowing subsurface commingling from different reservoirs, modifying the platform design wave criteria, increasing time between required BOP tests, increasing time between underwater structural inspections, allowing flexibility for subsea well testing, revising site clearance requirements after structural abandonment, revising directional survey requirements, and revising the casing stub covering and monitoring requirements.

In September 1992, the OOC provided this list with supporting documentation to the MMS Gulf of Mexico Region. MMS reviewed these suggestions and has taken action on BOP testing with a September 1993 workshop in New Orleans. Currently, OOC is updating our list and considering a meeting with MMS Headquarters in early 1994 to determine how to proceed with the other suggestions.

My last point deals with an industry initiative to consider MMS regulation changes for deepwater development. Current MMS regulations were written primarily for fixed platforms. Deepwater production facilities such as tension legged platforms, subsea production systems, etc. can not comply with some parts of the regulations, and compliance with other parts should not be necessary. Examples of the types of regulations not appropriate for deepwater development are well annulus pressure monitoring, Christmas tree design, underwater safety valve testing, underwater safety valve and surface controlled subsurface safety valve closure times. We believe MMS regulations should be amended recognizing new technology for deepwater developments.

About a year ago, industry formed a group called DeepStar, to look at sharing and developing technology to address all issues associated with deepwater oil and gas production. One DeepStar sub-group is beginning to identify potential revisions to MMS regulations. MMS is participating this sub-group which will identify suggested revisions to regulations for deepwater developments flexible enough to handle evolving deepwater development scenarios.

In summary, I want to once again urge the government agencies to consider our quality characteristics for good regulations and to recognize that OOC is not only ready to consult with and advise agencies regarding proposed regulations in a reactive mode, but proactively to suggest initiatives that can help maintain a viable oil and gas producing industry in the Gulf of Mexico.

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SESSION 1B

GOOMEX PROGRESS REPORTS

Session: GOOMEX PROGRESS REPORTS

Co-Chairs: Dr. Pasquale Roscigno and Dr. Mahlon Kennicutt II

Date: December 14, 1993

Presentation	Author/Affiliation
Introduction: GOOMEX Progress Reports	Dr. Pasquale Roscigno Environmental Studies Section Minerals Management Service Gulf of Mexico OCS Region Dr. Mahlon C. Kennicutt II Geochemical & Environmental Research Group Texas A&M University
Program Design and Study Elements of GOOMEX Phase I	Dr. Mahlon C. Kennicutt II Geochemical and Environmental Research Group Texas A&M University
Physical Setting and Contaminant Gradients in Sediments and Biota of GOOMEX Sites	Dr. James M. Brooks Geochemical and Environmental Research Group Texas A&M University
GOOMEX Infauna Biological Studies	Mr. Paul A. Montagna Marine Science Institute University of Texas at Austin
Macroinvertebrate Reproductive Report	Mr. Matthew S. Ellis Dr. Elizabeth A. Wilson-Ormond Dr. Eric N. Powell Department of Oceanography Texas A&M University
Biomarkers of Aromatic Hydrocarbon Exposure	Dr. S. H. Safe Ms. K. Willett Ms. C. Erickson Mr. K. Connor Department of Veterinary Physiology and Pharmacology Texas A&M University Dr. S. J. McDonald Dr. T. R. Narasimhan Ms. K. Beatty Geochemical and Environmental Research Group Texas A&M University

INTRODUCTION: GOOMEX PROGRESS REPORTS

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Dr. Mahlon C. Kennicutt II
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The Minerals Management Service (MMS) is interested in understanding whether discharges from the oil and gas drilling and development on the Outer Continental Shelf (OCS) of the Gulf of Mexico are producing chronic impacts on marine ecosystems. The Geochemical and Environmental Group (GERG) of Texas A&M University won a competitive contract procurement to implement a study entitled Gulf of Mexico Offshore Operations Monitoring Experiment (GOOMEX) — Phase I.

GOOMEX is the initial phase of a multidisciplinary investigation which seeks to develop a suite of environmental indicators. These indicators will be refined in subsequent phases into standard monitoring procedures that may be implemented in future OCS exploration and development.

By developing techniques to measure biochemical responses of resident fauna chronically exposed to discharges from long-term OCS production platforms, early warning indicators can alert managers and operators before damages to populations and communities are manifested.

GOOMEX attempts to quantify natural variability associated with Gulf marine ecosystems so that perturbations caused by chronic exposure to contaminant discharges can be measured. Levels of interaction range from responses at the molecular level to the organism and the community level.

Presented in this session are a series of papers that report on the results of the first year of study.

Dr. Pasquale F. Roscigno is program manager for various research projects in the MMS' Environmental Studies Program in New Orleans. Previously, he held several positions as a researcher and program manager in the Department of Interior's Fish and Wildlife Service. Dr. Roscigno's research interests are in estuarine and marine ecotoxicology, environmental risk assessment, and marine process ecology.

Dr. Mahlon C. Kennicutt II, Research Scientist, is Chief Chemist for the Geochemical and Environmental Research Group with the College of Geosciences and Maritime Studies at Texas A&M University. Dr. Kennicutt has expertise and research interests in marine chemistry, environmental chemistry, and organic geochemistry. He received a B.S. in chemistry in 1974 from Union College and a Ph.D. in oceanography from Texas A&M University in 1980. In addition to numerous scientific publications, Dr. Kennicutt has over 100 peer-reviewed publications and numerous book chapters.

PROGRAM DESIGN AND STUDY ELEMENTS OF GOOMEX PHASE I

Dr. Mahlon C. Kennicutt II
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A closely coordinated series of investigations is being used to test for biological impacts in the vicinity of long duration activities associated with oil and gas exploration and production. The fundamental objective is to assess sublethal effect of the chronic exposure of marine organisms to contaminants derived from offshore oil/gas exploration and development activities. A chronic impact is defined as an effect on the biota that is caused by exposure to the long term accumulation of chemicals in the environment. All study components provide information on the aerial and temporal distribution of pollutants. The biological components identify possible responses as reflected in biochemical detoxification, life history, reproductive success, reproductive effort and assemblage composition.

The basic program structure includes four field activities conducted during a total of 56 days at sea over a two-year period. The sampling plan is designed to detect nearfield impacts and contaminant gradients extending out from each site. The study will evaluate five test sites and narrow the long-term study to the three most appropriate sites. The sampling design includes a radial pattern with sample stations at 30-50, 100, 200, 500 and >3,000 m. A radial design employs a dose-response model to test the hypothesis that changes in biological variations with distance from the platform are due to platform related contaminants. Multiple comparisons of sites subject to chronic exposure to oil and gas activities versus ecologically similar, nearby unexposed sites are used to look for chronic effects.

Study components include contaminant analysis in sediments, pore waters, and biological tissues (Trace metals and hydrocarbons); assemblage analysis of benthic meiofauna, infauna, and epifauna; assessment of community health based on life history and reproduction studies; and the presence and intensity of detoxification responses. Sample collection is by boxcore and beam trawl with alternatives such as grab samplers, divers, gill nets, and divers as needed. All trace metal and hydrocarbon analytical protocols are equivalent to methods used in the NOAA NS&T program.

The biological effects program covers a wide range of important species from meiofauna to macrofauna including infauna, epifauna, mobile invertebrates and demersal fishes. The biological measurements provide a breadth of potential markers of impact from molecular alterations to traditional assemblage compositions. Assemblage data is being collected for meiofauna and benthic infauna/epifauna. Reproduction and life history concentrates on meiofauna with emphasis on harpaticoid life histories. Individual copepodite stage, class structure of population, number of sexually mature males and females, number of gravid females, number of eggs per gravid female, size of eggs in clutches, and clutch volume. Invertebrate reproductive effort and health is assessed by (1) size and age structure of the population; (2) the stage of gonadal development in the population; (3) the portion of the biomass represented by reproductive tissue; (4) the size and number of mature eggs in the individual; and (5) the histopathology of reproductive organs. Large infauna and epifauna are the target organisms with molluscs preferred. All analyses are coordinated with measurement of tissue contaminants. Demersal fishes are being examined for chronic impacts at several levels of detail. Analyses include necropsies (gross pathology), histopathology of representative tissues, stomach content food analysis, liver and stomach content contaminant analysis, and fish biliary PAH metabolites.

Biological exposure to and/or effects of organic xenobiotic exposure is evaluated using a series of biochemical biomarkers that measure P4501A induction. The *in vivo* biomarkers used for demersal fish liver tissues include catalytic enzyme assays [ethoxyresorufin-O-deethylase (EROD) and aryl hydrocarbon hydroxylase (AHH activities] and levels of P4501A mRNA. Additionally, the concentration of PAH metabolites is measured in the bile of demersal fish. Highly Ah-responsive *in vitro* cell bioassays (i.e., rat hepatoma H4IIE cells) are used to determine the induction (as measured by EROD activity) potency of extracts from invertebrates. All analyses are coordinated with measurements of tissue contaminants.

Optional work elements have been added to the core program to assess pore water toxicity based on sea urchin embryological development tests and an immunological probe development to estimate reproductive effort in macroinvertebrates. A series of new techniques is being developed including meiofauna genetic diversity, utilization of more appropriate organisms for bioassays, and evaluation of various *in vitro* toxicological assays presently utilized in mammalian systems.

Data synthesis includes maps of important physical, chemical, and faunal characteristics, correlations, regressions, and plots of dependent versus independent variables. Variations in benthic faunal assemblages are described by power diversity (rare fraction curves) and multivariate analysis. Statistical analyses are being conducted to determine the relationships between the MFO system and PAH levels in tissues and sediments. Additionally biliary PAH metabolites and histopathology are compared to the MFO system activity measured in fish tissues.

Dr. Mahlon C. Kennicutt II, Research Scientist, is Chief Chemist for the Geochemical and Environmental Research Group with the College of Geosciences and Maritime Studies at Texas A&M University. Dr. Kennicutt has expertise and research

interests in marine chemistry, environmental chemistry, and organic geochemistry. He received a B.S. in chemistry in 1974 from Union College and a Ph.D. in oceanography from Texas A&M University in 1980. In addition to numerous scientific publications, Dr. Kennicutt has over 100 peer-reviewed publications and numerous book chapters.

PHYSICAL SETTING AND CONTAMINANT GRADIENTS IN SEDIMENTS AND BIOTA OF GOOMEX SITES

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The sediments on the continental shelf offshore Texas, where the GOOMEX study sites are located, were deposited by fluviatile and deltaic processes. They consist primarily of quartz sands, silts, and clays with an admixture of the skeletons or fragments of organisms living at the site of deposition. After a period of more than 10 years, even in relatively shallow water where the bottom sediments are susceptible to movement by frequent winter storms, the sediments beneath and for some distance away from the platform are still coarser than unaffected sediments in the area. An ANOVA analysis of variance of the grain size data (i.e., percentage of sand) shows a highly significant interaction (P=0.01) with distance, direction, and often time for sediment texture. These strong interactions will be carefully analyzed and considered in the interpretation of other work element results. Differences related to time are most likely reflective of localized heterogeneity and the ability to resample in areas of rapidly changing sediment texture. A characteristic feature of all sites is a lens of sand directly under the platform most likely due to cutting discharges at the site.

The X-ray diffraction study was conducted to determine if barite could be identified on the diffraction record. The limit of sensitivity of the technique was about 5 percent by weight barite. X-ray diffraction was able to identify barite at two of the five study sites. Neutron activation analysis is a much more sensitive technique and therefore it can be used to determine the presence and amount of barite in the sediments. Mineralogic analyses were discontinued after the first cruise.

Analysis of variance of sediment carbon content at the platform sites revealed a number of significant interactions between total organic carbon (TOC) and distance and often with direction. These interactions reflect the large increases in sand content beneath the platform which apparently dilutes the organic carbon content. The areal distribution of TOC is determined by the prevailing bottom currents. Total inorganic carbon (TIC) enrichment near the platform most likely reflects deposition of debris from platform biota but the increases in TIC cannot account for the observed decrease in TOC. As with sediment texture, between cruise (i.e., time) variations most likely reflect significant localized heterogeneity in areas of rapidly changing sediment type.

Redox conditions as measured by Eh electrode were highly variable at the sites studied. In many cases, Eh showed a significant interaction with distance from the platform (P=0.01). A more detailed analysis of the data and more data will be needed to evaluate the significance of the observed variations in sediment Eh (mV).

Sediments are a long-term repository of the residues of petroleum released to the marine environment. Petroleum in the offshore environment can be altered by evaporation, dissolution, photooxidation, and microbial degradation and tends to adhere to particulates and become deposited in sediments. The presence and composition of petroleum contaminants in sediment are a record of the long-term, chronic accumulation of contaminants in the vicinity of platforms, thus reflecting the potential for exposure of the resident biota. Based on these considerations, aliphatic and polycyclic aromatic hydrocarbons were measured at all quantitative boxcore locations. Strong gradients with distance from the platform are apparent in total alkane, UCM, and PAH concentrations at MU-A85 and HI-A389 sites. A less dramatic gradient is present at MAI-686 and little or no gradient is present at MAI-622 and GA-288. Shallow water erosional settings are unlikely to accumulate contaminants.

Based primarily on the cruise one results (hydrocarbons and trace metals), the two sites with the weakest contaminant gradients were eliminated as study sites. Most stations within a study site contained little or no evidence of petroleum contamination. As demonstrated in previous studies, the concentration of contaminants decreases rapidly with distance from the platform, has a directional component, and generally reaches background levels at distances greater than 100 m from the platform. Two exceptions are a total alkane anomaly at MAI-686, which is evident to at least 200 m distance, and the presence of PAH as far as 500 m from the platform at HI-A389. The MAI-686 stations exhibited evidence of fresh condensate contamination during both cruises one and two suggesting either a pipeline leak or a seep. In contrast, the contaminants at HI-A389 and MU-A85 were highly degraded as evidenced by the lack of n-alkanes and the presence of a large UCM. Sediment hydrocarbons at HI-A389 also exhibited a range of compositions suggestive of several sources of contamination. One area appeared to be contaminated with a low molecular weight, fresh spill while other areas exhibited a biomodal UCM suggestive of two different sources of degraded petroleum.

The areal distribution of the hydrocarbon contaminants was relatively symmetrical around the platforms of HI-A389 and MU-A85, but did show preferential accumulation along the directions of the prevailing currents. The contaminant fields were similar from cruise one to cruise two, suggesting that the features are relatively permanent. The greatest cruise to cruise variations were detected at the stations nearest to the platform, suggesting localized heterogeneity as a primary cause of variability, i.e., patchiness. An ANOVA analysis of the sediment hydrocarbon data by site highlights the significant trends in the data. At P=0.01, cruise one to cruise two variations are not significant at MU-A85 and HI-A389. At site MAI-686, cruise one to cruise two variations are significant (P=0.0023) due to the weak gradient observed. Many of the contaminant values at MAI-686 are close to background or the method detection limit. As suspected at MU-A85 and HI-A389, distance, radii, and distance∘radii interactions are highly significant. At MAI-686 at P=0.05, radii and radii∘distance interactions are important.

Contaminant concentrations in tissues have been widely used to assess the level of exposure to petroleum contamination. Tissue contaminants may not directly reflect environmental levels due to several factors including preferential uptake, bioaccumulation, detoxification, metabolism and depuration. These confounding factors can obscure the relationship between body burden and actual exposure. The uptake and ability to eliminate contaminants is dependent on species with invertebrates generally less capable of elimination than vertebrates (i.e., fish). The presence of detoxification enzyme systems in fish provides an ability to transform and eliminate contaminants from their tissues. However, the presence of contaminants in tissues does confirm recent exposure. The targeted tissues were the soft tissues of invertebrates, liver tissues from fish, and fish stomach contents. Invertebrates may accumulate contaminants due to their often intimate relationship with the benthos. Fish livers are a primary site of PAH metabolism/storage and thus would be the most likely tissue to exhibit PAH contamination. The liver is also very lipid-rich compared to muscle tissue, and PAH tend to preferentially accumulate in lipid-rich organs.

Stomach contents were identified and analyzed to attempt to determine if contaminant exposure in fish is due to dietary sources, ingestion of contaminated sediments, or uptake across exposed external organs such as gills. ANOVA analysis of variance revealed few trends in the pairwise comparisons of near and far stations by site. The data set is limited and multiple species were grouped for this preliminary analysis of the data. As the database is expanded by further sampling, more refined statistical analyses will be possible. A significant (P=0.01) difference in PAH levels in fish liver tissues from HI-A389 was observed. The statistical comparison was made on normalized data to eliminate artifacts due to variable method detection limits. Species, ecological niche, and other factors that may control contaminant exposure and expression will need to be evaluated in order to properly evaluate the tissue contaminant data.

Pore waters extracted from sediments collected at each boxcore location are being utilized for bioassay estimates of toxicity. Pore water bioassays have been shown to be an effective method of detecting the potential for injury at a given location. Standard assays utilizing sea urchin embryos and indigenous copepod species are being conducted. To attempt to link apparent biological effects with pore water constituents, contaminant concentrations were measured on those pore water samples which exhibited the greatest toxicity. In general, PAH in the pore water were low in concentration. The bulk of the PAH were low molecular weight naphthalenes.

The concentrations measured were far below values known to cause toxic effects in benthic organisms and did not correlate with the observed toxicity. Pore water PAH also did not correlate with solid phase PAH. PAH are relatively insoluble in water and these results suggest most sedimentary PAH are in portion from the particulate phase to the pore waters. These preliminary results suggest PAH are not responsible for the observed toxic properties of the pore water.

Barium is the major elemental tracer in drilling muds, and all previous studies have shown strong trends of increasing sediment Ba concentrations with decreasing distance from the drilling site. Two of the three study sites (High Island Block A389 and Mustang Island Block A85) showed highly significant negative correlations between Ba and distance. The Ba versus distance trend at Matagorda Island 686 was apparent for both cruises but not significant because the Ba concentrations are lower and similar at the first three sampling distances (40, 100, 200 m). At all sites the Ba values at the 3,000 m control stations are higher than the typical 500 ppm background level observed in Texas-Louisiana Shelf sediments. This is most likely due to Ba input from other drilling sites in the vicinity of the 3,000 m stations. At both HI-A389 and MU-A85, several metals showed similar negative correlations with distance as well as significant correlations with sediment Ba. For most of the metals, the correlation with Ba is so strong that it suggests the metals are constituents of the barite itself. However, the greater scatter for Pb and Zn suggest an independent, rig-related source is also important. The HI-A389 site clearly has the strongest spatial gradients and should be the location most likely to exhibit trace element related effects in the local biota. Trace metal concentrations close to the platform often exceed those levels believed to cause biological effects. An ANOVA analysis of Ba concentrations confirms the highly significant ($P=0.01$) interactions with distance and direction as for the organic contaminants. Barium concentrations were also similar between cruises as reflected in the less significant interactions with cruise (time). The observed variability between cruises is most likely due to localized heterogeneity and rapidly changing gradients in sediment contaminant concentrations.

Pore water samples that exhibited an effect during toxicity testing were chosen for trace metal analysis. It should be noted that the samples were not processed using metal-free equipment and may be affected by post-collection contamination. Samples were stored un-acidified in glass jars prior to analysis. This may result in an underestimate of the dissolved metals present. These shortcomings in sample processing are being evaluated and improved. However, good correlations were observed between the bioassay results and solid phase metal levels. However, no correlations were seen between the bioassay and pore water data. This lack of correlation could be related to the sampling problems discussed above. No consistent correlations between pore water and solid phase metal levels were observed.

Trace element tissue samples include fish livers, soft tissues from shrimp, crabs, molluscs, echinoderms, polychaetes, and fish stomach contents. Only data from the three sites selected for further study are discussed here. Interpretation of the tissue data is based on near versus far-field comparisons. Preliminary comparisons were made for those tissue groups with sufficient numbers. This comparison involves combining several different species into a single group, which may confound the analysis. The between-sites means for most elements are similar. Where differences occur, they are not significant because of the considerable variability in the data. The stomach contents data do show possibly significant differences in Ba and Fe levels reflecting the ingestion of bottom sediments during feeding. More comparisons are needed using smaller comparison groups composed of the same or similar species. These tests may reveal additional significant differences in trace element levels within sites as the database increases.

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GOOMEX INFAUNA BIOLOGICAL STUDIES

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The goal of GOOMEX is to develop and recommend sensitive and appropriate techniques to assist monitoring activities of offshore oil and gas production. To accomplish this goal, a range of biological, biochemical and chemical methodologies is being tested to detect and assess chronic sublethal effects of offshore oil and gas production. Documentation of detoxification response to contaminant exposure is defined as the primary objective of GOOMEX. A secondary objective is to document the impacts of any contaminant exposure at the organism, population, or community level. Benthic infauna studies are designed to fulfill the secondary objective.

The benthic infauna component of the GOOMEX program focuses on organisms that live in sediments. Both meiofauna and macrofauna are being studied. Meiofauna are the smallest living metazoans, passing through a 500 μm sieve and retained on a 63 μm sieve. Macrofauna are larger, being retained on a 500 μm sieve. Although the operational definition of these two groups is based on sieve sizes, the groups are dominated by different taxa. The meiofauna are composed primarily of nematodes and harpacticoids. Macrofauna are composed primarily of polychaetes and amphipods.

Samples for both infaunal groups come from subcores of box cores. As described previously (Kennicutt), the box core stations are located at five distances from the platform along five different axes, yielding 25 stations per platform in a radial design. The boxcore is subdivided into 25 subcores. Two meiofauna cores (area=2.8 cm^2) are taken from two different subcores of each boxcore. Three subcores (area=100 cm^2) are taken for macrofauna. Samples are preserved in the field and analyzed back at the laboratory.

The response variables of interest for both the meiofauna and the macrofauna are total abundance, abundance of specific groups known to be sensitive to contamination, and total community structure. Additional data is being collected for the meiofauna component. Harpacticoid life history characteristics and nematode feeding guilds are being determined to test for sublethal response and changes in community trophic dynamics. We are testing hypotheses to detect changes in benthic infauna with respect to distance from the platforms. Abundance changes are detected using analysis of variance procedures. Community structure changes are detected using diversity and evenness indices, cluster analysis, and multivariate statistical procedures. Infauna data will be compared and correlated to changes in other biological and environmental data. Relevant biological data are: levels of chemical body burdens, pore water toxicity test results, and life history parameters. Relevant environmental data are: water depth, bottom water salinity, temperature, and oxygen content; and sediment grain size, total organic carbon, trace metals and hydrocarbons. One particular strength of our program is the ability to combine standard measures of benthic community analyses, pore water toxicity, and sediment contamination to perform sediment quality triad tests.

To date, all samples from the January 1993 and June 1993 cruises have been sorted and identified to major taxa. Five platforms with 25 stations each (=125 stations) were sampled on the first cruise, and three platforms were resampled on the second cruise. This report discusses preliminary results from the first cruise only.

MEIOFAUNA

A pre-study was performed to determine vertical distribution of meiofauna in Gulf of Mexico continental shelf sediments. In a 10 cm deep core, 71 percent of the meiofauna were found in the top 2 cm, and 93 percent in the top 4 cm. Almost all (95 percent) of the harpacticoids were distributed in the top one cm of sediment. Since very little information is gained from sampling below 2 cm, we determined to perform the GOOMEX study at the 0-2 cm depth interval.

During the first cruise, two stations at each platform, designated "near" and "far," were oversampled to examine sampling statistics. Cores were also split into two sections at 0-2 and 2-4 cm to verify the adequacy of using just the top two cm of sediment.

The majority of organisms (82 percent of the meiofauna) were concentrated in the top 2 cm of sediment. Generally, fewer organisms were found in surface sediments near the platforms indicating a platform affect on vertical distribution. A analysis was performed to determine the power of our sampling design. The overall average density was 722 individuals$\cdot$core^{-1}, and the mean square error was 62,983. The break in the power curve appears after four samples, meaning more than four samples does little to increase resolving power. A test for near versus far effects would be based on 20 samples (=2 replicates $\times$ 5 radii $\times$ 2 distances), and we could detect a 40 percent change with this design with 0.80 power (β=0.20). With just two samples, we can detect a 100 percent change (a doubling) among stations. Variance components analysis was performed to determine if using subcores as replicates from one box core is sufficient. Alternatively, one subcore from two boxcores might be a better sampling design. Most of the variability in the study is among platforms (54 percent) and the platform*station interaction (33 percent). Practically, none of the variability is due to replicate boxcores (0.1 percent). Therefore, one boxcore per station and using replicate subcores is a sufficient sampling protocol.

The overall average density at all study sites during the first cruise was 656 individuals$\cdot$core^{-1} (which is equivalent to 2,320$\cdot$10 cm^{-2}) to a sediment depth of 2 cm. This density is much higher than previously reported in the Gulf of Mexico. Overall, nematodes comprise 70 percent of the organisms, harpacticoids are 14 percent, and 11 other taxa represent the remaining 15 percent. None of these "other" taxa occur in large numbers.

Meiofauna community composition did vary within platform stations. At GA-288, harpacticoids were most abundant at the 1,000 m ring. At HI-A389, nematodes were most abundant at the D and E radii. Trends at MAI-622 and MAI-686 were almost identical. There were increases of harpacticoids and total density with increasing distance from the platforms. A similar trend is found at MU-A85, but harpacticoids were very abundant at this platform at most distances. A statistical analysis reveals that there were no significant differences among radii, but there were differences with distance from platforms in all meiofaunal components. The nematode:harpacticoid ratio was significantly different with different distances.

Platform effects are clearly evident. For all variables, either the 50 m or 100 m distance had the lowest density estimates. The effects seemed to be indistinguishable at 200 m. Harpacticoid abundance was the best indicator of a platform effect. Density increased steadily to about 1,000 m, where the density was indistinguishable from background levels at 3,000 m. Even though both nematodes and harpacticoids had low densities near platforms, the nematode:harpacticoid ratio did predict platform effects. There were more nematodes relative to harpacticoids near the platform (within 200 m) than at background levels (1,000- 3,000 m).

The platforms are different (Table 1B.1). The significance of this relationship is driven by a strong trend at the two Matagorda Island platforms (MAI-622 and MAI-686). For total density, which is driven by nematode abundance, there is a slight enrichment at HI-A389, and only slight platform effects at GA-288 and MU-A85. Harpacticoid abundance is the best indicator of platform effects. Harpacticoid density increases with distance at all platforms. Even though the trend in platform effect is weakest at HI-A389, the nematode:harpacticoid ratio is the highest at this station. Abiotic factors, e.g., sediment texture, depth, salinity and oxygen concentration are all correlated with depth, and are therefore confounded with platforms. The highest densities are found at platforms that are the shallowest, lowest salinity, highest oxygen content and most coarse grained. Within platforms there are few trends that can be attributed to these abiotic factors. The only exception would be the distribution of harpacticoids. Harpacticoids are affected by sediment composition. The sediment grain size increases near the platforms. Harpacticoids are negatively correlated with the sand content and positively correlated with fine sediment content. Factor analysis confirms this observation. The first factor explains 92 percent of the variability of the data, and it is related to differences among platforms. The second factor explains 7 percent of the variability and it relates to distance from platforms. Although platforms are having a negative impact on local fauna, the natural variability in Gulf with respect to water depth on northeast-southwest gradients has a much greater effect in controlling abundance patterns.

Table 1B.1. Average values of biotic and abiotic factors at each platform. Values for abiotic factors from other GOOMEX Components. Units for meiofauna=$n \cdot 2.8\ cm^{-2}$ and macrofauna=$n \cdot 300\ cm^{-2}$.

	Platform				
Variables	GA-288	HI-A389	MAI-622	MAI-686	MU-A85
Depth	17.47	119.82	21.89	21.15	72.55
Salinity (ppt)	34.14	36.34	34.44	34.30	35.92
Oxygen ($ml \cdot l^{-1}$)	5.91	3.12	5.36	5.46	5.01
Sand (%)	72.25	19.03	56.57	46.81	32.87
Silt (%)	13.93	35.04	18.95	22.83	34.57
Clay (%)	13.82	45.92	24.48	30.36	32.56
Total Meiofauna	794	257	1023	1043	213
Nematodes	541	203	732	736	122
Harpacticoids	120	23	133	157	48
Others	133	31	158	150	43
Nem:Har ratio	5.56	10.32	6.61	5.30	2.71
Macrofauna	133	36	55	34	26

There are no statistically significant differences among the platforms and distances from platforms for nematode diversity indices. There is a gradient of decreasing nematode diversity at the HI-A389 platform only. There was a strong gradient in nematode feeding guilds around platforms. There were more non-selective deposit-feeding nematodes near the platforms than away from them.

Harpacticoid species distributions have been analyzed from all the near and far stations, and all the GA-288 stations. There is a definite platform effect on diversity. At four of the five platforms, diversity is higher away from the platform than near it. At GA-288, where the data is complete, there is a strong trend of increasing diversity away from the platform. Only at HI-A389 is different, but this may be due to a paucity of organisms at this platform. There seems to be a platform effect on the number of gravid harpacticoid females present. Three of the five platforms had more gravid females near the platform than away from them, and there was no difference at the other two. Body lengths of mature individuals also appear to indicate an enrichment effect under the platform. Body lengths of both males and females decrease with distance from the platform GA-288.

In conclusion, meiofauna, particularly Harpacticoida, are restricted to the surface of Gulf of Mexico shelf sediments. Therefore, meiofauna are affected by deposition of contaminant materials associated with platforms. The current sampling regime has sufficient power to detect small changes in the meiofauna community. Harpacticoids are the best indicators of platform affects. This is true for both total abundance and species diversity. Harpacticoid abundance and diversity declines as we sample nearer the platforms. Nematode diversity does not appear to be useful for detecting platform effects, since there were no discernable trends, but feeding group guilds indicate changes in the sediment near platforms. Patterns of nematode abundance showed only a weak platform affect. The nematode:copepod ratio was only an effective indicator at the HI-A389 platform, suggesting that this is not a good general index of platform affects. All platforms have completely different abiotic characteristics in terms of depth, oxygen content, and sediment grain size (except for the two MAI platforms, which are identical). Within a platform area, there seems to be little influence due to these environmental characteristics on community structure, but most differences among platforms can be attributed to natural variation and gradients in these abiotic components. Life history characteristics of harpacticoids appear to indicate an enrichment effect under the platforms. There appears to be a potential for an organic enrichment affect near platforms due to the reef-like nature of the organisms associated with the platform legs. It is possible that there is a great deal of detrital input to the seafloor adjacent to platforms and this is counteracting or confounded with contaminant toxic affects. The ability to detect differences in harpacticoid community, life history, and reproductive parameters demonstrates that we will be able to develop reliable indicators of sublethal responses. Coupled with genetic and toxicity studies, the study of the biology of the harpacticoida should prove to be a powerful tool monitoring purposes.

MACROFAUNA

The total number of species and individuals and the number of dominant species at each station were determined. At platforms MU-A85 and HI-A389 there were seven and eight stations, respectively, where no species were numerically dominant. Numerical dominants at most stations in the MU-A85 and MIA-686 study areas were present in relatively low abundances. At both of these sites, abundances of infauna were slightly larger in the near-field area than at greater distances from the platforms. At MIA-622, numerical dominants were present in low to moderate abundances. The numbers of individuals are quite variable; the only trend appears to be a slight reduction in abundances in the near-field area of the east through west region. At HI-A389, abundances of numerical dominants were as low as at platform MU-A85, except at three of the near-field stations. The exceptions were caused by large populations of the polychaetous annelids *Cirratulus cirratus* and *Cirriformi* sp. A close to the platform on transects A, B and E. This resulted in abundances in the near-field area being much higher than elsewhere in the study area. At GA-288, which contained the largest overall abundances of organisms, the numerical dominants were moderately abundant at most stations. The trend appeared to be reduction of numbers of individuals toward the periphery of the study area.

No single species appeared to occur more frequently at platform MU-A85 stations, and many stations had no dominant species. At MIA-686, stations frequently contained the polychaetes *Mediomastus californiensis, Paraprionospio pinnata* and *Neanthes micromma* in the near-field to intermediate-field regions, and ampeliscid amphipods in the far-field region. Ampeliscid amphipods appear to be sensitive to stress, and their absence close to the platform may indicate a platform effect. At MIA-622, stations contained the same near-field dominant as platform MIA-686. Far-field stations contained ampeliscids, the polychaete *Aricidea catherinae* and a few *P. pinnata.* Again, ampeliscids were absent in the near-field region. The stations at HI-A389 displayed no particularly abundant species, and, as noted above, eight stations had no species in sufficient abundance to be considered a numerical dominant. GA-288 was the only study area in which ampeliscid amphipods were numerical dominant in the 3 (100 m), 1 (200 m), 4 (500 m) and 5 (3,000 m) rings around the platform. A few other numerical dominants occurred, *i.e.* the polychaetes *Cossura soyeri, Lumbrineris verrilli,* an unidentified paranoids. There is no indication of widespread stress at this site.

Cluster analysis suggests that near-field assemblages are different from far field assemblages at platforms MU-A85 and MIA-686. The differences appear due to the occurrence of different species rather than absence of species at both platforms. The data from platform MIA-622 suggest at best an intermediate field effect from the west through the north to the east. Again there appears to be no abundant difference between groups. Platforms HI-A389 and GA-288 share the characteristic of having isolated stations grouped in clusters, and showing no trends at all.

Near-field stress at platforms MIA-686 and MIA-622 may be indicated by the absence of ampeliscid amphipods. At platforms MU-A85 and HI-A389, abundances of benthic infaunal organisms were relatively low and dominant species were not as dominant as at other platforms. Abundances of macroinfauna were higher in the GA-288 study area than other sites (Table 1B.2). There was no indication in platform GA-288 data of a platform-related stress.

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Table 1B.2. Summary of meiofauna data. KEY: - = Decline near platform; 0 = No platform effect; + = Enrichment near platform.

	Platform					
Variable	GA-288	HI-A389	MAI-622	MAI-686	MU-A85	**Effects**
Total Abundance	0	+	-	-	-	**3**
Vertical	-	+	-	-	-	**4**
Nema/Harp	-	+	0	+	-	**2**
Nema Abundance	-	+	-	-	-	**4**
Nema Diversity	0	-	0	0	-	**2**
Nema Feeding	-	+	-	-	-	**4**
Harp Abundance	-	-	-	-	-	**5**
Harp Diversity	-	0	-	-	-	**4**
Gravid Harp	-	+	+	0	+	**1**
Harp Body size	+					
Effects	**6**	**2**	**6**	**7**	**8**	

MACROINVERTEBRATE REPRODUCTIVE EFFORT

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A component of the Gulf of Mexico Offshore Operations Monitoring Experiment (GOOMEX) project involves the assessment of macroinvertebrate reproduction. Very little is known about the reproductive effort of most continental shelf invertebrates. Accordingly, whether reproductive effort is affected in these species by gas field development is also largely unknown. We have utilized several different methods to assess differences in the reproductive effort of invertebrate species living near by and far from gas producing rigs. Differences in size-frequency distribution, stage of reproductive development and health (determined by the presence of parasites and pathologies), were used as indicators of possible sublethal effects of exposure to chemical contaminants or other gas field-associated factors in target species. Species-specific immunological probes are also being developed so that the rate of instantaneous reproductive development can be measured in some of these species.

Animals were collected by trawling from locations close to (near-field) and far from (far-field) the platforms to assess the effect of gas field development on macroinvertebrate reproduction. After collection, all individuals were measured. Reproductive development for these species was evaluated by two methods; visual inspection and histological analysis. Immediately after collection, individuals were sexed and a visual determination of the reproductive stage of females was made based on the development and color of the ovary. Whole specimens were preserved and returned to the laboratory for complete histological analyses. Tissue sections were analyzed for sex, stage of reproductive development, and presence and intensity of parasites and pathologies.

The reproductive cycle of most of the species involved in this study has not heretofore been studied; therefore a semi-quantitative reproductive scale was developed for each species based on the appearance of the gonads and the quantity of gametes present for both methods. Results show that when a difference in size-frequency distribution did occur between populations from the near and far-field stations, as seen for *Sicyonia dorsalis* at MAI-622, *Portunus spinicarpus* at MU-85, and *Trachypenaeus similis* at MAI-686, the individuals collected at the far-field station were usually larger. Differences in the stage of reproductive development are not as clear; however, preliminary results show that more crabs from the far-field stations were gravid. Shrimp at the near-field stations (*Penaeus aztecus* and *Trachypenaeus similis*) had an increased presence of parasites and pathologies suggesting variations in population health on a scale of 3 km. These results indicate that detectable differences exist, possibly due to chronic exposure to environmental contaminants, in populations living close to and removed from gas producing platforms.

Instantaneous rates of reproduction will be measured using a radioimmunoassay based on the gonadal probes described by Choi *et al.* (1989). Labeled leucine will be injected, and incorporation into egg protein followed. Work on these probes is progressing for the scallop (*Amusium papyraceum*) and 3 portunid crabs (*Portunus gibbesii*, *Portunus spinicarpus*, and *Callinectes similis*). The eggs collected from these species during Cruise 1 were injected into rabbits and all have produced a high antibody titre. Purification and calibration of the probes is underway.

Proximity to the platforms influences the size class distributions of some species, the percent of female crabs that were gravid and the prevalence of disease and parasites in shrimp. A few populations sampled in this study were significantly different in size at the near and far-field sites; in these cases, the organisms collected from the far-field station were typically larger. Differences in size-frequency distributions, with the smaller individuals being found in closer proximity to these platforms, could be explained by (1) decreased growth in near-field individuals, (2) movement of larger individuals away from the platforms, or (3) higher mortality of adults nearer the platform. Causative factors might include differences in food resources near the platforms, increased exposure to contaminants that detrimentally affect growth and health, or differences in the predator abundances near and far-field.

Evidence for an impact of proximity to the rig on reproductive development is less clear from the data. Environmental stresses such as exposure to contaminants can affect reproductive activity by delaying reproductive development or by decreasing the quantity of gametes produced. In some cases the far-field station had a higher proportion of gravid female crabs than the near-field. Histological analysis follows the trend in gravid females, with more reproductively advanced individuals found far from the platforms. For these stations it is possible that exposure to contaminants has slowed reproductive development in those organisms near the platform, so that the population at the far-field station spawned earlier. Alternatively, near-field crabs may have already spawned. Sampling frequency is inadequate to differentiate these two possibilities.

In certain species collected during this study, particularly the shrimp *P. aztecus* and *T. similis*, population health, as defined by the presence of parasites and disease, differed between some near-field and far-field stations. Higher prevalence of parasites and disease in shrimp taken at the near-field may be the result of several factors. (1) First, we examined the largest individuals collected in the trawls. If size is used as a surrogate for age in these species, these individuals should have been the oldest collected. Older individuals should have a greater possibility of being parasitized or diseased by virtue of their longer life and extended exposure to the chemical contaminants present in their environment. However, near-field shrimp tended to be smaller, so age is an unlikely explanation. (2) Second, final hosts (probably fish) may be more common around rigs; thus a source of infectious stages may be higher. (3) Third, the near-field populations may be more susceptible. We saw no correlation of reproductive stage and parasite prevalence, but these correlations are inherently difficult to identify.

The results obtained to this point signify physiological impacts on populations living in close proximity to gas platforms in some developed fields, however causative factors remain elusive. The individuals tend to be smaller, have a different rate of reproductive development (at least in crab species) and have a greater incidence of parasitism and pathologies. Additionally, differences observed between the near and far-field sites indicate that these communities do not significantly commingle over the scale of this study (3 km) at least at some sites. Further statistical analyses, particularly correlations between the body burdens of chemical contaminants and the stages of reproductive development, may help to clarify the relationship and the impact of offshore gas production on these species.

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BIOMARKERS OF AROMATIC HYDROCARBON EXPOSURE

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The detoxification work element was designed to meet the primary objective of the GOOMEX project, namely, to assess the sublethal effects of the potential chronic exposure of marine organisms to contaminants derived from offshore oil/gas exploration and development activities.

Polynuclear aromatic hydrocarbon (PAHs) mixtures are a major class of organic contaminants in the marine environment. PAHs are typically derived from spills of crude oil and refined petroleum, runoff, and combustion sources (Boucart *et al.* 1961; Hites *et al.* 1977; Suess 1970; and Huggett *et al.* 1987). PAHs are susceptible to biodegradation, and their presence in water, sediment, and organisms is usually due to relatively recent petroleum spills and/or chronic exposure from non-point sources. Numerous studies have demonstrated that organic contaminants such as PAHs are probably etiologic agents in many diseases which can result in adverse health effects in fish and wildlife populations (Tanabe 1989; Tanabe *et al.* 1989; Kannan *et al.* 1989; and Tillitt *et al.* 1992). Historically, hydrocarbon contaminant studies measured ambient concentrations in water, sediments and tissues using highly sensitive analytical methods to quantify these chemicals. However, these mixtures are invariably complex, and it is often difficult to identify and quantify all components. Even if the concentration of all components of these mixtures is obtained, the extrapolation of this data in terms of potential adverse effects is difficult at best. The biological significance of contaminants is difficult to assess due to the vagaries associated with a wide diversity of exposure routes, differences in bioavailability, and individual and species-dependent differences in response to toxicant exposure. Thus, the use of biomarkers and bioassays for evaluating environmental contamination are potentially powerful alternatives to historical analytical (chemical) approaches.

The biomarkers proposed for this study include measurements of P450IA-dependent enzymes [ethoxyresorufin O-deethylase (EROD) and aryl hydrocarbon hydroxylase (AHH)], P4501A mRNA levels, cell bioassay responses (rat hepatoma H4IIE), and the production of biliary PAH metabolites. This report summarizes preliminary data from cruises one and two.

Both fish and invertebrates were collected by trawling. All specimens were maintained alive until dissection. Fish livers were immediately frozen in liquid nitrogen until analysis. Invertebrate tissues were frozen at -20°C until extraction. Bile was frozen at -20°C until analyzed.

Microsomes were prepared from fish livers by homogenization followed by differential centrifugation. EROD and AHH activities were determined fluorometrically from hepatic microsomal preparations. Naphthalene, phenanthrene, and benzo[a]pyrene (BaP) equivalent metabolites were measured in bile by high performance liquid chromatography (HPLC) and fluorescence detection. Total RNA was isolated from homogenized liver samples by subcellular fractionation and extraction. P450IA mRNA was determined by Northern Blot analysis using a cDNA probe for rainbow trout P450IA.

Invertebrate tissues were extracted with methylene chloride and purified by column chromatography and HPLC. The methylene chloride extracts were transferred into DMSO. Subsequently, rat hepatoma H4IIE cells were dosed with aliquots of tissue extracts. EROD activity was measured to determine the P450IAI induction potency of these extracts.

The following results are based on those species of fish captured at both the near and far stations at each of the three final study sites. One hundred and eighty-four bile samples were analyzed, and of these approximately 30 percent were excluded from data analyses because their chromatograms indicated that the samples were compromised. Samples collected from fish captured at HI-A389 and MU-A85 were particularly prone to degradation presumable due to depth-related stresses. The presence of BaP metabolites indicates exposure to pyrogenic PAH and the presences of naphthalene and phenanthrene metabolites indicates exposure to low molecular weight PAH. The levels of biliary BaP equivalent metabolites were generally low and no significant differences in near/far station comparisons were observed. Naphthalene and phenanthrene equivalent metabolite concentrations were variable, depending upon the species. It is not known at this time if the species differences are due to exposure or to intrinsic species variations. However, no significant near/far station differences were observed.

Ah receptor mediated P450IA-dependent catalytic enzyme activities, EROD and AHH, were measured in all fish hepatic samples. Generally, there was a good correlation between the two assays with the exception of a few species. (i.e., *Lagodon rhomboides* and *Synodus foetens*) The fish that are outliers for the coordinated induction of AHH and EROD activity undoubtedly express an altered CYPIA protein compared to most other fish species, and this observation is unique. Consequently, these fish will be dosed with [^{3}H]2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) on future cruises to characterize the Ah receptor. Species differences were also observed in EROD and AHH activities. Again there was no significant difference in near/far station comparisons.

The levels of P450IA mRNA were determined in approximately 45 fish livers collected during cruise two. P450IA mRNA was detected in all samples, but the levels suggest only minimal induction. However, P450IA mRNA transcripts differed in molecular weights for various species, suggesting genetic differences in this gene between species.

Thirty-three extracts of invertebrate tissues collected during cruise two were analyzed using an *in vitro* cell bioassay (i.e., rat hepatoma H4IIE cells) to determine their CYPIAI induction potency as measured by EROD activity. All extracts induced CYPIAI activity in the rat hepatoma H4IIE cells. The data set is too small to evaluate near/far station differences with any confidence. However, qualitatively, higher EROD activities were measured using extracts from scallops and crabs compared to shrimp, and this is consistent with expected levels of bioaccumulation in these organisms.

In summary, the data from the first two cruises indicate that fish and invertebrates are at best only minimally exposed to PAHs. PAH contaminant (tissue and sediment) data suggest that platform gradients are at the low end of documented exposure. Moreover, the PAHs that are detected are often highly degraded, which reduces the content of PAH and may also render the residues unavailable to organisms. Additionally, potent carcinogenic P450IA-inducers (≥ 4-ring PAH) are low or non-detected at all GOOMEX sites. However, future cruises should provide a large enough data base to determine if there are any differences in PAH exposure and induction responses as a function of distance from the platform.

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SESSION 1C

GIS APPLICATIONS FOR OIL SPILL AND MARINE/COASTAL ENVIRONMENTAL ANALYSES IN THE GULF OF MEXICO

Session:	GIS APPLICATIONS FOR OIL SPILL AND MARINE/COASTAL ENVIRONMENTAL ANALYSES IN THE GULF OF MEXICO
Co-Chairs:	Dr. Norman Froomer and Dr. Shea Penland
Date:	December 14, 1993

Presentation	Author/Affiliation
Introduction	Dr. Norman Froomer Minerals Management Service Gulf of Mexico OCS Region
Document not submitted	Dr. Norman Froomer Minerals Management Service Gulf of Mexico OCS Region Mr. Robert Hughes Jackson state University
Design and Development of an Environmental GIS to Support Oil Spill Contingency Planning and Environmental Analyses in the Northern Gulf of Mexico	Ms. Linda Wayne Louisiana State University
Research and Development Cartography Overview	Dr. Mehrdad Moosavi Director, GIS Research & Development Mr. Robert D. Martin Chief of Research Cartology Mr. Lee A. Smith GIS Analyst Mr. Leo S. Loza Technology Transfer Analyst Texas General Land Office
Use of Florida's GIS Oil Spill Response Prototype	Mr. Christopher A. Friel Florida Marine Research Institute St. Petersburg, Florida
Marine Spill Research Consortium's GIS Development	Mr. Barry Berkowitz Marine Spill Research Consortium

IINTRODUCTION

Dr. Norman Froomer
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The Geographic Information System Session at the Information Transfer Meeting focused on the applications of GIS for oil spill contingency planning and response. MMS's responsibilities for leasing and managing the development of the energy resources of the Outer Continental Shelf have always made oil spill planning and response issues important to the agency. Recently, with MMS's increased regulatory responsibilities for oil spill contingency planning under the Oil Spill Act of 1990, oil spill issues have become even more important to the agency. GIS is becoming widely used for oil spill planning and response strategies because of its ability accurately to hold and analyze the spatial relationships among large amounts of locational and descriptive information pertinent to a spill. MMS, as well as other federal and state agencies and private organizations, will be increasingly using GIS in oil spill analyses.

The MMS has recently begun a cooperative agreement with Louisiana State University under the Coastal and Marine Initiative to develop a GIS database and clearinghouse to support oil spill contingency planning. After a brief overview of MMS's ongoing GIS initiatives to support leasing and environmental analyses, Linda Wayne of LSU presented an overview of what the five-year cooperative agreement between LSU and MMS was being designed to accomplish. The successful completion of this project will require cooperation and coordination among the federal and state resource agencies and industry cooperatives and organizations that use data on resources at risk from a spill.

The Texas General Land Office (GLO) is undertaking an ambitious GIS initiative to support oil spill planning and response along the Texas coast. Mehrdad Moosavi and Scott Friedman and Robert Martin presented an overview of the ongoing mapping and oil spill trajectory modelling efforts at the GLO. Next, Chris Friel, Florida Marine Research Institute, described a GIS application developed by the State of Florida that integrates a variety of information with analytical routines needed to implement an oil spill contingency planning, response, and damage assessment strategy. He also described how this system was used during the recent large fuel spill near Tampa Bay, Florida. Finally, Barry Berkowitz described the efforts at the Marine Spill Response Corporation to build a GIS to help plan for, manage, and respond to spills.

DESIGN AND DEVELOPMENT OF AN ENVIRONMENTAL GIS TO SUPPORT OIL SPILL CONTINGENCY PLANNING AND ENVIRONMENTAL ANALYSES IN THE NORTHERN GULF OF MEXICO

Ms. Linda Wayne
Louisiana State University

BACKGROUND

The MMS recently established the Coastal Marine Institute (CMI) at Louisiana State University as part of the LSU Center for Coastal Energy and Environmental Research (CCEER). CMI was created to promote environmental research related to the oil, gas, and mining industries. One of the primary initiatives of CMI is to create an environmental information program to support government and industry oil spill contingency planning needs. The information program will coordinate and compile critical information about the location and character of environmental resources, infrastructure, and administrative boundaries that occur within the coastal region of the U.S. northern Gulf of Mexico. Information needed to support the program will be collected from state and federal resource agencies, industry, and other data providers. Priority missing or inadequate resources may be generated as part of the program.

FACILITY AND PERSONNEL

LSU will establish a laboratory facility on campus to house needed equipment and personnel. The laboratory will be composed of information technology including a large capacity Unix-based server, Sun SPARC workstations, personal computers, digitizing equipment, and a hardcopy map plotter. Primary software products will include ESRI Arc/Info geographic information system (GIS), ERDAS GIS and image processing software, and Oracle relational data base management system. Access to the system will be provided via Internet. The laboratory will be staffed by a team of computer scientists, remote sensing/GIS analysts, and environmental scientists. Primary personnel will include a program coordinator responsible for coordinating the needs and objectives of program participants, a program manager responsible for overall system development and operations, a data manager responsible for implementing quality control and data development, a system manager responsible for maintaining technical operations, and a project coordinator responsible for managing data inventory and requests.

SERVICES AND CAPABILITIES

The primary function of the CMI information laboratory will be to facilitate access by agencies and industries to information needed for oil spill contingency planning. Information will be provided in both digital and hard copy formats. Users may request individual data themes or combinations of themes from the resident data set. An easy-to-operate user interface will be developed to provide users on-line review of available information resources. Users without Internet access may request data by telephone. Hard copy maps will be generated in a fixed format to be determined by a Steering Committee comprised of program sponsors. Custom cartography and analytical services will be available at an additional cost.

RESPONSIBILITIES

The CMI laboratory staff will be responsible for locating, assessing, collecting, compiling, documenting, and managing the oil spill contingency planning data resources. The staff will be responsible for translating existing digital data resources to a common geographic base, digitizing non-digital data resources, and deriving needed information from existing digital resources such as imagery. Program staff will devise and implement programs for quality control, data tracking, and data documentation. All data included within the program will meet federal digital data standards including the Spatial Data Transfer Standard (SDTS) and the emerging data documentation (metadata) standard.

POLICY AND MANAGEMENT

LSU and the MMS will be responsible for establishing program policies and deliverables. A program steering committee will be established to guide system development. The committee will be composed of representatives from LSU, MMS, and other program sponsors. The committee will develop recommendations for data types to be included in the system, establish user access requirements, and review program products and capabilities. A scientific/technical committee may be established at the discretion of the steering committee to address specific issues such as data assessment and methods of data translation and to provide information and recommendations to the steering committee. The steering committee will meet as needed the first year (estimated two to four times) and annually, at a minimum, thereafter. Individual agencies will be responsible for travel costs associated with committee participation.

INITIAL DATA DEVELOPMENT

The MMS and industry sponsors have already identified two data sets that will be necessary for successful program development. A base map of suitable spatial resolution and descriptive character must be developed as a backdrop for the selected data layers. LSU has proposed the development of a pseudo color digital image derived from EOSAT Thematic Mapper (TM) satellite imagery. The image would provide a detailed visual reference for the interpretation of other data resources and provide a current land/water interface line for the entire Gulf coastal zone. The per-pixel cell size of the base map would be 25 meters and the original multiband 24-bit satellite image would be reduced to a more manageable single band 8-bit image. In addition, industry has expressed the need for a shoreline characterization map which provides specific information about the shoreline type, vegetative character, environmental resources, and protective/cleanup strategies. This information will enable industry to identify the sensitivity of specific shorelines to oiling and is critical to the development of effective oil spill contingency plans. Comments will be solicited from the Steering Committee regarding the methods and criteria used to develop each of these data resources.

SCHEDULE

LSU proposes to begin developing the CMI information program in January 1994. Program development is expected to continue for five years. The steering committee will convene in March 1994, and data set inventory and development is expected to begin immediately thereafter. Development of the Louisiana basemap is being sponsored by the Louisiana Governor's Office and is expected to be completed in early 1995. Completion of the Texas base map is expected by the end of 1995, and the remaining study areas will be completed by July 1996. The shoreline characterization maps will also be developed within the first two and a half years of program development. Data entry and collection will continue throughout the five-year program; however, primary system design is expected by the end of year four. The primary focus of program years four and five will be the continued development and documentation of data resources and the implementation of the data distribution program.

BUDGET

The cost of developing the CMI information program will be approximately $1 million annually. Because the CMI was established as a "cost-share" program, the MMS has agreed to provide the program $500,000 in annual funds. The remaining funds must be provided by other non-federal agencies and industry groups.

RESEARCH & DEVELOPMENT CARTOGRAPHY OVERVIEW

Dr. Mehrdad Moosavi
Director GIS Research & Development

Mr. Robert D. Martin
Chief of Research Cartography

Mr. Lee A. Smith
GIS Analyst

Mr. Leo S. Loza
Technology Transfer Analyst
Texas General Land Office

OVERVIEW

In March 1991, the Texas Legislature unanimously adopted the Oil Spill Prevention and Response Act (OSPRA) of 1991. The Texas General Land Office (GLO) was designated the lead state agency in oil spill planning and response.

Oil spills pose a threat not only to our dwindling natural resources, but also to the economic vitality of the coastal region. Oil spills could devastate the fishing, recreational boating, commercial shipping, and tourism industries. As a natural resource trustee agency and constitutionally designated steward of Texas's public lands, including the state's four million acres of submerged lands, the GLO is committed to developing the nation's finest oil spill prevention and response program.

MISSION STATEMENT

The mission of the Texas General Land Office is to serve the school children, veterans, and all people of Texas by preserving their history, protecting their environment, providing economic opportunity, and increasing state revenue through innovative administration and prudent stewardship of state lands and resources.

It is our goal to improve and protect the Texas environment, to promote efficient use of our resources, and to create new markets and jobs. We can achieve our goal through environmental initiatives in partnerships with the public and private sectors.

Our immediate objective is to be able to respond effectively to threats of environmental degradation along the entire Texas coastline. Strategic planning thus dictates that we develop and implement a comprehensive oil spill prevention and response program to monitor the integrity of oil transport through Texas's coastal waters and to respond quickly and efficiently to oil spills.

GEOGRAPHIC INFORMATION SYSTEM

Applications Development

Oil Spill Planning & Response Interface (OSPRI) has been designed for accessing the various GIS data stored in the large map library. OSPRI is a resource for map production and maintenance and general GIS data management. OSPRI also facilitates contingency planning, spill response and mitigation and can document injury and damage impact.

GIS Thematic Data Layers

Thematic data layers needed for OSPRI and the Coastal Management Program are, in brief: Base Map hydrography, transportation, submerged state lands, bathymetry; environmental wetlands distribution, shoreline characterization, environmental sensitivity index maps (ESI), and plant and animal species distribution.

RESEARCH & DEVELOPMENT

Research and development of new technology for containment, removal, and cleanup of pollutant spills is an integral part of Texas's prevention and response program. OSPRA authorizes the GLO to spend up to $1.25 million annually on oil spill-related research and development projects. The GLO has ongoing projects involving bioremediation, trajectory modeling, remote sensing, sorbent testing, and sensitive area identification. Contracts have been awarded to Texas A&M University; the University of Texas at Austin; Lamar University; Texas Tech University; and Texas A&M University at Corpus Christi. Other projects have been initiated with Texas agencies, Texas Parks and Wildlife Department (TPWD) and the Texas Water Development Board (TWDB) as well as with the National Oceanic and Atmospheric Administration (NOAA). The following are brief descriptions of several GIS and trajectory-related projects.

Texas A&M University at Corpus Christi: Conrad Blucher Institute

This project's objective is to make available real-time water level and meteorological data for display on digital maps of the Texas coast. The focus is on a pilot project to incorporate data from five existing Next Generation Water Level Measurement Systems providing data on water level, water temperature, air pressure, air temperature, wind speed and wind direction. The research will lead to the development of a prototype interface for the display of real-time information provided by the Texas Coastal Ocean Observation Network (TCOON) for the Texas coast.

University of Texas: Department of Aerospace Engineering & Engineering Mechanics, Center for Space Research, and the Department of Mechanical Engineering

This project focuses on developing techniques using satellite data to identify and predict the evolution of mesoscale surface features in the western Gulf of Mexico. Methods are being developed that reduce the effects of atmospheric attenuation and cloud cover to reveal important details in the imagery. The methods being explored include improved multi-channel corrections to the AVHRR data, investigation of the application of TOVS data to reduce limb darkening effects, and new dynamic compositing techniques that utilize improved image registration and cloud detection algorithms. The University of Texas Center for Space Research is also responsible for acquiring, processing, analyzing, and archiving satellite data from the NOAA polar orbiting satellites and for delivering processed image products to the Texas A&M University.

Texas A&M University: Department of Oceanography

This project, co-funded with MSRC, seeks to generate functional portions of an operational, all-weather flow prediction system using satellite images and drifting buoy trajectories. The Texas Flow Experiment (TEXFLEX) requires daily processed NOAA satellite visible and infrared (1,000 x 1,000 pixels, 1.1 x 1.1 km pixel) imagery referenced to a Mercator grid and temperature adjusted with a single channel correction algorithm to generate surface current flow fields. Processed position and surface temperature drifter data as well as sea surface wind vectors at one degree resolution and 12-hour intervals over the northwestern Gulf, within the bounds of 25°N and 89°W, is acquired during drifter deployments.

The analysis phase of the experiment produces descriptions of the flow field evolution over the drifter trajectory intervals in relation to wind and ocean forcing of the shelf. The numerical treatment of the drifter data assesses the relationships between flow estimates and satellite-derived flow fields, characterizing the dynamic nature of the mesoscale and submesoscale physical features.

The results of this project provide verification for a computer modeling effort, TEXFLOW, capable of predicting sea surface circulation at spatial and temporal scales necessary for oil spill response. These models accept realistic initial environmental conditions synthesized from synoptic flow fields and real-time subsurface information.

GLO and Texas Water Development Board: Trajectory Modeling

The GLO has selected a trajectory model, Spillsim, developed by Seaconsult Marine Research Ltd., Vancouver, B.C. for modeling the movement of oil spills in Texas bay and Gulf waters. Seaconsult and the GLO worked together to identify sources and formats of shoreline properties, meteorological data, currents, tidal information, and water temperature. Both historical and real-time sources from federal and state agencies have been examined to serve as model inputs. Precise knowledge of flow patterns obtained in near real-time is critical to improving assessments of the distribution of contaminant spills such as oil.

The research at Texas A&M University is designed, in part, to help test the concept of using satellite-derived 12 to 24 hour-old surface current data to run the trajectory model for Gulf spills. Similarly, the work at Texas A&M University at Corpus Christi seeks to make real-time tidal conditions and recent tidal history available for Texas bay systems. Using tidal information from TCOON along with forecast winds and river inflow data from other sources, the Texas Water Development Board modelers can run their hydrodynamic models for various Texas bay systems to generate flow fields for use in the trajectory model. To facilitate this joint effort, the GLO and the TWDB have recently created an interagency agreement allowing the TWDB hydrodynamic modelers to work with GIS staff on the model implementation and operation.

GLO, BEG, NOAA, RPI: Environmental Sensitivity Index Mapping

Working together, GLO, NOAA, and their respective contractors (the Bureau of Economic Geology and Resource Planning, Inc.) intend to develop new Environmental Sensitivity Index (ESI) maps for coastal areas of Texas. Most of the existing oil spill response maps for Texas are dated and are limited in their usefulness by their small scale. The newer maps will be drawn at a scale appropriate to field use (1:24,000) will provide more current information for oil spill response and contingency planning and will reside within a GIS to facilitate data exchange and updating. An additional objective of this cooperation is to ensure that state and federal users have access to uniform ESI data in a form that helps them meet specific mandates under state and federal laws. The first year of this effort will focus on mapping the coastal area from the Texas-Louisiana border to the southwest end of the Galveston Bay system. The project will first derive a set of draft maps from aerial photography, digital hydrography, and recent shoreline video coverage of the Gulf Coast, intercoastal waterway, Houston Ship Channel, and associated bay areas. Air and land surveys will be used to field check the draft maps. The mapping effort will also make use of biological data collected by the Texas Natural Resource Inventory project.

CARTOGRAPHIC DEVELOPMENT

Graphic elements, attributes, and related geographically referenced data are all components of GIS data. Graphic data is stored topologically in layers within a map library. These layers can be stored as objects or features that can be accessed to form numerous combinations of overlays. The GIS Cartographic Production Group has implemented over 30 layers into the map library and is currently working on 28 additional layers. United States Geological Survey (USGS) digital line graph data (DLG) currently serve as the base map for most GIS operations. The Group has edited both 1:24,000 and 1:100,000 scale hydrography and is currently replacing the DLG transportation layer with new Texas Department of Transportation (TxDOT) road data. The TxDOT road network is being converted from Intergraph IGDS format into ARC/INFO coverages. The USGS Geographic Names Information System (GNIS) files have also been edited for optimum display at varying scales. The GNIS provides important place name information to accompany the base map.

Thematic Data Layers and Atlases

Acquisition, input, and implementation of these layers has begun. Many of these data layers reside in hard copy and digital formats at various state agencies including the Texas Railroad Commission, Texas Parks & Wildlife Department, Bureau of Economic Geology, and the Texas Natural Resource Conservation Commission. Important data layers include plant and animal species habitat, wetlands distributions, environmental sensitivity index maps, priority protection areas, oil and gas infrastructure, and base map information.

Map symbology is currently being worked on and standards put into place for lines, polygons, and icons. The GLO is standardizing symbology used by NOAA and other Gulf Coast states. Standardized symbols will be developed for depicting wildlife habitat, human use areas, and response logistic facilities.

The GIS Cartographic Production Group is also in the process of designing new oil spill response atlases for distribution to field personnel and oil spill response personnel. Research is being conducted to determine the size, scale, and data-layer combination(s) for display of the atlases. The atlases will be easy to update, portable, and weather-resistant for use in adverse field conditions. Collaboration on atlas design is through GLO field personnel, the U.S. Coast Guard, and other responders.

Digital Orthophoto Quarter Quads (DOQQ)

Digital orthophoto quarter quads (DOQQs) are also being researched for use in base mapping, oil spill response, and coastal zone management. DOQQs are made from USGS NAPP (National Aerial Photography Program) photography and have been corrected for geometric and radial distortion caused by camera platform and earth topography. The GLO is involved in a pilot project to create eight-color infrared DOQQs with a ground resolution of one meter. The project also involves using satellite imagery (SPOT, Landsat TM) to test for updating small scale changes in features on the DOQQs. The DOQQs will also be used to extract vector data such as roads and hydrography for updating existing base map data. DOQQs could also have widespread use for developing booming strategies and area contingency plans.

USE OF FLORIDA'S GIS OIL SPILL RESPONSE PROTOTYPE

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Florida's coastal and marine resources are constantly threatened by accidental spills of oil into the ocean. After the catastrophic Exxon Valdez spill in Alaska in 1989, the Florida Legislature convened a task force to evaluate Florida's spill-prevention and cleanup capabilities. It was evident that the data needed to anticipate and manage oil spills was either lacking or inaccessible. One task force concern specifically focused on the shortcomings of the maps intended for use in responding to oil spills. The only available map series that targeted oil spills was the "Sensitivity of Coastal Environments and Wildlife to Spilled Oil in Florida" series, developed in 1979-80. These atlases consist of 7.5-minute United States Geological Survey (USGS) topographic maps annotated with Environmental Sensitivity Index (ESI) shoreline types, wildlife-resource areas, and spill-response staging areas and strategies. The ESI ranking of shorelines is critical because it cartographically indicates the vulnerability of specific shorelines to oil spills. Explosive urbanization and coastal alteration over the last decade in Florida rendered these ESI rankings obsolete in many areas.

The recommendation of the task force was that the Florida Department of Environmental Protection (DEP) review the existing ESI atlases, update the information where needed, and integrate the information into a GIS to facilitate more frequent updates and real-time analyses. The DEP-Office of Coastal Protection selected the Florida Marine Research Institute (FMRI) to implement the GIS effort because one of the Institute's mandates is to support the DEP-Office of Coastal Protection in their oil-spill contingency planning, response, and damage assessment. In addition, the Coastal and Marine Resource Assessment (CAMRA) group had been developing the Marine Resources Geographic Information System (MRGIS) since the early 1980s, and spill-response expertise existed within FMRI.

In 1992, CAMRA received a legislative appropriation to develop an "automated marine spill sensitivity atlas." After soliciting proposals, CAMRA contracted with Environmental Systems Research Institute's (ESRI) Application Development Group to initiate development of the Florida Marine Spill Analysis System (FMSAS). The principal goal of the FMSAS project was to design and develop a prototype GIS application that integrates a variety of information (digital maps, imagery, and tabular data) with targeted analytical routines needed to implement an oil-spill contingency planning, response, and damage assessment strategy focused on natural resource protection. An additional requirement was to implement a selected set of these requirements for a pilot study area in the Florida Keys and develop a strategy for expanding the prototype to a statewide, fully operational system. The project included a needs assessment, conceptual and physical application design, database integration, interface development, and the formulation of a user's guide, program maintenance manual, and statewide implementation plan.

At the onset of the project, ESRI conducted interviews at the FMRI with various representatives from selected agencies involved in marine spill management in Florida and the United States, including the National Oceanic and Atmospheric Administration (NOAA), the Marine Spill Response Corporation (MSRC), and the United States Coast Guard (USCG). These interviews were made during a week-long "rapid prototyping" workshop in which the application software and geographic databases that had been developed by ESRI for spill management groups in the United States and abroad were utilized. The premise of the rapid-prototyping approach was that marine spill requirements are similar from place to place and that using information gained from past efforts would help the workshop participants visualize the proper form and content for the FMSAS.

The needs expressed during the rapid-prototyping process were used several ways. They helped us determine the functional requirements of and formed the basis for the FMSAS database design. The needs assessment and database and application designs determined data types and guided a thorough inventory and evaluation of coastal data available in Florida. All of these exercises helped us design the FMSAS prototype and develop the statewide implementation strategy to fully extend the FMSAS in functionality and geographic coverage.

Several tests helped keep the rapid prototyping design process centered in the "real world." For example, CAMRA was contacted by a consultant developing a facility contingency plan for a large oil tank near Boca Chica Naval Station in Key West, Florida. This plan estimated that if the oil tank ruptured it could damage natural and cultural resources within a 30-mile radius. The plan was due in two weeks and the FMSAS prototype was used with ten different databases including data on marinas, habitats, and threatened and endangered species to generate a resource-at-risk report. Lessons learned from this and other exercises were used to further refine the evolving FMSAS design and prototype.

In July 1993, one year after contract initiation, FMRI took final delivery of a user-friendly prototype spill analysis system that included over 30 natural resource and spill response-related databases for South Florida including threatened and endangered species, ESI shorelines, benthic habitats, bathymetry, managed area boundaries, National Wetland Inventory (NWI), satellite imagery, aerial photography, and on-line tabular reference material with response strategies for specific shoreline types.

On 10 August a few days after the FMSAS was loaded onto the MRGIS, the Coast Guard received a distress call after the outbound 345-foot freighter *Balsa 37* collided with the inbound tugs *Seafarer* and *Fred Bouchard* near Tampa Bay, Florida. *Seafarer's* 546-foot barge, *Ocean 255*, burst into flames and burned for more than 14 hours before firefighters on local government and Coast Guard vessels were able to bring it under control. *Ocean 255* was carrying 188,000 barrels (8 million gallons) of Jet A fuel, a kerosene-type fuel used in jet turbine engines. The 442-foot barge that the tug *Fred Bouchard* was pushing, *B-155*, lost an estimated 388,000 gallons of number 6 fuel oil -- a thick product used for industrial heating-- before the leaking slowed and stopped. *B-155* contained more than five million gallons of oil at the time of the accident. *Balsa 37*, a bulk carrier transporting phosphate, was also damaged and began taking on water. The leaking chemicals moved with the tides toward some of Florida's ecologically sensitive habitats and pristine beaches.

Several divisions and bureaus of the DEP teamed with federal, state, and local agencies to handle this emergency. The Tampa Bay spill would prove to be the largest, most complicated spill to occur in Florida waters and provided a rigorous test of the FMSAS design. Immediately following the initial spill report, the DEP-Florida Marine Research Institute (FMRI) used its Marine Resources Geographic Information System (MRGIS) and Global Positioning System (GPS) units to analyze changing spill conditions, logistical alternatives, resources-at-risk, and environmental sampling strategies. Upon notification of the spill, CAMRA analysts were split into three teams. One team began producing maps using the MRGIS, another team began altering the prototype FMSAS so that it would be applicable for Tampa Bay as well as the Florida Keys, while the third team identified, gathered, and entered necessary data for Tampa Bay that was not already in the MRGIS.

During the first few days of the spill, CAMRA's role was to provide responding agencies with maps depicting existing natural and cultural resources relative to the predicted path of oil movement. Providing quality, high-resolution map products was critical to preventing misinformation in the early stages of spill control. From almost the moment the ships collided, responding state and federal agencies wanted very detailed information on the bay's natural resources, such as bathymetry, sea grass beds, mangroves, marshes, turtle nesting sites, and sites of endangered wildlife, displayed in conjunction with the current location and extent of the spill and vessels. Each day, the teams had to anticipate how map requirements would change as spill conditions changed; then, in order to meet those requirements, they had to acquire and integrate necessary data and generate targeted map products. CAMRA combined many data resources to provide maps for simultaneous evaluation and monitoring aspects of the response efforts.

To assimilate spill-boundary information in near real time, the Institute utilized the GPS resources of its Marine Mammals Section. Marine Mammals staff relied upon GPS receivers from helicopters to record locations of the vessels and the changing perimeter of the spill. The GPS files were immediately imported into the MRGIS and used to produce maps. The first map was plotted just hours after the spill occurred and was hand-carried to the Coast Guard command center so that each agency could formulate its response plans. Maps produced during the first three days were considered critical aids in developing possible scenarios at the Coast Guard command center. The helicopter-based GPS crew collected data several times a day throughout the project. As the spill continued, air-to-plot time decreased to just three and a half hours, and maps more than five hours old were considered "out of date."

During these first days after the spill, media reports gave the impression that Tampa Bay had "dodged a bullet" because the oil was floating out to sea. However, changing weather conditions soon drove the oil back toward John's Pass, a passage into the Intracoastal Waterway. The type and scale of mapping changed with the spill conditions. When the oil slick was "migrating," relatively small-scale (1:60,000) maps showing shoreline, islands, aids-to-navigation, and critical habitats were most appropriate. Scanned NOAA nautical charts (250 dots-per-inch) used with ARC/INFO's Image Integrator provided a valuable visual backdrop to actual spill boundaries and natural resources. The Coast Guard, NOAA, and state response officials specified that these nautical charts be used because all responders were familiar with the basic format.

As the spill neared land and finally washed ashore, maps with ESI shoreline rankings and with significantly more annotation were required to coordinate the 1,200 volunteers and response contractors coming from around the state to assist in the cleanup efforts. Since many experts flew in from other states and countries, these maps required information such as road networks, navigational aids, and the locations of temporary rescue headquarters such as schools and municipal buildings. Scanned USGS quadrangle (1:250,000 and 1:24,000) images were used as the visual background to provide maximum annotation quickly. The various databases and images were combined to create different maps: those showing the changing locations of spill boundaries and resources-at-risk were used by command center staff, the media, and field workers;

and those showing information necessary for determining environmental sampling strategies were used by those individuals involved in response and damage assessment.

Assembling the data needed to conduct the analyses and mapping required the collective efforts of several agencies and companies. On very short notice, a variety of organizations mobilized to help the FMRI respond. ESRI sent a GIS analyst to the FMRI for three days to help convert data, create maps, and document future design considerations for the FMSAS. Geonex Corp., a full-service mapping company headquartered ten miles from the Institute, created the scanned images of NOAA navigational charts, USGS quads, and other documents used as visual backdrops.

The Marine Spill Response Corp. (MSRC) of Washington, D.C., and Research Planning Inc. (RPI) of Columbia, South Carolina, provided additional support by releasing and delivering preliminary files of Tampa Bay's ESI shoreline just 48 hours after the spill occurred. The ESI shoreline rankings were converted and plotted over the scanned 1:24,000 USGS maps to produce "value-added" response maps. A total of 2,500 feet of maps were plotted during the spill. When supplies ran out on a Sunday, the U.S. Fish and Wildlife Service, National Wetlands Inventory office in St. Petersburg graciously provided electrostatic plotter paper.

Many of the lessons learned during the Tampa Bay spill will be used to further refine the conceptual design and physical characteristics of the FMSAS. Assumptions made during the design process were tested in a crisis setting and additional databases and functionality were identified. For instance, it would have been helpful to have all licensed landfills and incinerators in the vicinity in the system to identify disposal options for recovered product and soiled clean-up materials. To focus future refinements, the Institute is holding debriefings of involved parties to identify functions the FMSAS performed well and those that need enhancements. Unanticipated uses for the system continue to emerge. Four months after the spill, submerged oil concentrations still persist offshore. Data from acoustic sampling devices have been imported into the FMSAS to map submerged oil concentrations in conjunction with various databases.

The FMSAS full-scale implementation report prepared by ESRI described a long-term plan for the incremental development of a statewide, GIS-based oil spill response system for Florida. The plan prioritizes key databases, and the challenge is to assemble and automate the data for each region of the state before a spill occurs there. Several paths for extending the functionality of the FMSAS are also included in the plan. Several governmental agencies, utility companies, and private firms have expressed an interest in obtaining the FMSAS. The DEP is exploring the possibility of cooperative agreements and Memoranda of Understanding (MOU) with other agencies and organizations such as the Association for Oil Spill Information Management, to foster a collective investment so that the FMSAS design and prototype application can be shared and improved without redundant expenditures. It has become apparent that the basic design, natural resource sensitivity databases, and "resources-at-risk" analyses that form the basis of the FMSAS have widespread utility for analyzing a variety of marine and coastal impacts such as dredge-and-fill and coastal construction proposals. The long-term goal is to continue development of the FMSAS to provide the information management tools needed to protect Florida's natural resources.

Christopher Friel is research administrator of the Coastal and Marine Resource Assessment section of the Florida Marine Research Institute in St. Petersburg, Florida. He directs geographic information system (GIS) and remote sensing activities at the Institute. Prior to this appointment, he used GIS for environmental research at many levels of government in Michigan, Illinois, and Florida. His areas of research interest are automated cartography, spatial analysis, and GIS applications for environmental management. Mr. Friel received his B.S. in geography from Northern Michigan University, and his M.A. in geography from Western Illinois University.

MARINE SPILL RESEARCH CONSORTIUM'S GIS DEVELOPMENT

Mr. Barry Berkowitz
Marine Spill Research Consortium

INTRODUCTION

The Marine Spill Response Corporation (MSRC) has built a Geographic Information System (GIS) to help plan, manage and respond to oil spills. The presentation discusses the design, implementation, data issues, digitization standards and lessons learned in this development.

The GIS was initiated as a portion of the overall MSRC Information System development effort and is an integral part of the Spill Operations System (SOS) that MSRC utilizes in spill response. The specific design of the system and implementation, although important, is not the driving issue. Data access and maintenance are the keys to viable use of the GIS.

METHODS AND RESULTS

The MSRC GIS is a management decision support system as well as a tactical planning tool. The system presents information on the spill location and movement; coastline location and shoreline type; water depth; location of navigation channels, major roads, beach access points, and resources at risk. With the use of the "Strategy Sketch Plot," the response manager can display ship and barge stations/locations, boom placement, command center locations, work crew assignments, oil locations, over flight information, remote sensing output and plot spill trajectories (rule of thumb, NOAA).

The system can be shared by many players in the company; i.e. environmental advisor, response planners, response manager and headquarters operations. To enable use of the system without extensive training on the native GIS, a Graphic User Interface (GUI) was created. To keep the cost down, reduce training requirements and enable distribution across the company and out to the forward command post, a familiar office platform was used: Apple Macintosh. The MAC is the standard MSRC desktop system; by using this standard desktop in conjunction with a GUI for the GIS operations, we have been able to minimize GIS system training as well as limit user complexity and possible data corruption.

The MSRC data network is very flexible and designed to allow remote operations at any location. Local Area Networks (LANs) at each location are supported by a Wide Area Network (WAN) that connects all operations. Via the Mobile Communications Suite, a forward-command-post LAN can be established and connected by means of a Ku band satellite to the MSRC WAN.

The overall SOS architecture is built on a client server design. The GIS utilizes a mainframe data warehouse server for attribute data storage and a LAN Unix server for GIS feature display data. The client server architecture chosen enables large volumes of data to be accessed and yet provides mobility of operations. User operation requires a client server design that supports data sharing across the WAN from LAN location to LAN location. This requirement demands the ability to perform data synchronization. To enable the concurrent viewing and sharing of the information, MSRC created a means to display changes made on one region's server on another region's or headquarter's server. This led to the development of the concurrancy manager software which controls all user update access to the GIS servers. The concurrancy manager also automatically updates all system-administrator-designated GIS servers when they come up on the network and continues to keep them updated with changes and additions as they are made to the designated primary server.

As mentioned earlier, data acquisition and maintenance of the GIS data are the backbone to the GIS. The MSRC system is comprised of information covering the 23 coastal states and data from 600 NOAA charts, 700 Tiger files, 2000 USGS Quad maps. It resources at risk data from 1700 Environmental Sensitivity Index (ESI) maps. All in all, MSRC'S GIS data is contained in 140 layers of information.

The system design issues, however challenging, are readily solvable with the state-of-the-art-technology available today to the systems analyst. The data acquisition and maintenance issues are understood and easily solved. However, the cost of acquisition, coordination and constant updating along with the agreement by responsible parties on the standards of display lead to difficulties not as easily surmounted. The data issue requires cooperation, sharing and the release of preceived stewardship requirements that lead to secretive data restrictions. Also, the varied uses of such data lends itself to conflicting purposes. As politics leads to strange bedfellows, so does GIS information on resource at risk.

It has always been the goal of MSRC to create an environment where data sharing is possible. In conjunction with NOAA, MSRC funded the creation of the first digitization standard that was published in draft one year ago. The standard has been used throughout the initial digitization of the MSRC required data. The company that created the ESI maps, RPI, authored the specification and prepared the hard copy ESI maps for digitization. RPI also provided the quality check on the digitized product produced by the digitization contractor. The total process from preparation, digitization, quality check, correction and final critical quality check has taken twice the original estimate in time and effort.

As of the date of this presentation, MSRC has signed data sharing agreements with the States of Florida and Texas. MSRC looks forward to like agreements with all the coastal states, and welcomes inquires regarding all aspects of our systems as well as data sharing.

SESSION 1D

CETACEAN POPULATIONS OF THE WESTERN AND CENTRAL GULF OF MEXICO

Session: CETACEAN POPULATIONS OF THE WESTERN AND CENTRAL GULF OF MEXICO

Co-Chairs: Dr. Robert Avent and Dr. Randall Davis

Date: December 14, 1993

Presentation	Author/Affiliation
Distribution and Abundance of Marine Mammals in the North-Central and Western Gulf of Mexico: The GulfCet Program	Dr. Robert Avent Minerals Management Service Gulf of Mexico OCS Region Dr. Randall Davis Texas A&M University at Galveston
GulfCet Aerial Surveys: Survey Design, Methods and First-Year Results	Dr. Keith D. Mullin Mr. Larry J. Hansen Mr. Wayne Hoggard Southeast Fisheries Science Center National Marine Fisheries Service National Oceanic & Atmospheric Administration
Distribution and Abundance of Marine Mammals in the North-Central and Western Gulf of Mexico: Draft Interim Report	Dr. Bernd Würsig Mr. Thomas Jefferson Texas A&M University at Galveston
NOAA Oregon II Visual Survey Design and Results	Mr. Larry J. Hansen Dr. Keith D. Mullin Ms. Carol L. Roden Southeast Fisheries Science Center National Marine Fisheries Service National Oceanic & Atmospheric Administration
Bioacoustic Survey Design and Results	Dr. Robert Benson Dr. Jeff Norris Texas A&M University at Galveston
Hydrographic Survey Results	Dr. G. S. Fargion Department of Marine Biology Texas A&M University at Galveston
Remote Sensing and Geographic Information System Support for the Gulfcet Project	Mr. L. N. May, Jr. Mr. T. D. Leming Mr. M. F. Baumgartner Southeast Fisheries Science Center National Marine Fisheries Service National Oceanic & Atmospheric Administration
Satellite-Monitored Radio Tagging of Sperm Whales in the Gulf of Mexico GulfCet Tasks 5 & 6	Dr. Bruce R. Mate Ms. Kathleen M. Stafford Hatfield Marine Science Center Oregon State University
Document not submitted	Dr. Randall Davis Texas A&M University at Galveston

DISTRIBUTION AND ABUNDANCE OF MARINE MAMMALS IN THE NORTH-CENTRAL AND WESTERN GULF OF MEXICO: THE GULFCET PROGRAM

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Minerals Management Service
Gulf of Mexico OCS Region

Dr. Randall Davis
Texas A&M University at Galveston

INTRODUCTION

The Gulf of Mexico is a semi-enclosed extension of the Atlantic Ocean surrounded by the United States to the north and east and by Mexico to the west and south. The entrance to the Gulf is partially blocked by Cuba. The maximum dimensions of the Gulf are about 1,000 miles from east to west and 700 miles from north to south. The continental shelf is very wide in some places, extending up to 150 miles from the west Florida coast. In contrast, it is only 20 miles wide at the mouth of the Mississippi River. Most of this broad continental shelf is less than 100 m deep. At its deepest point, the Gulf is 3,700 m deep. Numerous rivers flow into the Gulf; the largest by far is the Mississippi River.

At least 28 species of cetaceans inhabit or have been observed in the Gulf of Mexico (Table 1D.1). Some of these species were historically rare or have become so as a result of human activities.

BACKGROUND

The Minerals Management Service (MMS) has the responsibility to assure that oil and gas operations on the Outer Continental Shelf (OCS) Leases in the Gulf of Mexico are conducted in a manner that reduces risks to the marine environment. To meet their responsibilities under the Marine Mammal Protection Act (MMPA) of 1972 and the Endangered Species Act (ESA) of 1973, the MMS must understand the effects of oil and gas operations on marine mammals. As the oil and gas industry moves into deeper water along the continental slope in their continuing search for extractable reserves, information is needed on the at-sea distribution, movements, behavior and preferred habitats of cetaceans, especially large and deep water species in the Gulf of Mexico. The GulfCet Program is designed to be responsive to the needs of the MMS and to produce a first-step estimate of the potential effects of deepwater exploration and production on marine mammals in the Gulf of Mexico.

PROGRAM OBJECTIVES

The primary objective of the GulfCet Program is to determine the seasonal and geographic distribution and movements of cetaceans in areas potentially affected by future oil and gas activities along the continental slope in the north-central and western Gulf of Mexico. The study is restricted to the area bounded by the Florida-Alabama border, the Texas-Mexico border, and the 100- and 2,000-m isobaths (Figure 1D.1). In addition to conducting systematic aerial surveys and shipboard surveys, the GulfCet Program will attempt to tag and track a limited number of sperm whales using satellite telemetry. Finally, environmental data from shipboard surveys (acquired during this program and other oceanographic studies in the Gulf) and remote sensing will be used to characterize the preferred habitats of cetaceans in the study area. We will identify those environmental variables that seem most likely to affect the seasonal distribution, abundance, and activities of cetaceans. The ultimate goal of GulfCet is to improve the ability of MMS to assess the effects of oil and gas operations, including oil spill impacts, on the distribution and behavior of marine mammals.

OVERVIEW OF PROGRAM ACCOMPLISHMENTS TO DATA

To date, the GulfCet Program has completed six aerial surveys, seven Texas A&M University shipboard visual, acoustic and hydrographic surveys, two NMFS shipboard surveys, and two attempts to attach satellite telemeters to sperm whales. The survey methods include the following:

1. Aerial surveys from an altitude of 750 ft;
2. Shipboard, visual surveys using 25-power binoculars;
3. Shipboard, acoustic surveys using a towed, acoustic array;

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

Balaenidae	
Right Whale	*Eubalaena glacialis**
Balaenopteridae	
Blue Whale	*Balaenoptera musculus**
Fin Whale	*B. physalus**
Sea Whale	*B. borealis**
Bryde's Whale	*B. edeni*
Minke Whale	*B. acutorostrata*
Humpback Whale	*Megaptera novaeangliae**
Physeteridae	
Sperm Whale	*Physeter macrocephalus**
Pygmy Sperm Whale	*Kogia breviceps*
Dwarf Sperm Whale	*K. simus*
Ziphiidae	
Cuvier's beaked whale	*Ziphius cavirostris*
Blainville's beaked whale	*Mesoplodon densirostris*
Sowerby's beaked whale	*M. bidens*
Gervais' beaked whale	*M. europaeus*
Delphinidae	
Melon-headed whale	*Peponocephala electra*
Pygmy killer whale	*Feresa attenuata*
False killer whale	*Pseudorca crassidens*
Killer whale	*Orcinus orca*
Short-finned pilot whale	*Globicephala macrorhynchus*
Rough-toothed dolphin	*Steno bredanensis*
Fraser's dolphin	*Lagenodelphis hosei*
Common dolphin	*Delphinus delphis*
Bottlenose dolphin	*Tursiops truncatus*
Risso's dolphin	*Grampus griseus*
Atlantic spotted dolphin	*Stenella frontalis*
Pantropical spotted dolphin	*S. attenuata*
Striped dolphin	*S. coeruleoalba*
Spinner dolphin	*S. longirostris*
Clymene dolphin	*S. clymene*

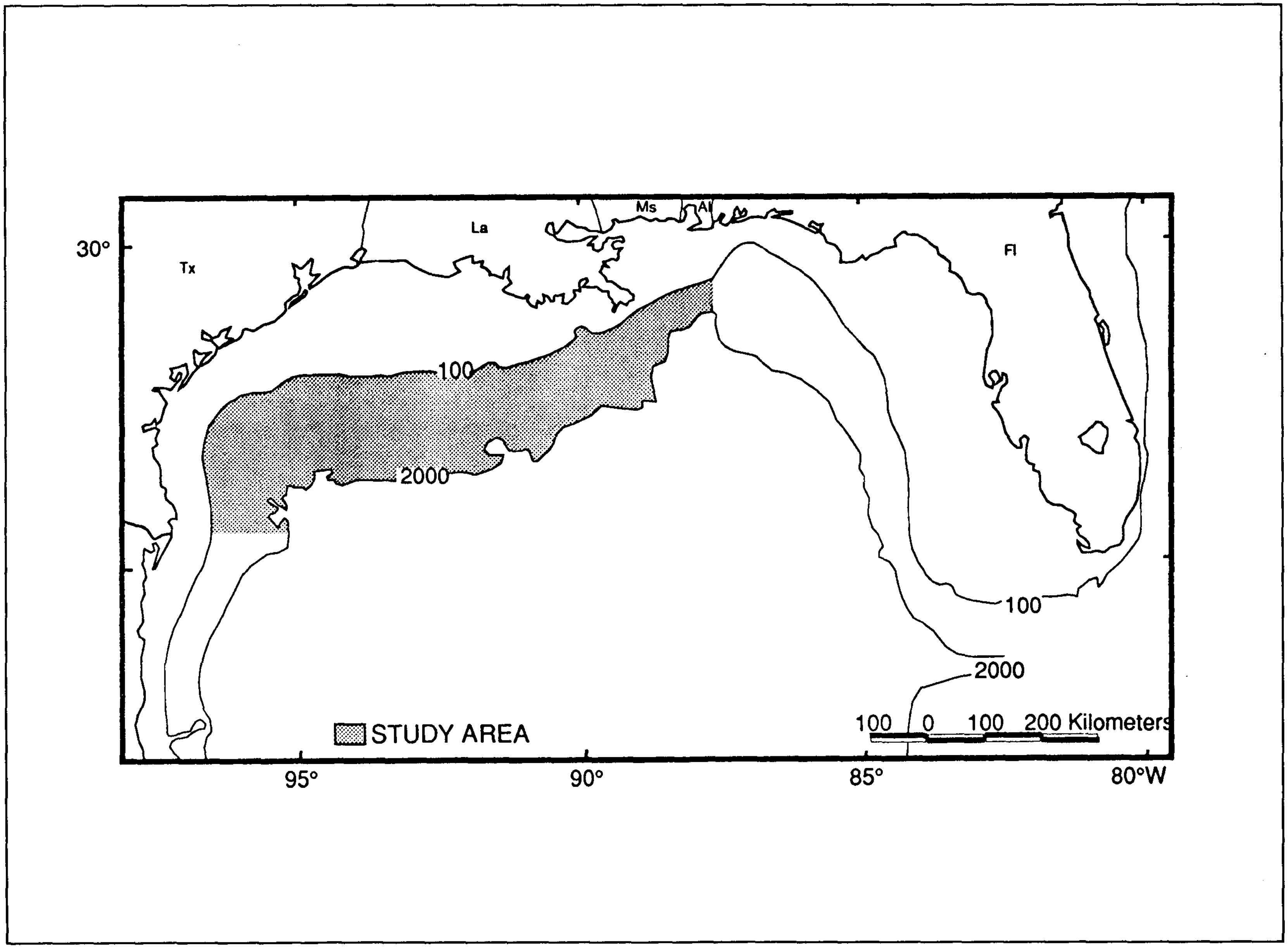

Figure 1D.1. GulfCet Program study area.

4. Hydrographic data collected using a CTD and rosette (40 mile resolution to 800 m) and XBTs

   a) conductivity (salinity)
   b) temperature
   c) chlorophyll and other pigments
   d) dissolved oxygen
   e) turbidity
   f) density (calculated)
   g) geostrophic currents (calculated)
   h) potential temperature (calculated); and

5. Satellite remote sensing of sea surface temperature.

The results from the individual components of this program are reported in the following sections.

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GULFCET AERIAL SURVEYS: SURVEY DESIGN, METHODS AND FIRST YEAR RESULTS

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National Oceanic and Atmospheric Administration

INTRODUCTION

Previous studies of cetaceans in the oceanic (>100 meters) northern Gulf of Mexico covered relatively small geographic areas (Fritts *et al.* 1983, Mullin *et al.* 1991) or did not provide seasonal coverage (NMFS-SEFSC 1991). However, these studies indicated that cetacean species were diverse (at least 20 species), widely distributed in both space and time, and relatively abundant. The objectives of the GulfCet aerial surveys were to provide uniform seasonal coverage of oceanic waters over a wide area in the northern Gulf in order to collect data for estimating the relative abundance of cetaceans and for correlating cetacean distributions with oceanographic features. Surveys were designed to cover two years (eight seasons) as a first step in the study of interannual and interseasonal variation in cetacean diversity, abundance and distribution in the Gulf.

METHODS

Study Area & Survey Design

The GulfCet study area was bounded by the Florida-Alabama line, the U.S.-Mexico border, the 100 meter isobath and the 2,000 meter isobath. Primarily for logistic reasons, the aerial survey study area extended only to the 1,000 meter isobath west of 90°00' W (Figure 1D.2). The GulfCet study area, east of 90°00' W, was relatively narrow and close to land compared to the western portion. Also, the area south of the Mississippi River delta was of special interest because previous seasonal aerial surveys (Mullin *et al.* 1991) indicated that cetacean diversity, distribution and abundance in this area were seasonally variable.

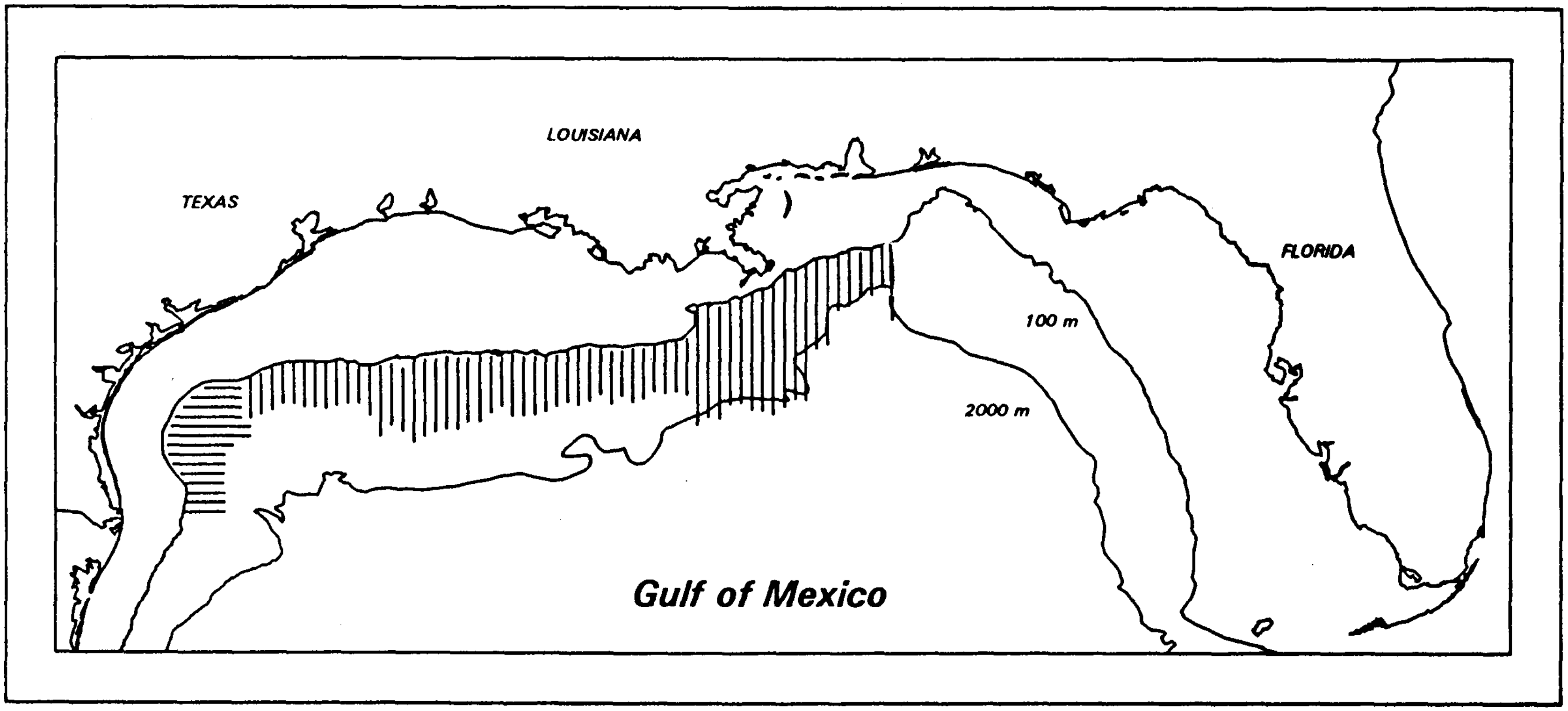

Figure 1D.2. GulfCet aerial survey transect lines.

Based on several considerations, including projected availability of acceptable survey conditions and available funding, the study was designed to survey about 6,300 transect kilometers per season. Each season, the study area was covered uniformly by surveying 74 transects placed equidistant from a random start. Transects were oriented perpendicular to the bathymetry. Transects ran north-south off Alabama, Mississippi and Louisiana and east-west off Texas. Survey flight bases of operation were Harlingen, Texas; Galveston, Texas; Lafayette, Louisiana; and Pascagoula, Mississippi. A window of 45 days was allocated to each season, and surveys were only conducted on days when flying conditions were safe and there were few whitecaps.

Line Transect Methods

To estimate the density of cetaceans, data were collected using line transect sampling methods. This method was also compatible with the need to collect data for distributional analyses. Line transect sampling theory and its application to cetaceans has been well developed (Buckland *et al.* 1993). Line transect sampling methods have been used for cetacean surveys for well over a decade and have been used successfully from both aerial and ship based platforms (e.g., Barlow 1988, Heide-Jorgensen 1992). A comprehensive, state-of-the-art software package for analysis of line transect data has been developed (Laake *et al.* 1993). This package will be used to make density estimates when all eight seasonal surveys are completed.

Survey Platforms & Methods

The survey platform of choice was a DeHavilland Twin Otter aircraft modified with large bubble windows that provided transect line visibility. This aircraft was used in Minerals Management Service supported aerial surveys in the north-central Gulf during 1989 and 1990 (Mullin *et al.* 1991). Because a Twin Otter was not available for the first (summer 1992) aerial survey, a similarly modified Partenavia aircraft was contracted. However, the aircraft had a flight time of only four and a half hours. Because the transit time to the study area was about one hour, the amount of survey time per flight was limited. A Twin Otter was available for the fall surveys and all subsequent GulfCet surveys. The Twin Otter has a flight time of six and a half hours.

Surveys were conducted using standard cetacean aerial survey methods. A typical survey flight began at around 0800 hours and lasted about four and a half to six and a half hours. Three observers participated in each flight and rotated through two observer positions and the computer station. Transect lines were surveyed from 230 meters (750 feet) at 204 km/hour (110 knots). When a cetacean group was sighted, the distance to the group from the transect line was measured with an inclinometer. A dye marker was usually dropped to mark the position, and the aircraft was diverted to circle the group. Species were identified to the lowest taxonomic level possible. The number of adult and calf animals were counted and the location recorded. Data on survey conditions (i.e., weather, water color, glare, water clarity and sea state), sea turtles and other marine life were also collected.

RESULTS AND DISCUSSION

Seasonal aerial surveys were completed for the summer (10 August-19 September 1992), fall (3 November-16 December 1992), winter (1 February-22 March 1993), and spring (25 April-1 June 1993) seasons. All of the proposed transect lines were completed for the summer, winter and spring surveys. During the fall, high winds and rain persisted throughout much of the survey window and only 80 percent of the proposed survey effort was completed. The area between 89°47'W and 90°44'W was not surveyed.

During the four surveys, 38 leatherback sea turtles, an endangered species, were sighted (summer—27, fall—4, winter—4, spring—3). Except for three, all of the leatherback sea turtles sightings were, relative to the entire study area, aggregated south of the Mississippi River delta. Ten chelonid sea turtles were also sighted (summer—4, fall—1, winter—4, spring—1).

The number of cetacean groups, total animals, and number of species sighted varied seasonally (Table 1D.2). The highest number of group sightings was made during summer (51) and spring (51), and the smallest during the fall (24). The number of animals sighted was the largest in the spring (1,159), similar in summer (946) and winter (912), and much smaller in fall (226). The total number of species sighted each season ranged from nine (fall) to 13 (summer). The number of sightings of each species

Table 1D.2. Summary of Summer 92, Winter 93, and Spring 93 GulfCet Aerial Surveys.

	Sum. 92	Fall 92	Win. 93	Spr. 93
Days in window	40	44	50	38
Survey days	15	10	12	16
Weather days	17	31	28	17
Travel days	6	3	4	1
Other days	2	0	4	4
Flight hours	97	80	90	100
Percent completed	100%	80%	100%	100%
Transect kilometers	6571	5506	6246	6370
Number of sightings	51	24	37	51
Number of animals	946	226	912	1159
Off-effort sightings	7	2	4	6
Number of species	13	9	10	12
Group sighting rate (groups/100 km)	.78	.44	.59	.80
Animal sighting rate (animals/100 km)	14.4	4.1	14.6	18.2
Average group size	18.1	9.4	24.6	22.7

also varied seasonally (Table 1D.3). For example, seasonal sightings of pantropical spotted dolphin groups ranged from one (fall) to 13 (summer).

Summer

Groups of pantropical spotted dolphins (13), bottlenose dolphins (eight) and dwarf/pygmy sperm whales (seven) were the most commonly sighted species. Two mixed species groups were sighted. One consisted of bottlenose dolphins and Risso's dolphins and the other of bottlenose dolphins and Atlantic spotted dolphins. Cetacean groups did not appear to be uniformly distributed in the study area (Figure 1D.3). A large number of sightings was aggregated in the vicinity of the Mississippi River delta and a smaller aggregation occurred off southern Texas.

Fall

Compared to the other seasons, a small number of groups (24) was sighted. This can be attributed partially to the reduced survey effort. However, group sighting rates (groups/100 kilometers surveyed) were much were much smaller compared to the other seasons. Only one group of pantropical spotted dolphins and one group of dwarf/pygmy sperm whales were sighted. Most of the sightings were aggregated off the central Louisiana coast.

Winter

The first sightings of Bryde's/sea whale, striped dolphins, clymene dolphins and spinner dolphins during the GulfCet aerial surveys were made. Groups of bottlenose dolphins (12) and Risso's dolphins (five) were the most commonly sighted species. Except for a small gap south of Galveston, Texas, the sightings were relatively uniform in distribution. A group of 150 striped dolphins and a group of 200 spinner

Table 1D.3. Species of cetaceans sighted, mean group sizes and mean water depths from the Summer 1992, Fall 1992, Winter 1993, and Spring 1993 GulfCet aerial surveys.

Species	n[1]	Group Size	Range	Depth (m)	Range	n[2] S	F	W	S
Brdye's/sea whale	1	1.0	-	213	-	0	0	1	0
sperm whale	10	2.1	-	934	499-1934	3	2	0	7
dwarf/pygmy sperm whale	18	1.3	1-3	743	151-1316	7	1	4	7
Mesoplodon sp.	1	4.0	-	630	-	1	0	0	0
beaked whale	5	2.6	1-4	1041	894-1316	1	2	0	2
melon-headed/pygmy killer whale	3	195.7	12-400	663	513-835	1	0	0	2
false killer whale	1	35.0	-	974	-	1	0	0	0
killer whale	0	10.0	-	874	-	1	0	0	0
pilot whale	6	15.1	5-35	904	241-1876	3	2	0	2
rough-toothed dolphin	5	20.0	3-48	829	85-1316	2	1	0	2
bottlenose dolphin	32	14.0	1-60	337	65-1316	8	4	12	12
Risso's dolphin	16	12.5	4-33	704	234-2088	2	2	5	8
Atlantic spotted dolphin	10	18.1	6-42	252	126-546	2	1	4	3
pantropical spotted dolphin	19	40.0	5-100	1024	435-1815	13	1	3	6
striped dolphin	1	150.0	-	1035	-	0	0	1	0
spinner dolphin	1	200.0	-	1055	-	0	0	1	0
clymene dolphin	3	29.0	9-40	885	601-1298	0	0	1	2
Fraser's dolphin	1	17.0	-	835	-	0	0	0	1
bottlenose/Atlantic spotted	3	12.3	2-25	259	64-329	1	0	1	3
stripe/spinner/clymene dolphin	5	19.6	2-60	504	98-795	2	1	2	0
unidentified dolphin	12	4.5	1-20	546	95-1613	11	4	4	2
unidentified small whale	9	1.8	1-3	1084	693-1748	6	1	0	2
unidentified large whale	2	1.0	1-1	1556	-	2	0	0	0
unidentified odontocete	4	1.0	1-1	544	93-1356	0	4	0	0

1 - total number of groups sighted on-effort.
2 - includes groups sighted off-effort.

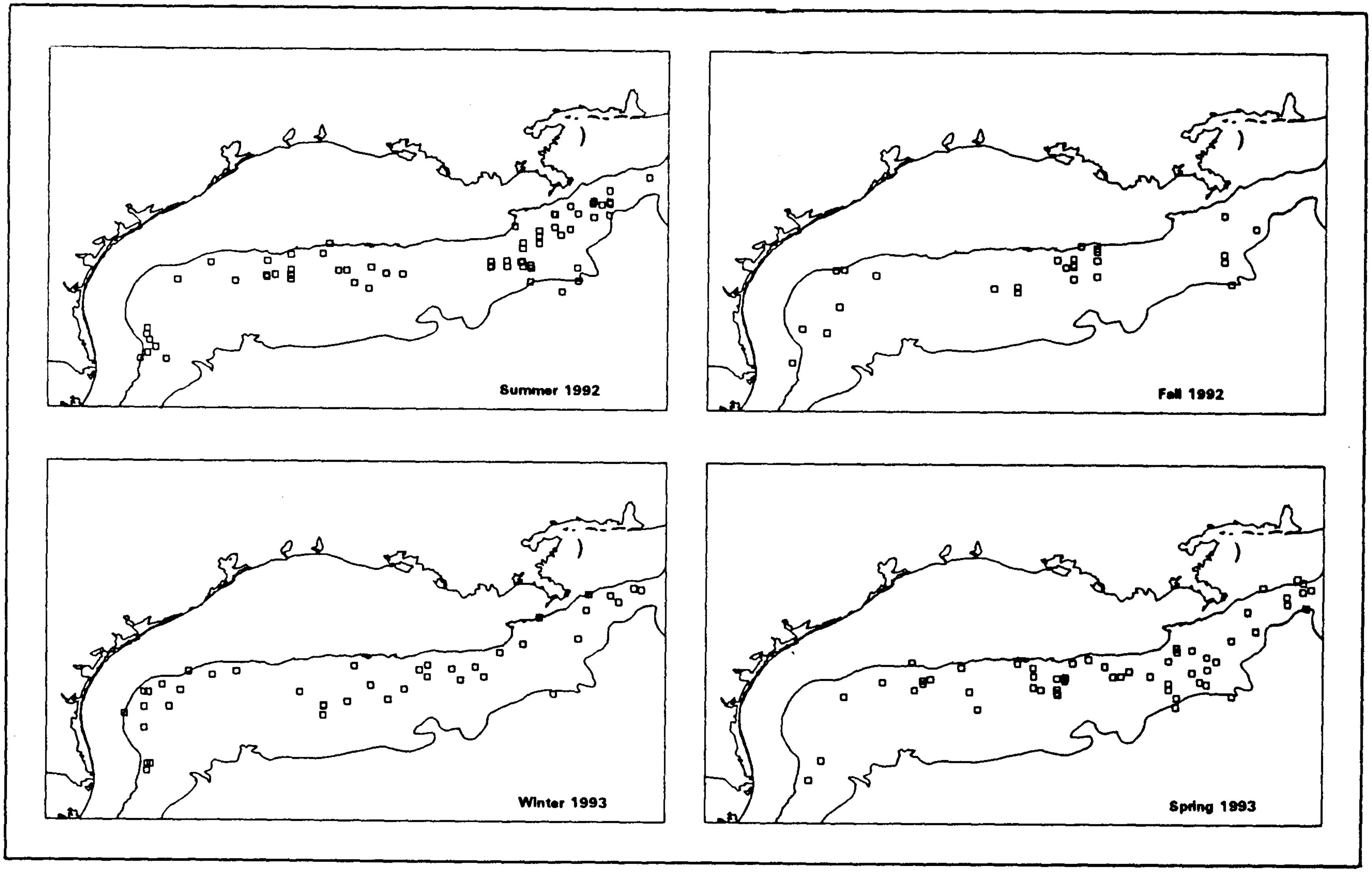

Figure 1D.3. Locations of cetacean groups sighted each season during the first year of GulfCet aerial surveys.

dolphins accounted for 38 percent of the animals sighted.

Spring

Groups of bottlenose dolphins (12) and Risso's dolphins (eight) were most commonly sighted. The first sighting of Fraser's dolphin during the GulfCet aerial surveys was made. Seventeen Fraser's dolphins were in a tight group among 400 melon-headed/pygmy killer whales. While melon-headed whales cannot be easily distinguished from pygmy killer whales from the air, because of the size of the group and the presence of Fraser's dolphins, we were confident that they were melon-headed whales. Elsewhere, pygmy killer whales usually occur in much smaller groups (<50) and are not associated with Fraser's dolphins (Wade and Gerrodette 1992). The 400 melon-headed whales were in many sub-groups spread out over a large area. There was also a group of rough-toothed dolphins among these whales. This group of 400 whales is the largest group of cetaceans of any species we have sighted in the Gulf. Earlier in the survey a group of 175 melon-headed whales was also sighted. These two groups of melon-headed whales accounted for 50 percent of the animals sighted in spring.

A total of 168 cetacean groups was sighted on-effort during the four surveys. Twenty-five off-effort sightings were made including a group of ten killer whales. At least 17 species of cetaceans were sighted. Bottlenose dolphins, pantropical spotted dolphins, dwarf/pygmy sperm whales and Risso's dolphins were the most commonly sighted species. On-effort group sighting rates were highest in summer and spring, and lowest in fall (Table 1D.2). The summer, winter, and spring average group sizes of all cetacean groups sighted were over twice the fall average. This resulted in a large difference in the sighting rate of animals in the fall compared to the other seasons.

Of the species sighted five or more times, pantropical spotted dolphins had the largest average group size (40.0; Table 1D.3). Dwarf/pygmy sperm whale, sperm whale and beaked whale groups all averaged less than three whales. The average group sizes of the other species sighted more than five times ranged from 12.5 to 20.

With sightings from all four seasons combined, cetacean groups were sighted throughout the length of study area and at all water depths surveyed (Figure 1D.3). Most species were widely distributed in the study area. However, species were found at different water depths (Table 1D.3). Bottlenose dolphins and Atlantic spotted dolphins were sighted primarily near the shelf edge, at average depths of 337 meters and 252 meters, respectively. Sperm whales, dwarf/pygmy sperm whales, beaked whales, pilot whales, rough-toothed dolphins, Risso's dolphins and pantropical spotted dolphins were found at much deeper average water depths (>700 m). Pilot whales, sperm whales and Risso's dolphins inhabited the greatest range of water depths (>1,400 meters) and Atlantic spotted dolphins and beaked whales smallest (<700 meters).

The results of the GulfCet surveys were similar in several respects to those found by Mullin *et al.* (1991) in the north-central Gulf. The only species identified by Mullin *et al.* (1991) that were not positively identified during the GulfCet surveys were the fin whale and Cuvier's beaked whale. Also, in both studies, species were distributed similarly with respect to water depth. However, compared to Mullin *et al.* (1991), there was a paucity of sperm whale and Risso's dolphin sightings. The overall group sighting rate from the GulfCet surveys was less than half that found by Mullin *et al.* (1991). Except for the Gervais' beaked whale, which is difficult to identify positively at sea, of the species that have stranded in the Gulf more than twice (Schmidly 1981), only the minke whale has not been seen at sea in the Gulf.

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DISTRIBUTION AND ABUNDANCE OF MARINE MAMMALS IN THE NORTH-CENTRAL AND WESTERN GULF OF MEXICO: DRAFT INTERIM REPORT

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MATERIALS AND METHODS

Two survey vessels, the R/V *Longhorn* and R/V *Pelican*, were used for the Texas A&M University shipboard marine mammal visual surveys. On the first cruise, we used the *Longhorn*, a 32-m, 210-ton research vessel operated by the University of Texas. For the next five cruises, we used the *Pelican*, which is also 32 m long and has a displacement weight of 244 tons. The *Pelican* is owned by the Louisiana Universities Marine Consortium (LUMCON).

The research vessel traversed the study area from either east to west or west to east on each cruise at a speed of six knots when on transect and nine knots when running between transect lines. The survey was conducted from the top of the pilothouse on both vessels (observer eye height was approximately 7.7 m on the *Longhorn* and 8.9 m on the *Pelican*).

Survey procedures followed closely those developed for dolphin surveys in the eastern tropical Pacific. There were two, three-person survey teams, one of which was on duty during all daylight hours while in the study area. The teams rotated every two hours.

Two primary observers searched for marine mammals through pedestal-mounted 25x150 mm *Fujinon* binoculars, while the third observer acted as data recorder and assisted in searching with 7X binoculars. Each primary observer searched a 100° swathe, from 90° on their side to 10° past the bow on the opposite side; the data recorder focused effort near the ship and around the trackline. Thus, the total primary search path was 180°, with a 20° overlap centered at the bow. Observers rotated positions every 30 minutes to avoid fatigue.

Sighting angle was recorded with the aid of a graduated scale at the base of the binoculars, and radial distance to the sightings was either estimated by eye (generally for sightings within a few hundred meters of the ship) or calculated using reticles etched into the right eyepiece of the binoculars. Radial distance was estimated from reticle readings by the equation:

$$R = x \tan (\arctan (89.173/ x) - 0.001088\ r),$$

where R = radial distance (km), r = reticle reading, and x = eye height (in nautical miles). Perpendicular distance was calculated from radial distance and sighting by

$$y = R \sin ø,$$

where y = perpendicular distance and ø = sighting angle.

Sighting effort was conducted during daylight hours in which sighting conditions were acceptable. Acceptable conditions were defined as Beaufort sea states of less than 4 with good visibility. Sometimes rain, fog, glare, or excessive ship roll interrupted the survey in sea states less than Beaufort 4. During daylight hours when survey effort was suspended due to poor weather, at least one observer was stationed on the bridge to record "off effort" sightings which could be used for determining species distribution and estimating herd size. Sightings and effort data were collected on standardized forms developed by the NMFS.

In the final report, density will be calculated using line transect methods with the computer program DISTANCE (Laake *et al.* 1993). Because sightings of individuals for most species of cetaceans are not independent events, herds will be considered the basic targets of the survey. We will use the 'rule of thumb' suggested by Burham *et al.* (1980) and Buckland *et al.* (1993) for the absolute minimum sample size for abundance estimation. This rule stipulates that estimates should be based on no fewer than 30 sightings or detections. Thus, any species with less than 30 "on effort" sightings will be pooled with others to obtain adequate sample sizes. The basic line transect density formula (Burnham *et al.*, 1980) is

$$D = \frac{n\ f(O)}{2L},$$

where D = density estimate of objects (herds), n = number or objects sighted, f(O) = probability density function of the perpendicular distance data, and L = total length of transect.

Multiplying the density estimate by the species or species group mean herd size yields an estimate of individual density. Multiplying this value by the total study area gives an estimate of the numerical abundance for individuals of that species or species group:

$$N = \frac{n\ f(O)\ E(s)\ A}{2\ L\ g(O)}$$

where N = abundance estimate, E(s) = mean herd size, A = total study area and g(O) = the probability that an object on the trackline is detected (Buckland *et al.*, 1993). In most cases, g(O) is assumed to be 1; however this is probably not true for long-diving species, and thus g(O) must be calculated and factored into the equation for these species.

The effective strip width (ESW), an index of the sightability of the species (or groups), will also be computed for each species group with a density estimate as

$$ESW = \frac{2}{f(O)}.$$

Because extremely large coefficients of variation could result from the survey effort being stratified by season to produce separate line transect estimates, seasonal differences will be examined instead by computing sighting rates for different seasons (i.e., number of herds or individuals per 1,000 km of

Table 1D.4. Summary of hours and kilometers of survey effort conducted (IO refers to independent observers effort).

Cruise #	1	2	3	4	5	6	Total
Hours of Effort	39.65	79.28	37.13	41.32	68.13	75.30	340.81
Hours of IO Effort	-	-	-	-	6.66	10.42	17.08
Km of Effort	487.40	1036.56	535.86	529.39	956.62	1041.66	4587.49

trackline surveyed), and comparing these between seasons.

RESULTS AND DISCUSSION

A total of 340.81 hours of sighting effort was conducted on the first six cruises (Table 1D.4). This represents 4,587.49 kilometers of transect line surveyed. In addition, 17.08 hours of independent observer (IO) effort were conducted. The independent observer effort will be used to test the assumption that g(O) = 1 (i.e. that all animals on the trackline are detected). For long diving species, such as sperm whales and beaked whales, such an assumption is probably invalid, and a correction for submerged animals will be included in the final abundance estimates for these species (see Barlow 1993).

A total of 258 marine mammal sightings were made within the study area on the first six cruises (Table 1D.5). Of these, 182 were "on effort" and are usable in the density and abundance estimates. The 76 "off-effort" sightings can be used only in estimating mean heard size, and will not be used to estimate density and abundance.

Based only on the sighting from these six cruises, the only species with an adequate sample size for abundance estimates is the bottlenose dolphin (32 on effort sightings). It is likely that the number of sperm whale sightings will equal to at least 30 by the end of the project. All other species will have to be pooled based on the number of sightings, taxonomic relationships, and general habitat types (Wade and Gerrodette, in press). For example, oceanic species of *Stenella* (pantropical spotted, striped, spinner, and clymene dolphins) all occur in large herds and may be pooled, but the fifth species (Atlantic spotted dolphin) is a continental shelf species that is found in small herds and would not be included in the above grouping.

There have been several unexpected results from these shipboard visual surveys. First, the most common species observed along the outer edge of the continental shelf in this region of the Gulf of Mexico is the bottlenose dolphin, not the Atlantic spotted dolphin as indicated by Schmidly (1981). Sperm whales and pantropical spotted dolphins were, by far, the most common cetaceans seen in oceanic waters. The only exception to this occurred on the sixth cruise in which very few pantropical spotted dolphins were sighted. The prevalence of sperm whales as the most abundant large cetacean was expected. However, previous research had not indicated that the pantropical spotted dolphin was the most common

Table 1D.5. Summary of marine mammal sightings: TAMUG.

Species	On Effort	Off Effort	Total
Sperm Whale	25	11	36
Cuvier's beaked whale	2	0	2
Pygmy sperm whale	1	0	1
Dwarf sperm whale	1	0	1
Short-finned pilot shale	0	1	1
False killer whale	2	1	3
Melon-headed whale	2	0	2
Risso's dolphin	5	0	5
Fraser's dolphin	2	0	2
Rough-toothed dolphin	1	1	2
Bottlenose dolphin	32	13	45
Pantropical spotted	5	2	7
dolphin	17	9	26
Spinner dolphin	1	0	1
Clymene dolphin	5	1	6
Striped colphin	3	0	3
Unid. cetacean	11	3	14
Unid. large whale	2	0	2
Unid. *Kogia*	2	1	3
Unid. beaked whale	5	3	8
Unid. *Mesoplodon*	3	3	6
Unid. small whale	22	3	25
Unid. dolphin	33	24	57
Total	182	76	258

oceanic species. Mullin *et al.* (1991) found Risso's dolphin to be more common in parts of the Gulf. However, their study was not directly comparable to ours, since it occurred in shallower water (mostly along the upper continental slope) and in a very limited geographic area.

Another unexpected finding is the paucity of short-finned pilot whales. Strandings and past sighting records would have led us to believe that this is one of the most common, medium-sized cetaceans offshore (Schmidly 1981).

Several poorly-known species have turned out to be moderately common (beaked whales, pygmy and dwarf sperm whales, melon-headed whale, and Fraser's and clymene dolphins). Both melon-headed whales and Fraser's dolphins were almost completely unknown in the Gulf of Mexico before this study began, each represented by one or two standings. The first live sightings of these species in the Gulf (and for Fraser's dolphin, the first for the entire Atlantic Ocean) were recorded during this project (Leatherwood *et al.*, in press; Mullin *et al.*, submitted). The clymene dolphin was well-known in the Gulf from strandings previous to this project, but also was poorly-represented by live sightings (Jefferson and Odell, in prep.)

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NOAA OREGON II VISUAL SURVEY DESIGN AND RESULTS

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INTRODUCTION

The Southeast Fisheries Science Center (SEFSC) has conducted three of four planned vessel surveys aboard the NOAA Ship *Oregon II* as part of the SEFSC contributed effort to the GulfCet Program. The first survey was conducted from 21 April-8 June 1992 (spring-summer), and the second survey took place during 4 January-14 February 1993 (winter), and the third survey during 2 May-15 June 1993. The surveys were designed to collect 1) marine mammal sighting data to estimate abundance, distribution and diversity, and 2) environmental data to evaluate factors which may affect the distribution, abundance and diversity of marine mammals. These surveys are also part of the SEFSC's overall marine mammal research program; similar vessel surveys have been conducted annually during the spring-summer in the northern Gulf since 1990. This paper provides a brief review of the methodology, results, and a discussion of a preliminary analysis of sighting data for density estimation.

SURVEY METHODS

The spring-summer surveys were conducted in three separate legs, with two legs covering the off-shelf waters of the northern Gulf between 83°-96° W, and one leg concentrating on the GulfCet study area between 87°-96° W. The winter survey consisted of three legs, all essentially within the GulfCet study area between 87°-96° W. The major difference in sampling between the two surveys was in visual sampling strategy. During spring-summer surveys, visual sampling on two legs occurred during daylight hours along a cruise track that was sampled 24 hours a day for ichthyoplankton; daylight transects could be latitudinal (E-W) or longitudinal (N-S) or a combination of both. Ichthyoplankton sampling did not occur on one leg of the spring-summer surveys or during daylight hours on all legs of the winter survey. This resulted in, as planned, visual sampling on only longitudinal transects.

Visual sighting data were collected by two teams of three observers during daylight hours, weather permitting (i.e, no rain, Beaufort sea state <6), utilizing standard vessel survey data collection methods for cetaceans developed by the Southwest Fisheries Science Center (e.g. see Holt and Sexton 1990). Each team had at least two members experienced in shipboard marine mammal observation and identification techniques. Two observers searched for marine mammals using high-power (25X), large format "Bigeye" binoculars mounted on the ship's flying bridge. The third observer maintained a search of the area near the trackline unaided, with handheld binoculars and recorded data. Sighting data were recorded with a computer data acquisition program in the format required for line-transect distance sampling analysis, which is used to estimate density of the species sampled (see Buckland *et al.* 1993 for a thorough and up-to-date treatment of distance sampling techniques and analyses). Information collected included species, herd-size, bearing and reticle for computing perpendicular sighting distance, and data on environmental conditions (i.e., Beaufort sea state, sun position, etc.) which could affect the observers' ability to sight animals. Ancillary data also collected included, but were not limited to, time of day, position, behavior, and associated animals.

In general, environmental stations were located every 30 minutes of latitude or longitude along the cruise track. The stations included CTD/STD hydrocasts to just off the bottom, or to 500m when depth exceeded 500m. An XBT sample was dropped halfway between the environmental stations. A thermo-salinograph operated throughout the entire cruise; surface water salinity and temperature were recorded every minute of time.

SURVEY RESULTS

Each of the spring-summer surveys visually sampled approximately 6,150 transect kilometers for marine mammals. Both spring-summer surveys resulted in 39 at sea sampling days, with each resulting in about 325 hours of sighting effort. The spring-summer visual sampling resulted in 273 sightings of at least 20 species of cetaceans during 1992 and of 272 sightings of at least 18 species during 1993 (Table 1D.6). The bottlenose dolphin (*Tursiops truncatus*) and the pantropical spotted dolphin (*Stenella attenuata*) were the most frequently sighted, and accounted for 21 percent and 19 percent (1992), and 22 percent and 27 percent (1993), respectively, of identified sightings. Risso's dolphins (*Grampus griseus*), sperm whales (*Physeter macrocephalus*), and dwarf and pygmy sperm whales (*Kogia simus* and *K. breviceps*) were the next most frequently sighted, and accounted for 11 percent, 8 percent, and 15 percent (1992) and 7 percent, 5 percent and 10 percent (1993), respectively, of identified sightings.

The winter survey resulted in the visual sampling of 4,017 transect kilometers, and weather conditions significantly hampered the sampling effort. Survey effort was suspended on two days due to severe weather (sea state >6), and somewhat reduced on eleven additional survey days with average daily sea state >4. At least 10 cetacean species were observed in a total of 46 sightings (Table 1D.6). Sperm whales were the most commonly sighted cetaceans, with nine sightings (25 percent of identified sightings). Atlantic spotted dolphins (*S. frontalis*) and pantropical spotted dolphins were the next most common with six sightings each (17 percent each of identified sightings).

PRELIMINARY ANALYSIS

The sighting data from the spring-summer surveys were pooled for a preliminary line transect distance sampling analysis. This analysis did not consider factors, such as weather conditions, which may negatively affect observers' abilities to sight animals. Two species were chosen for this preliminary analysis: sperm whales and pantropical spotted dolphins. Sperm whales were selected because of their listing as endangered under the Endangered Species Act, and the pantropical dolphins were chosen because of their large number of sightings, their distribution throughout the study area, and their variability in group size. The analysis was also exploratory and served to identify some potential biases which may decrease the precision and/or reliability of resulting density estimates. However, various strategies may be employed in further analyses to minimize effects on precision.

Table 1D.6. Summary of cetacean sightings from the spring-summer and winter vessel surveys.

COMMON NAME, *SPECIES*	SUMMER-SPRING 1992	SUMMER-SPRING 1993	WINTER 1993
Bryde's Whale, *Balaenoptera edeni*	1	-	-
Bryde's/Sea Whale, *B. edeni/borealis*	3	-	-
Sperm Whale, *Physeter macrocephalus*	19	11	9
Pygmy Sperm Whale, *Kogia breviceps*	5	2	1
Dwarf Sperm Whale, *Kogia simus*	18	14	-
Pygmy/Dwarf Sperm Whale, *Kogia* sp.	12	6	-
Beaked Whale, *Mesoplodon* sp.	6	5	-
Blainville's Beaked Whale, *Mesoplodon densirostris*	1	-	-
Beaked Whale, Unidentified Ziphiidae	2	4	1
Cuvier's Beaked Whale, *Ziphius cavirostris*	-	3	-
Melon-headed Whale, *Peponocephala electra*	2	2	1
Pygmy Killer Whale, *Feresa attenuata*	2	1	-
Pygmy Killer/Melon-headed Whale, *Feresa/Peponocephala*	1	-	-
False Killer Whale, *Pseudorca crassidens*	1	1	-
Killer Whale, *Orcinus orca*	1	4	-
Short-finned Pilot Whale, *Globicephala macrorhynchus*	3	1	2
Rough-toothed Dolphin, *Steno bredanensis*	5	4	-
Fraser's Dolphin, *Lagenodelphis hosei*	1	-	-
Bottlenose Dolphin, *Tursiops truncatus*	48	48	5
Risso's Dolphin, *Grampus griseus*	24	15	-
Atlantic Spotted Dolphin, *Stenella frontalis*	7	9	6
Bottlenose/Atlantic Spotted Dolphin, *Tursiops/Stenella frontalis*	1	3	-
Pantropical Spotted Dolphin, *Stenella attenuata*	43	57	6
Striped Dolphin, *Stenella coeruleoalba*	7	9	2
Spinner Dolphin, *Stenella longirostris*	6	5	-
Clymene Dolphin, *Stenella clymene*	6	9	2
Stenella sp.	1	4	1
Unidentified dolphin	27	34	8
Unidentified small whales	4	2	-
Unidentified odontocete	16	13	2
Unidentified large whale	-	6	-
TOTAL IDENTIFIED	225	213	35
TOTAL	273	272	46

Line transect distance sampling analysis, following Buckland *et al.* (1993), was used to evaluate the suitability of the sperm whale and pantropical spotted dolphin sighting data for density estimation. Software (DISTANCE) developed and distributed by Buckland and colleagues (Laake *et al.* 1993) was employed in the evaluation of the sighting data. The main goals of this analysis were to determine how well various models of the probability density function (pdf) fit the sighting data and whether any gross characteristics of the sighting data which may affect the fit, such as group size and ship avoidance or attraction of the species in question, could be identified.

Pooling the spring-summer surveys on-effort sightings resulted in a total of 26 sperm whale groups available for the distance sampling analysis. The group size ranged from one to 11, with a mean of 3.1 and a median of two. Seventy-five percent of the groups were of three or fewer animals. Although 26 sightings is somewhat less than the 60 or so recommended for obtaining a reliable fit of the various pdf models (Buckland, *et al.* 1993), the program DISTANCE was used to explore the perpendicular sighting distance characteristics of the available sightings. Figure 1D.4 illustrates the fit of the hazard rate model to these sightings. Even though a significant portion of the sightings occurred near the trackline, the fit is obviously poor. The lack of a "shoulder" and an increase in sightings at about two kilometers from the trackline contribute to the poor fit. Examination of Figure1D.5 indicates that group size may influence how the whales respond to the survey vessel. Only groups of three or fewer were sighted at a perpendicular distance of <0.30km, and while the minimum group size did not seem to significantly change as distance increased, the maximum group size appeared to have a significant relationship to distance. Thus, it appears that larger groups of sperm whales may have actively avoided the survey vessel. Survey platform avoidance by a target species renders distance sampling problematic (Buckland *et al.* 1993). However, the observed fit may, at least in part, be due to the relatively small sample size. Sightings from the final survey, the 1993 winter survey, and the 1990 and 1991 NMFS spring-summer surveys will be pooled with these data, and the resulting larger data set may permit reliable modeling of the pdf.

A much larger sample of 90 groups of on-effort pantropical spotted dolphin sightings was available for the distance sampling analysis. Group size of these dolphins ranged from three to 225, with a mean of 39.8 and a median of 30.5. About 75 percent of these groups were of 50 or fewer animals. Figure 1D.6 is an example of the hazard rate model fit produced by the program DISTANCE for these sightings. The fit is relatively good; there is a "shoulder" and the observed distribution of sighting distances does not differ significantly from the expected. However, DISTANCE also tests for group size bias, and results indicated that the effects of group size were significant. Figure 1D.7 shows the minimum, maximum and mean group size by perpendicular distance from the track line. The trend in all three parameters is the same; they increase as the distance increases. The trend in minimum group size may reflect some combination of two factors: one, small groups are more difficult to detect at greater distance, and two, small groups may be attracted to the vessel. The trend in maximum group size may reflect the same behavior as that postulated for large groups of sperm whales; that is, larger groups may actively avoid the vessel. Some of the effects of the group size biases can be minimized. For instance, most of the groups attracted to the vessel ride the bow and can be identified and excluded for modeling the pdf. The effect of group size on detection probability can be minimized by stratifying the analysis by group size. Pooling with the additional data sets should result in reliable modeling of the pdf, even after exclusion of attracted groups and stratification.

The preliminary analysis shows that there may be some problems in obtaining reliable density estimates from the vessel survey data. These difficulties may be resolved for sperm whale density estimation as more data is pooled for modeling the probability density function (pdf.). If not, the aerial survey data (see Mullin *et al.* this volume) may provide a more reliable estimate of density for sperm whales. Although there are some group size bias problems with the pantropical dolphin sighting data, they seem much less problematic than those of the sperm whale sighting data. The potential size of the pantropical dolphin data set allows for stratification that is not reasonable for the smaller data set of sperm whales. In addition, the aerial surveys may provide an unbiased estimate of group size for use in estimating density with the vessel sightings.

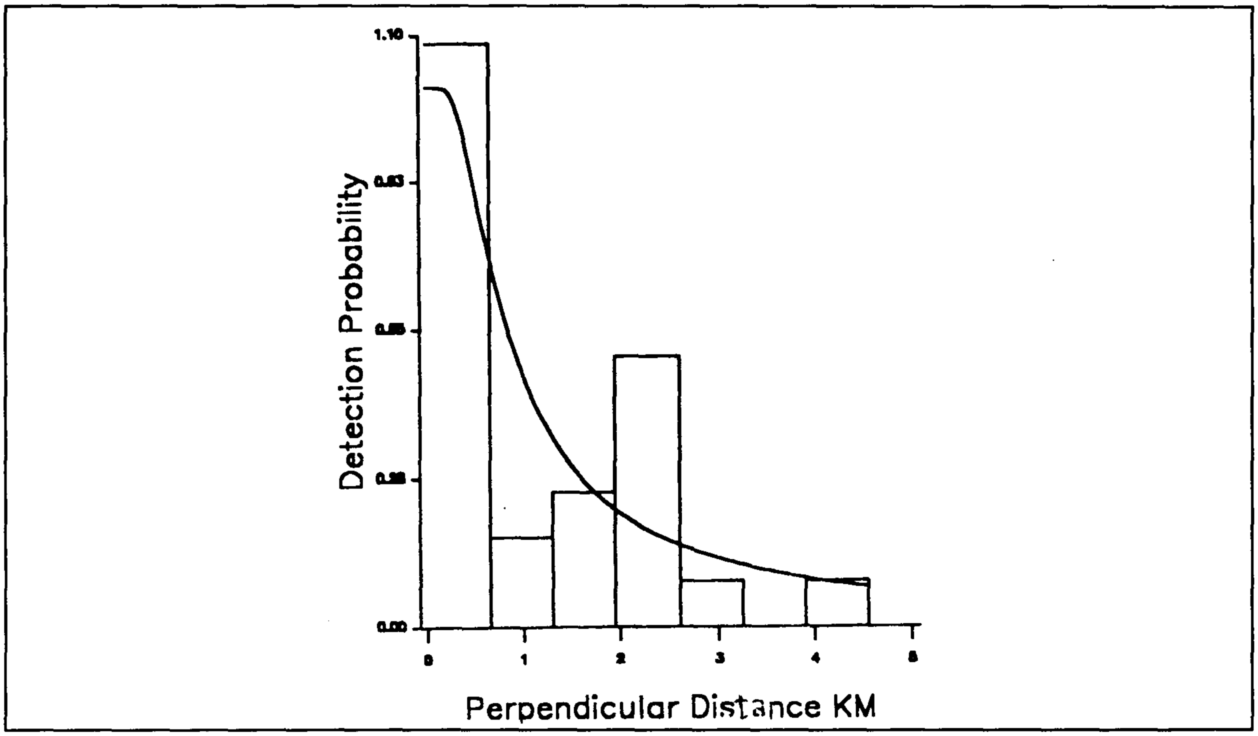

Figure 1D.4. Example of hazard rate model fit for sperm whale (*Physeter macrocephalus*) sightings. The sightings at mid-distance contribute to the poor fit.

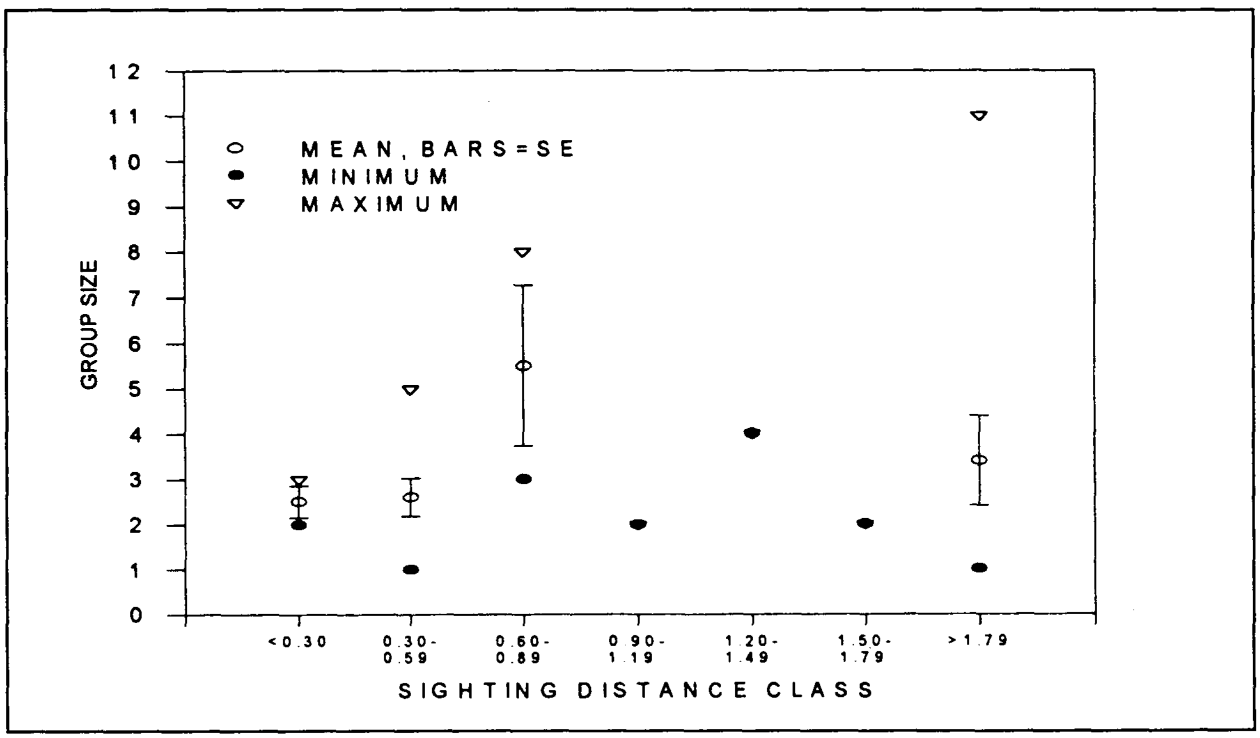

Figure 1D.5. Group size of sperm whales (*Physeter macrocephalus*) by perpendicular sighting distance. Note the relationship of maximum group size to distance.

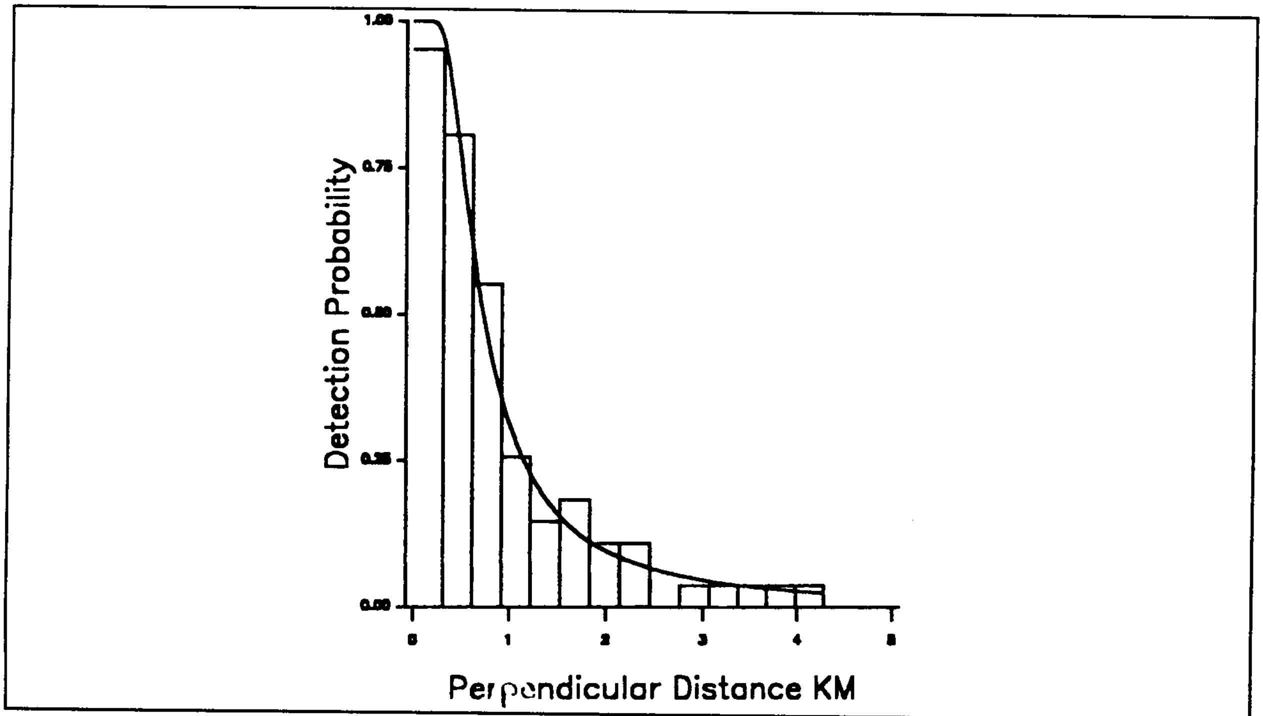

Figure 1D.6. Example of hazard rate model fit for pantropical spotted dolphins (*Stenella attenuate*)

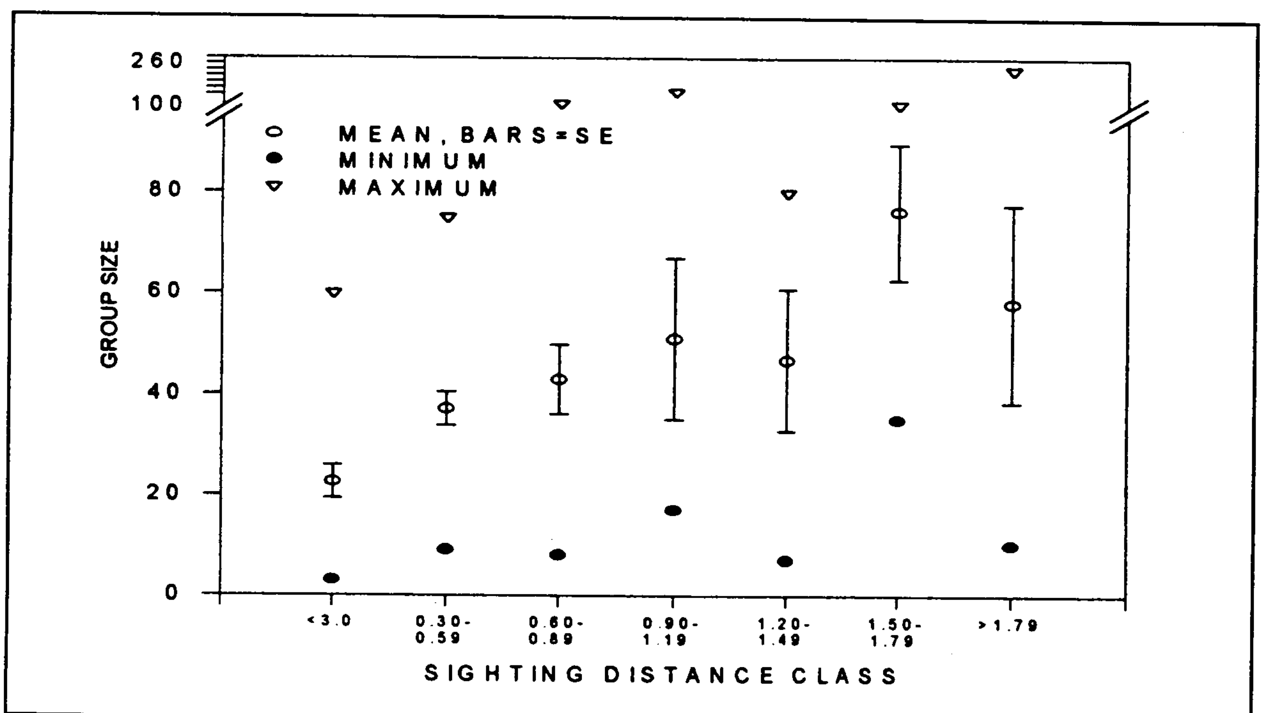

Figure 1D.7. Group size of pantropical spotted dolphins (*Stenella attenuate*) by perpendicular sighting distance. Note the relationship of mean, min., and max. group size to distance.

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Dr. Keith Mullin is a Research Fishery Biologist for the National Marine Fisheries Service. He has been conducting cetacean population assessment studies at the SEFSC Mississippi Laboratories for seven years, where he is the leader of the Marine Mammal Research Program. His research interests are distributional ecology of marine mammals and estimation of marine mammal abundance. Dr. Mullin received his B.A. in biology from Indiana University, and his M.S. and Ph.D. in zoology from Northwestern State University of Louisiana and Mississippi State University, respectively.

Carol Roden has been a Biologist with the National Marine Fisheries Service, SEFSC, Mississippi Laboratories, for eight years. She has participated in a wide variety of studies including aerial surveys of sea turtles, red drum, and marine mammals. Since 1991, she has coordinated and conducted marine mammal vessel surveys for the SEFSC. Ms. Roden received her B.A. from the University of Alabama.

BIOACOUSTIC SURVEY DESIGN AND RESULTS

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INTRODUCTION

The main objective of the acoustic segment of GulfCet is to provide support for assessing the distribution and abundance of marine mammals in the study area. We are also conducting visual assessments of the distribution of pelagic birds. The acoustic census is conducted using a linear towed hydrophone array, from which we record marine mammal vocalizations. We are compiling a data set of acoustic contacts that will provide additional marine mammals distribution information.

METHODS AND MATERIALS

Recordings are made using a linear towed array, owned by Texas A&M University. It is made of three sections: a deck cable, a tow cable, and a wet section which contains the active elements of the array. Figure 1D.8 provides a schematic diagram of the system. The active section of the array is 235 m long. It is made of four sections, a forward dead section, a fore and aft vibration isolating mechanisms (VIMs), a fore and aft high frequency section with depth and temperature sensors, and a middle low frequency section. (Figure 1D.9). There are 195 hydrophones within the active section in 18 different groups or traces. These 18 groups are tuned to six frequency bands. In the low frequency section there are eight groups of hydrophones tuned to 30 Hz, one group at 480 Hz, and a third group tuned to 3.84 kHz. In each fore and aft high frequency section there are groups tuned to 5, 10, and 15 kHz. A tuned system is designed to have increased sensitivity, described by its directivity index, at a particular frequency by separating the individual hydrophone elements of each group by the wavelength of the frequency of interest. Because of the 3 3/4 ips tape speed used, the realized overall bandwidth is from DC to 12.5 kHz. The array

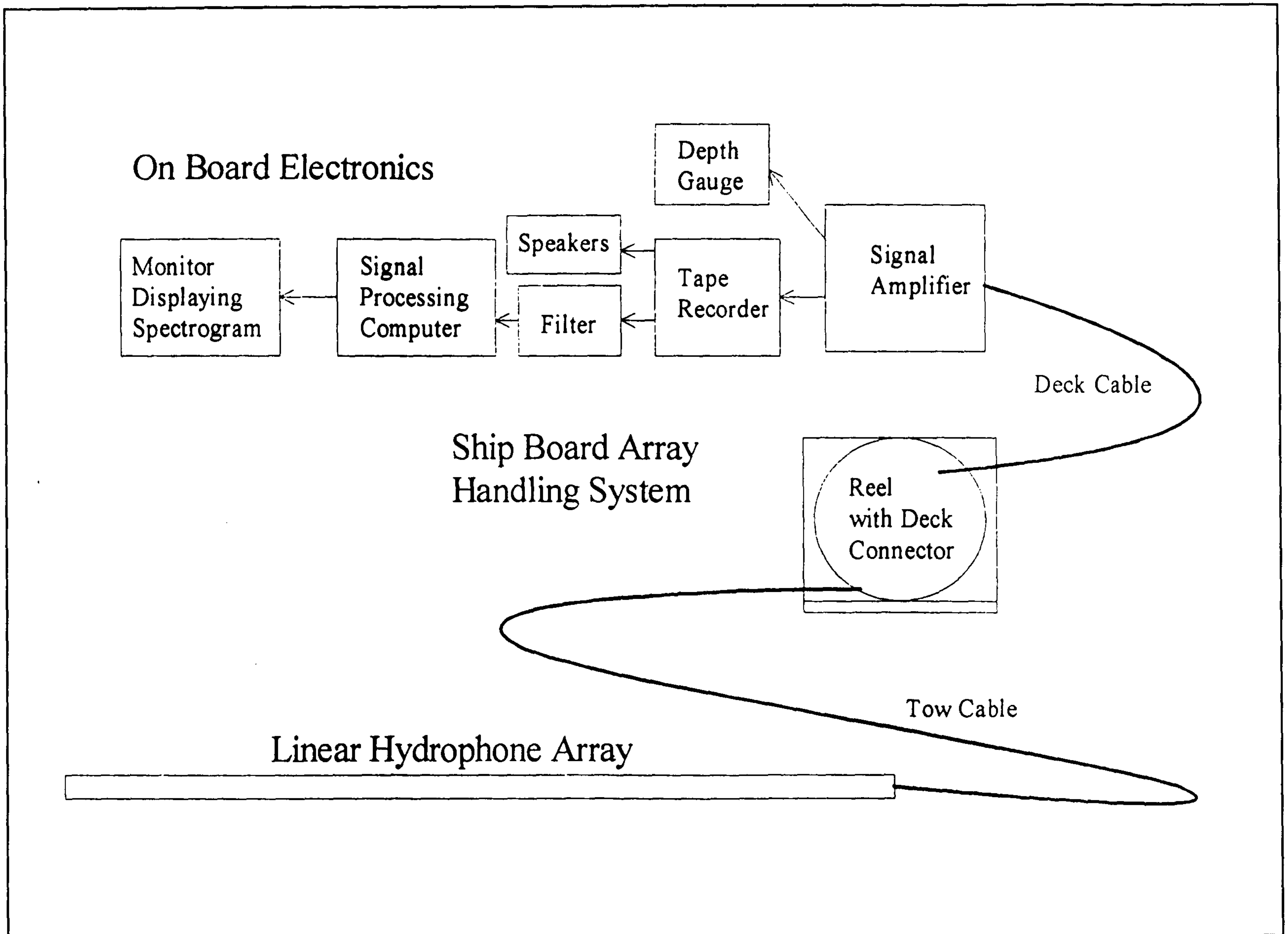

Figure 1D.8. The configuration of the On Board Electronics, Array Handling System, and Array.

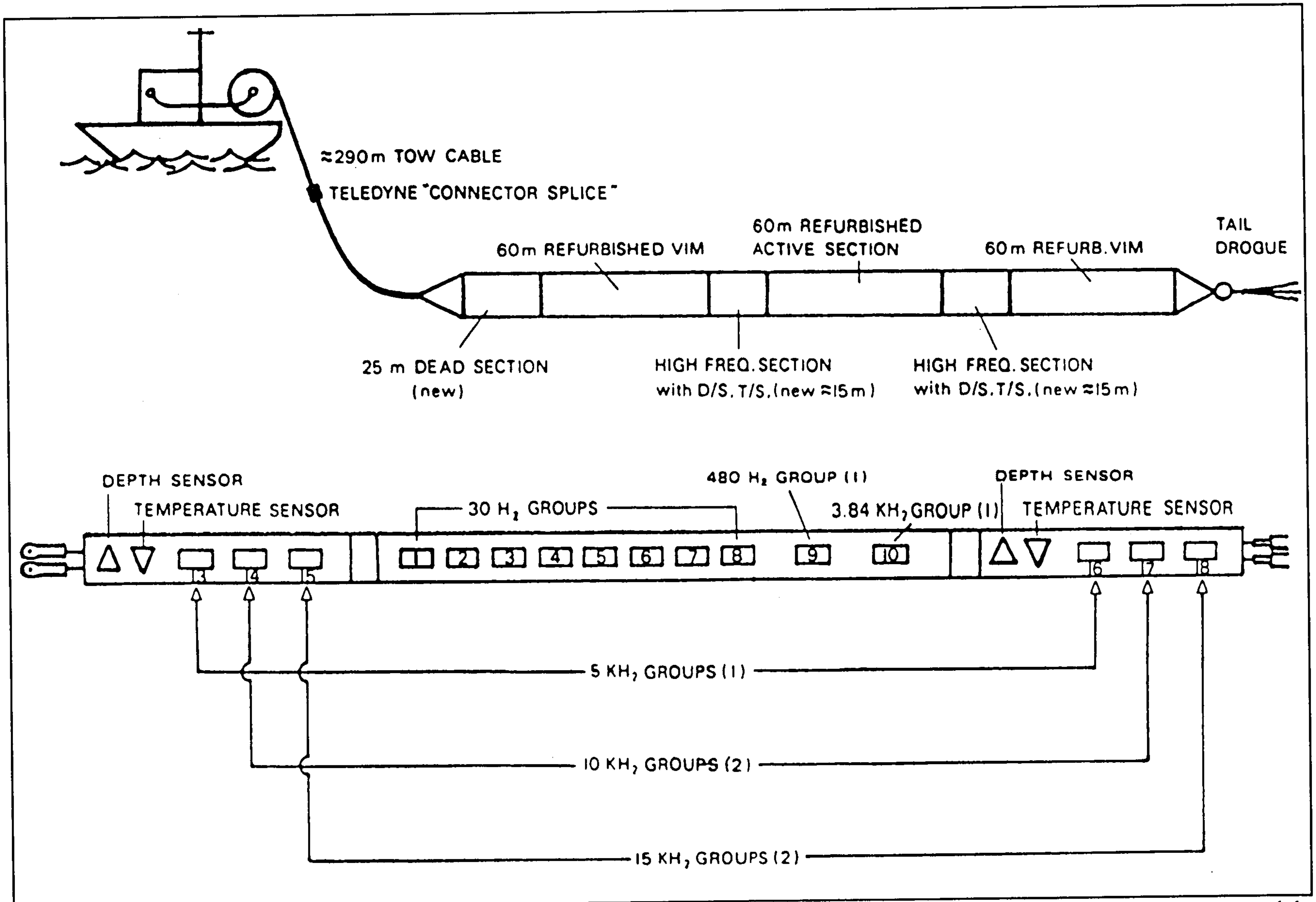

Figure 1D.9. Diagram of the linear acoustic array, illustrating its various components including the placement of depth and temperature sensors, and the various hydrophone groups and their respective frequency ranges.

has maximum sensitivity in a ringed pattern perpendicular to the long axis of the array and very little sensitivity either to the front or back. It therefore receives little ship-generated noise, particularly the higher frequency sections.

RESULTS

We have had a total of approximately 313 acoustic contacts during cruises 1-5, though the total for cruise 5 is incomplete (Table 1D.7). Over half of these contacts have been with unidentified dolphins. The large number of unidentified contacts is due to our hearing whistles and sonar pulses when no animals were seen, typically because the contact was made at night or during conditions when there was no sighting effort. We are now working to identify the source of these signals. The second most common acoustic contact has been with sperm whales, *Physeter macrocephalus*. The identity of some of the sperm whale contacts is known because they were concurrently seen and heard. Other contacts, however, were identified to species because sperm whale pulses are widely considered to be acoustically unique, which allowed us to identify them. This is the only species which we have identified at this date by acoustic characteristics. Pantropical spotted dolphins, *Stenella attenuata*, were also encountered often. We suspect this to be the dolphin that is the source for many of the unidentified dolphin contacts. We had numerous acoustic contacts with other biological sources, typically shrimp, which we believe can be easily recognized by a frying sound. Below is a species summary.

Sperm whales, *Physeter macrocephalus*

Sperm whales have been encountered during all cruises and on all transect legs. Figure 1D.10 presents the locations for these contacts. Several tentative conclusions are clear from our results to date. There appear to be many sperm whale in the study area. On some cruises we can hear their pulses for almost half the time that the array is in the water. We also consistently find sperm whales in specific areas. We have encountered sperm whales near the mouth of the Mississippi River and near the western end of the study are on almost every cruise. This

Table 1D.7. Number of acoustical contacts by species for cruises 1-5.

Species	Cruise 1	Cruise 2	Cruise 3	Cruise 4	Cruise 5*	Total
Sperm whale	8	7	10	11	17	53
Pantropical Spotted dolphin	2	2	1	6	4	15
Atlantic Spotted dolphin		1				1
Striped dolphin		3				3
Clymene dolphin	1					1
Pilot whale					1	1
Bottlenose dolphin	5	2	2			9
Rough toothed dolphin			1			1
Unidentified cetacean	3	3	8	4	8	26
Unidentified dolphin	22	56	24	52	27	181
Unidentified contact	3		1	2		6
Other Biological	2	2	2	4	6	16
	46	76	49	79	63	313

* Incomplete total

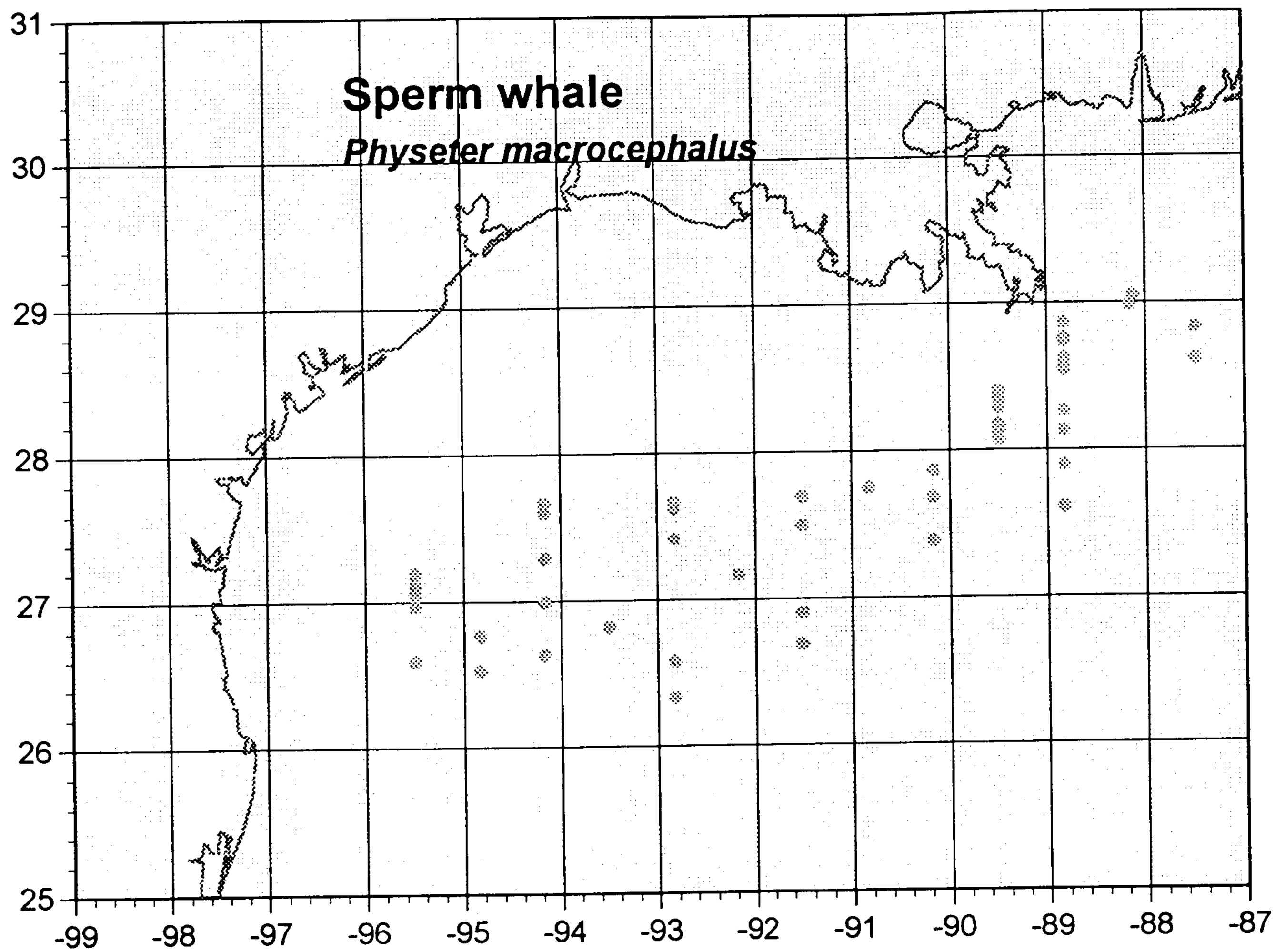

Figure 1D.10. Distribution of sperm whale acoustic contacts.

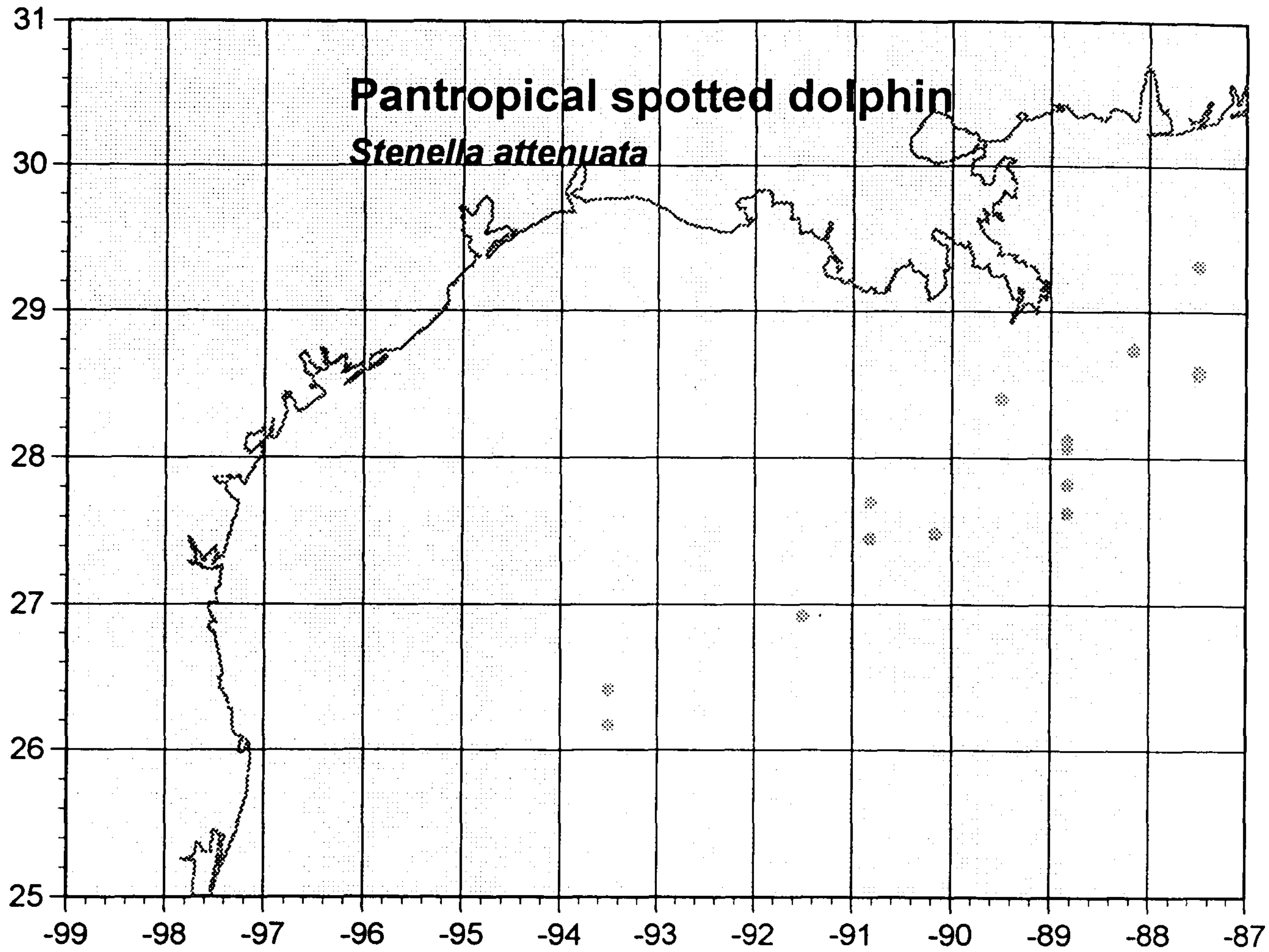

Figure 1D.11. Distribution of Pantropical spotted dolphin contacts.

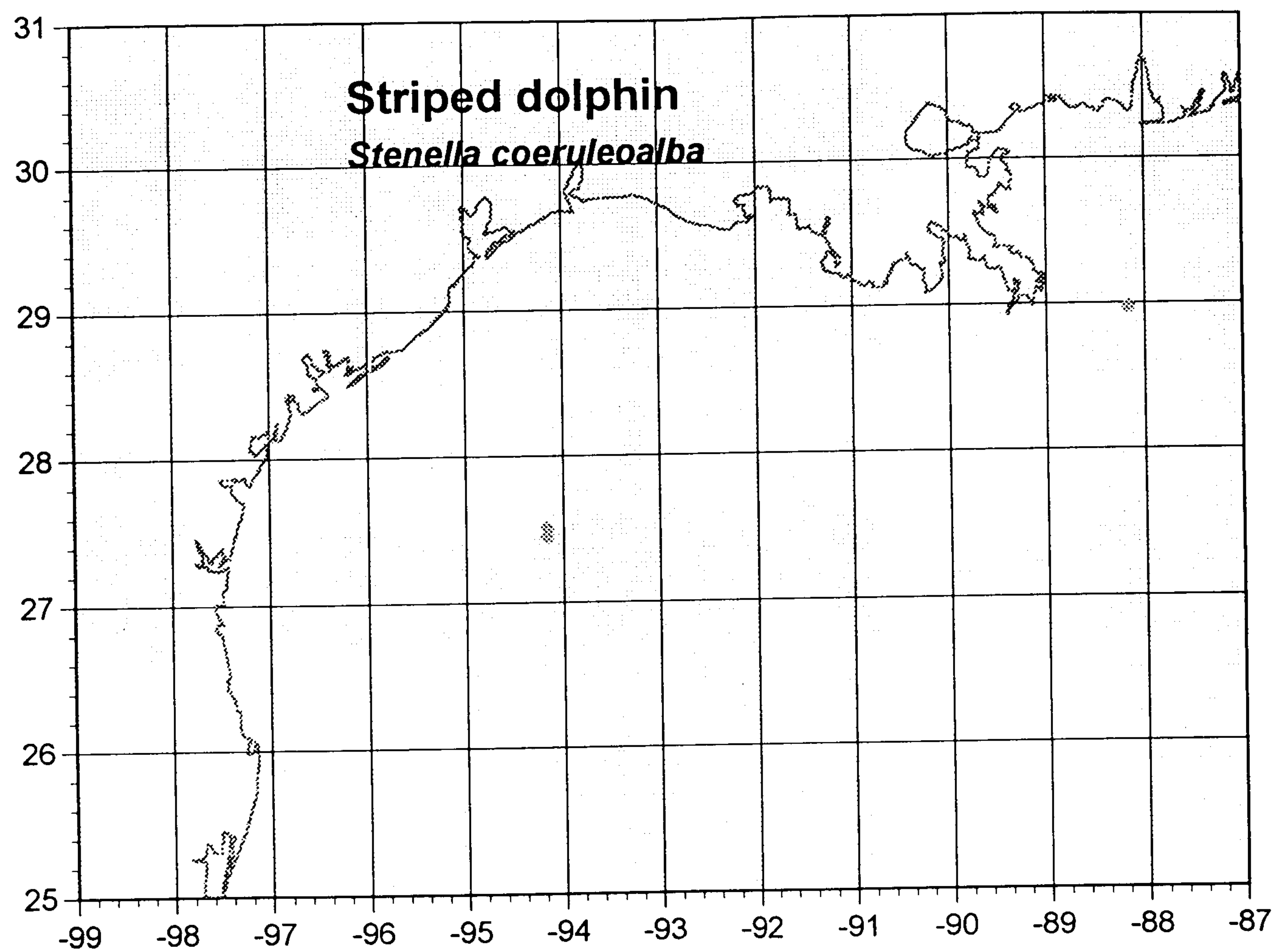

Figure 1D.12. Distribution of striped dolphin acoustic contacts.

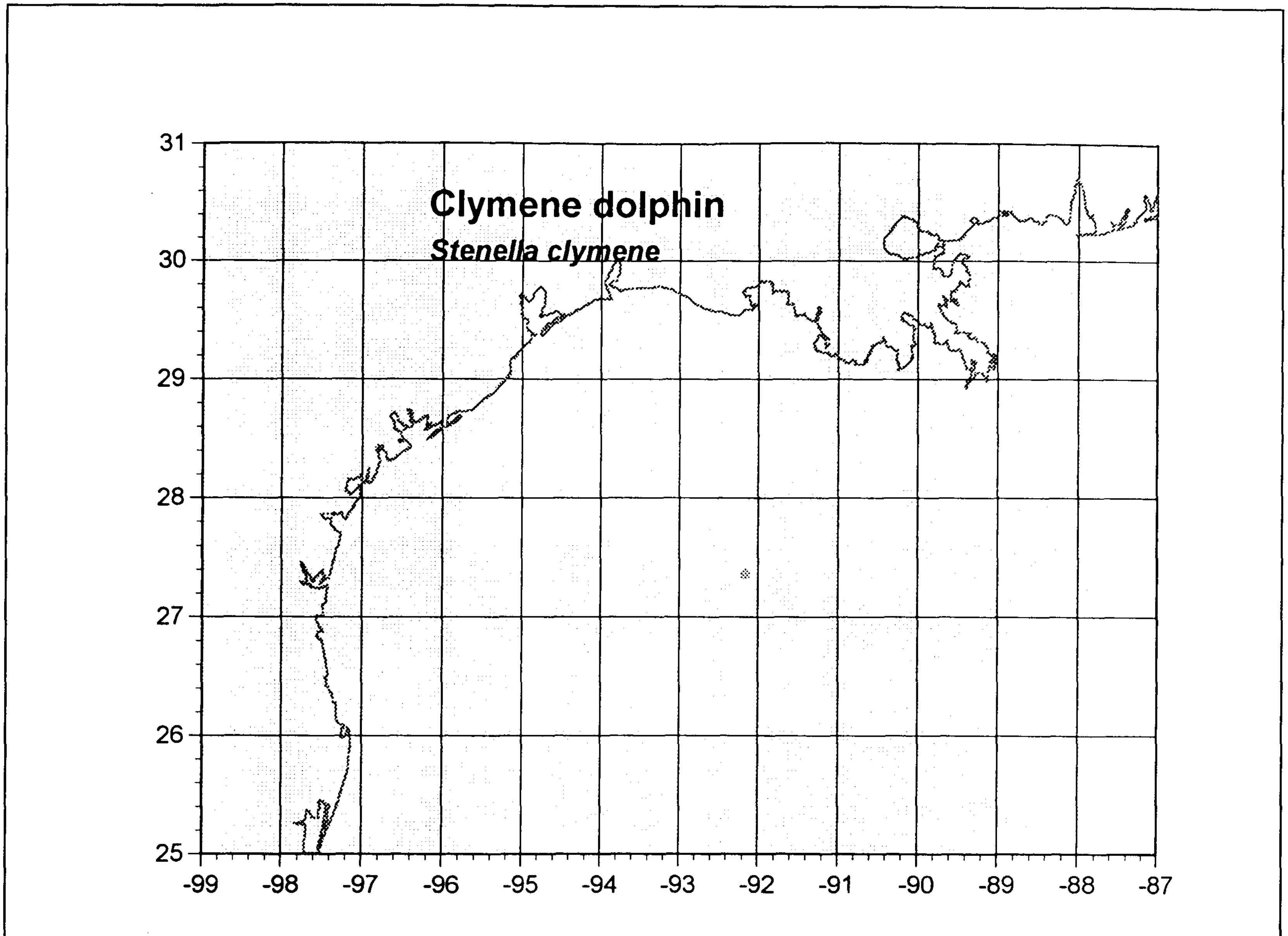

Figure 1D.13. Location of the single clymene dolphin acoustic contact.

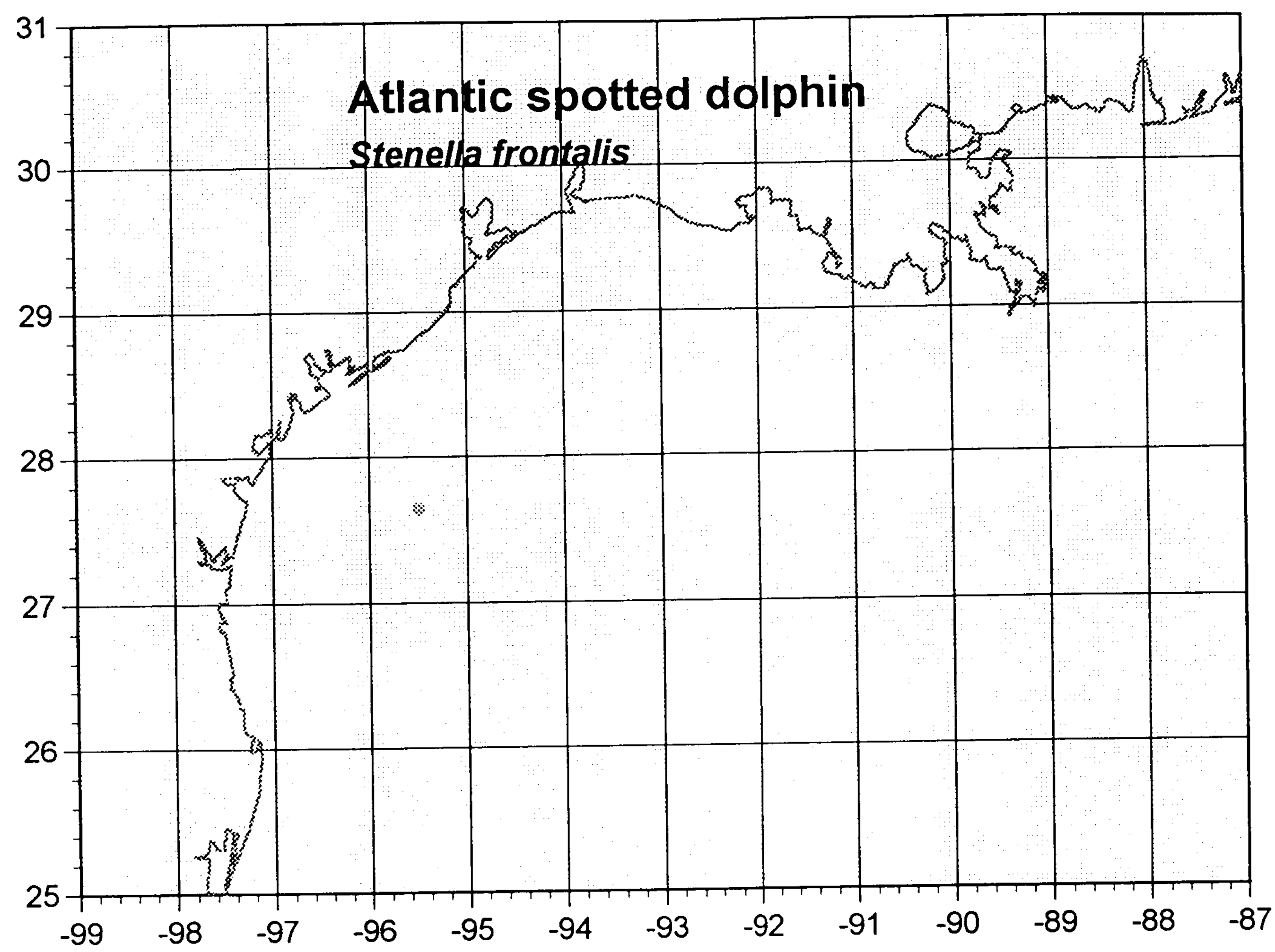

Figure 1D.14. Location of the single Atlantic spotted dolphin acoustic contact.

apparent site fidelity may be seasonal. It is also clear from Figure 1D.10 that we encounter sperm whales throughout the study area, though they appear to be concentrated in water between 500m-1,000m in depth. We have never encountered animals in shallow water, but also only infrequently near the southern ends of transect legs in 2,000m of water. Observed animals were also strikingly small, with calves often in evidence. This leads to a tentative conclusion that we are most often encountering female groups. We have on two occasions seen large animals, presumably male; once a solitary whale, and during cruise 1 we encountered a large pod that appeared to contain one large animal with several smaller whales with calves.

Stenella species

Pantropical spotted dolphin, *Stenella attenuata* is our most common identified dolphin source. Most contacts have been in deep water in the eastern half of the study area (Figure 1D.11). All other *Stenella* species have been encountered during some GulfCet cruise, though often only once. We have had a single encounter with spinner dolphins, *Stenella longirostris*, during a cruise of opportunity on the R/V Gyre into Mexican waters outside of the study area. We found a single group approximately 40 miles south of the border in approximately 600 m of waters. Striped dolphin, *S. coeruleoalba*, were encountered three times (Figure 1D.12). We have the first tape recording from *S. clymene* in all of the Gulf of Mexico (Figure 1D.13). We have had other visual sightings but did not hear any sounds. Likewise, we have had only a single acoustic contact with the Atlantic spotted dolphin, *Stenella frontalis* (Figure 1D.14). Based on that contact and other visual contacts, it appears that this dolphin is found in shallow waters, similar to the bottlenose dolphin.

Bottlenose dolphin, *Tursiops truncatus*

We have recorded these dolphins nine times, in all cases along the northern ends of transect legs (Figure 1D.15). There have been relatively more visual sightings of *Tursiops truncatus* because visual effort is maintained while crossing between transect legs; therefore, there has been relatively more visual effort in shallow waters.

Blackfish

During these cruises we have had a single contact with pilot whales, *Globicephala macrorhynchus* (Figure 1D.16). We had other encounters during later cruises. We also contacted false killer whales, Pseudorca crassidens, on cruise 5.

Other Dolphins

We have had acoustic contacts with several other cetaceans. These contacts include the first recordings made in the entire Atlantic Ocean from Fraser's dolphin, *Lagenodelphis hosei*. They were first seen and heard on the R/V gyre cruise in Mexico. We have also heard them along with melon-headed whales, *Peponocephala electra*, as a mixed school during cruise 5. We also recorded rough-toothed dolphin, *Steno bredanensis*, on the R/V Gyre cruise, as well as during later cruises.

A number of cetaceans are noteworthy in their absence. We have no acoustic or visual contacts with killer whales, *Orcinus orca*, or pygmy killer whales, *Feresa attenuata*. We also have no acoustic contacts with Risso's dolphin, *Grampus griseus*, though these may have been seen. All species are known to exist in the Gulf. We have no acoustic contacts with any beaked whale or Kogia, though we have seen species of both groups. Lastly, we have had no acoustic contacts with any baleen whale.

Pelagic Birds

Very little is known of the distribution of pelagic birds in the Gulf of Mexico. Existing specimen records are limited in number and widely varying in quality. The abundance, density, and seasonal movements of this group of birds is unavailable. Pelagic bird observers have been on all but two of the seven GulfCet cruises. Data collected suggest that GulfCet will dramatically change our view of how pelagic birds relate to the Gulf environment. As an example, the Texas Bird Records Committee reported in 1990 that Audubon's shearwater, Band-rumped storm-petrel, and Bridled tern had been seen fewer than four times off the coast of Texas out to a distance of 200 miles. In our study area, we have

Table 1D.8. List of pelagic birds observed on GulfCet cruises 1-5.

Pomarine jaeger	*Stercorarius pomarinus*
Audubon's shearwater	*Puffinus sherminieri*
Cory's shearwater	*Calonectris diomedea*
Bridled tern	*Sterna antillarum*
Royal tern	*Sterna maxima*
Band-rumped Strom-petrel	*Oceanodroma castro*
Storm-petrel species	*Family Hydrobatidae*
Herring gull	*Larus argentatus*
Laughing gull	*L. atricilla*
Northern gannet	*Morus bassanus*
Masked booby	*Sula dactylatra*
White-tailed Tropicbird	*Phaethon lepturus*

recorded 19 Bridled terns, 12 Band-rumped storm-petrels, and 37 Audubon's shearwater's (not all in Texas waters). Table 1D.8 lists the major species encountered.

WORK IN PROGRESS

We have several major projects now in progress. First, we have been working on a system for determining the source of our unidentified contacts. This involves defining a set of acoustic parameters that will describe all aspects of their whistled vocalizations. This has largely been completed, and we are now working to validate this system. Next, using these variables, we will analyze the vocalizations from all known dolphins. Once this is completed we will similarly describe the whistles from the recordings of unidentified contacts. Lastly, we will attempt to statistically pair the unidentified calls with those from identified sources. We expect to identify some but not all of the unidentified contracts.

We are also in progress in developing methods for acoustically assessing the density of sperm whales. This project will involve determining the exact location for all sperm whale contacts. Since we often hear sperm whale pulses for many hours, the exact position for each vocalizer is not always clear. We are also developing 3-D line transect theory for use with acoustic arrays. This includes descriptions of the biases involved in acoustic censusing, as well as descriptions of the procedures, from data acquisition through analysis. We are also working to calibrate the hydrophone array to determine the range from which we hear signals. Lastly, we are conducting a series of psychoacoustic experiments with sperm whale pulses to determine the detection function. This is necessary for calculating sperm whale density.

HYDROGRAPHIC SURVEY RESULTS

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SUMMARY

Analyses of hydrographic data have led to the detection of major eddies and circulation events in the north-central Gulf of Mexico for 1992 and 1993. Prominent anticyclonic eddies, such as Triton, Vazquez, and Whopper were observed. Small cold water cyclonic eddies were found coupled with the periphery of these warm water anticyclonic eddies. It is in association with these cold cyclonic eddies that high chlorophyll values have been found. These areas of greater productivity may be preferred habitats for marine mammals. Cetacean distributions have been correlated with hydrographic features and bathymetry.

The circulation of the Gulf of Mexico (GOM) is remarkable because of its variability and intensity. The most prominent circulation features in the Gulf are the intense Loop Current System in the eastern Gulf and an anticyclonic cell of circulation in the western Gulf (Nowlin and McLellan 1967; Behringer *et al.* 1977; Merrell and Vazquez 1983). The Loop Current's path and extent of intrusion into the Gulf varies with season, but reaches a maximum in the summer, at which time an anticyclonic eddy separates from the loop and drifts westward (Hofmann and Wortley 1986; Merrell and Vazquez 1983). High fluctuations in frequency of eddies (from eight to 17 months) have been reported by Behringer *et al.* (1977). Different types of eddies have also been described, including anticyclonic eddies and cyclonic-anticyclonic eddy pairs (Merrell and Morrison 1981; Brooks and Legeckis 1982).

The prominent GOM circulation features (i.e., Loop Current, the 1992-1993 eddies Triton, "U," Vazquez (V), and Whopper (W), and the high fresh water input during "the great flood" of August-September, 1993) interact to make the GOM a very complex environment. A detailed eddy summary will be presented at the LATEX III slope section (Fargion *et al.* ITM 1993; Hamilton *et al.* ITM 1993; Biggs *et al.* ITM 1993).

Nearly two-thirds of the U.S. mainland and half the area of Mexico drains into the Gulf of Mexico (Weber *et al.* 1990). The Mississippi and other rivers with their associated nutrient and sediment loads have a great influence on the Gulf. A time series of chlorophyll pigment was extracted from the Global NASA CZCS images to evaluate areas of high productivity, seasonality, and interannual variations in the Gulf of Mexico. Data for the first time series was extracted to coincide with the GulfCet CTD station positions, and the second time series was derived form three regions in the Gulf (Texas-Louisiana shelf, Texas-Louisiana slope, and Mississippi River mouth area). Figure 1D.17 shows the flow of the river from November 1978 to June 1986, with the Texas-Louisiana shelf/slope time series of chlorophyll pigments. It is clear from these data that the Mississippi River plays an important role in the interannual variations of chlorophyll and in developing areas of high productivity in the Gulf. Therefore, the Mississippi river should ultimately affect the spatial and temporal distribution of cetaceans in the Gulf of Mexico.

The data presented have been collected from five seasonal aerial and six shipboard surveys. These surveys have been conducted by Texas A&M University and the Southeast Fisheries Science Center of National Marine Fisheries Service. The study is restricted to the area bounded by the Florida-Alabama border, the Texas-Mexico border, and the 100 m and 2,000 m isobaths. The survey methods include

1. Aerial surveys from an altitude of 750 ft;
2. Shipboard visual surveys using 25-power binoculars; and
3. Hydrographic data collected using a CTD (40 mile resolution to 800 m) and XBTs.

Isotherms at 8, 15, and 20° C have been computed from CTD and XBT data, and plotted for each cruise. A region where these isotherms dip downwards or deepen corresponds to an anticyclonic warm water eddy, and conversely, an area where the isotherms shallow upwards corresponds to a cyclonic eddy (cold water). Figure 1D.18 shows the 8° C isotherm for GulfCet cruise four (February 93) with a cold water eddy clearly visible. This cyclonic cold water eddy is usually paired with an anticyclonic warm water eddy and is likely to be found if the anticyclonic eddy has recently detached form the Loop Current. High chlorophyll pigment concentrations were detected in conjunction with this cold water cyclonic eddy (Figure 1D.19). Such high chlorophyll concentrations indicate areas of high productivity. To summarize, areas of high productivity in the Gulf are found (1) offshore in conjunction with a cold water cyclonic eddy which is paired with a warmer anticyclonic eddy; and (2) inshore (i.e., Texas-Louisiana shelf), an area influenced by fresh water input.

XBT data were combined with CTD data to compute local geostrophic circulation fields. A micro VAX computer was used for the calculations of dynamic height and mass transport/geostrophic velocity between station pairs, as described by Biggs, *et al.* (1990). All of our geopotential computations are referenced to the 800 dbar surface. Hofmann and Worley (1986) have shown empirically that the choice of an 800 to 850 dbar reference level should allow baroclinic transport calculations to be in mass balance throughout the western Gulf of Mexico. Dynamic height (Figure 1D.20) was superimposed on sperm whale sighting locations. The whales were found to be associated with the periphery of the anticyclonic eddies. This association will be further tested statistically.

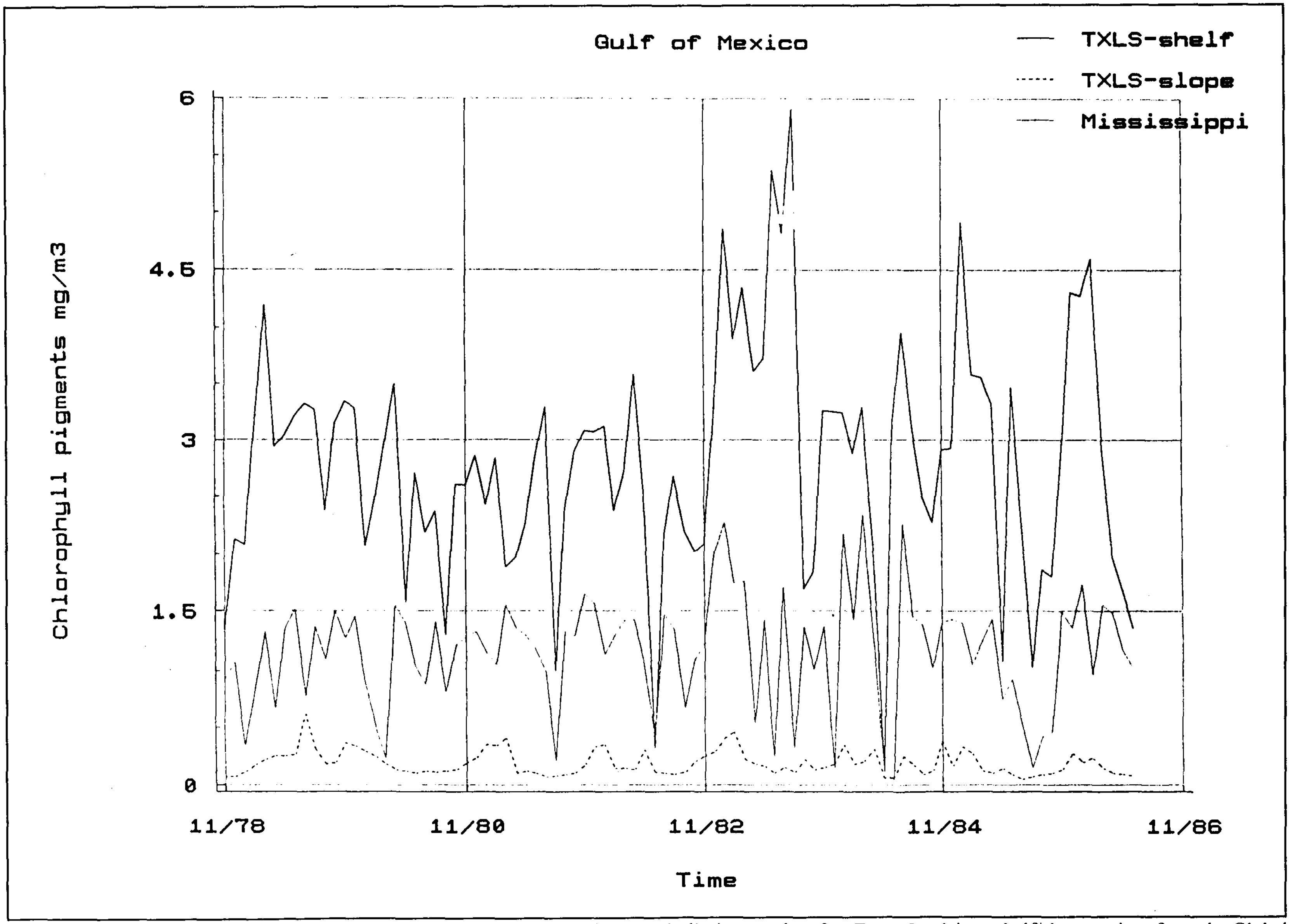


Figure 1D.17. Time series 1979-1986 of Mississippi River flow and chlorophyll pigment data for Texas-Louisiana shelf/slope region, from the Global NASA CZCS data.

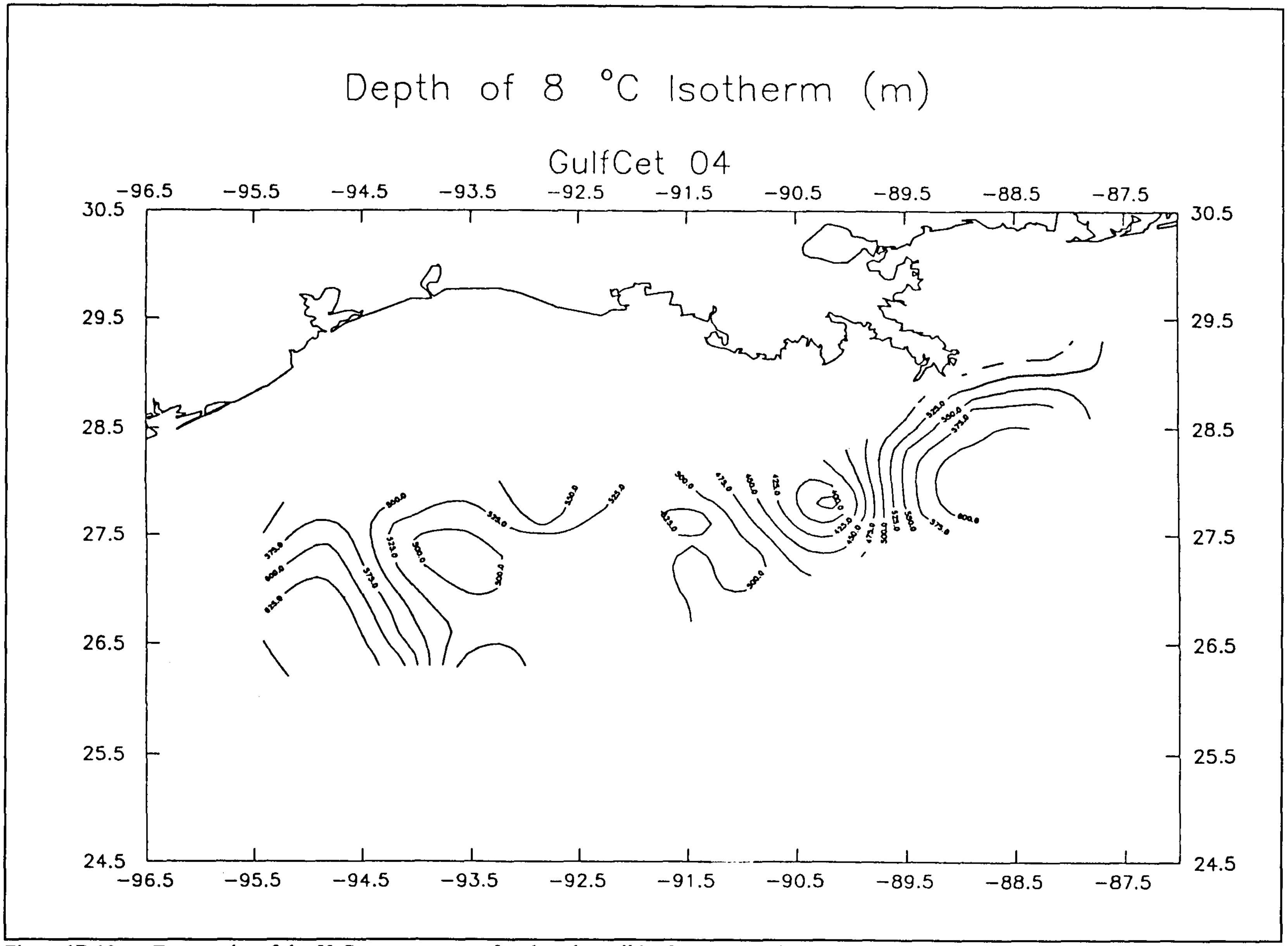


Figure 1D.18. Topography of the 8° C temperature surface based on all XBT and CTD data Cruise 4 (February 1993).

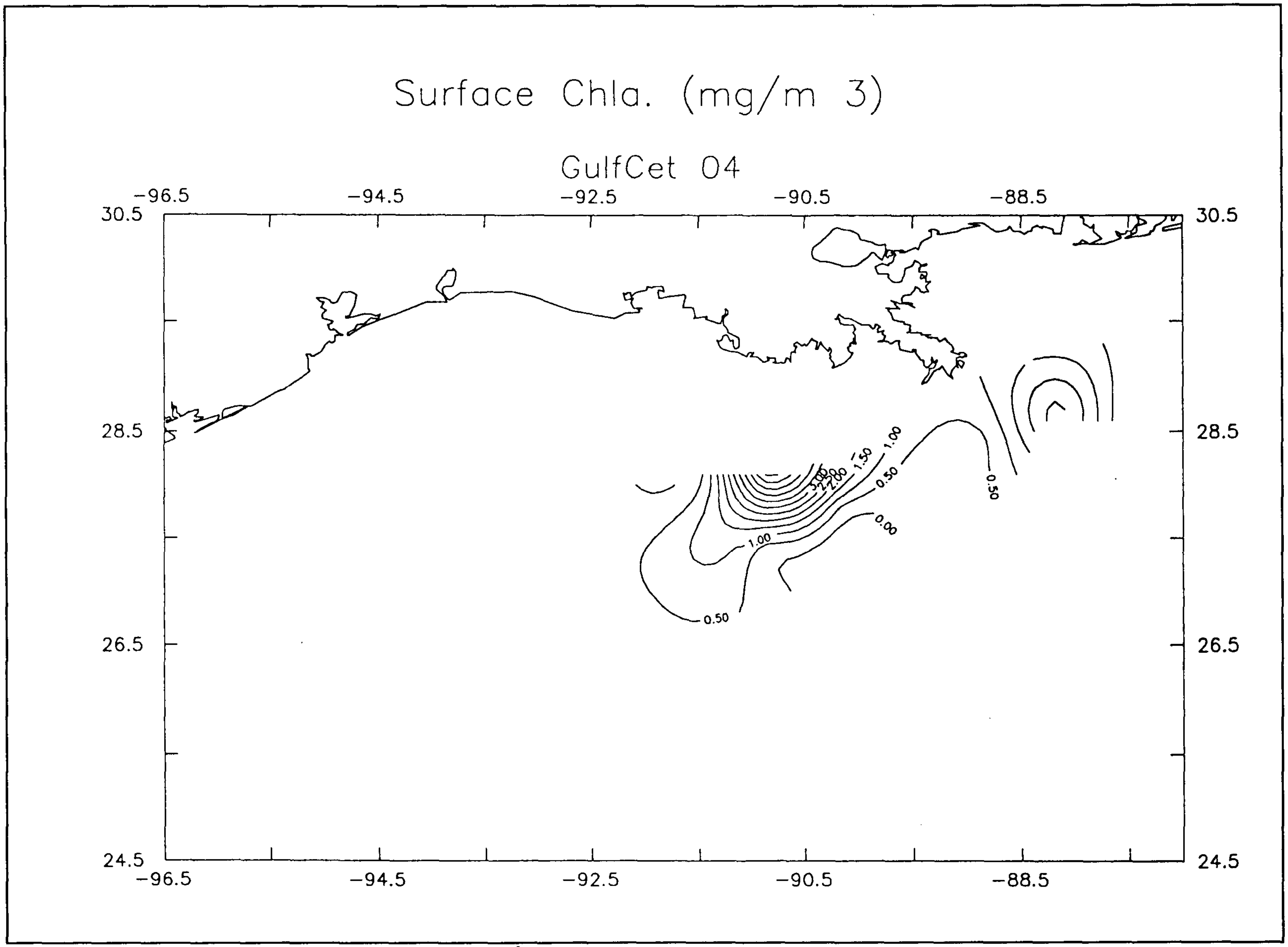


Figure 1D.19. Chlorophyll a surface distribution in mg/m^3 from GulfCet Cruise 4 (February 1993).

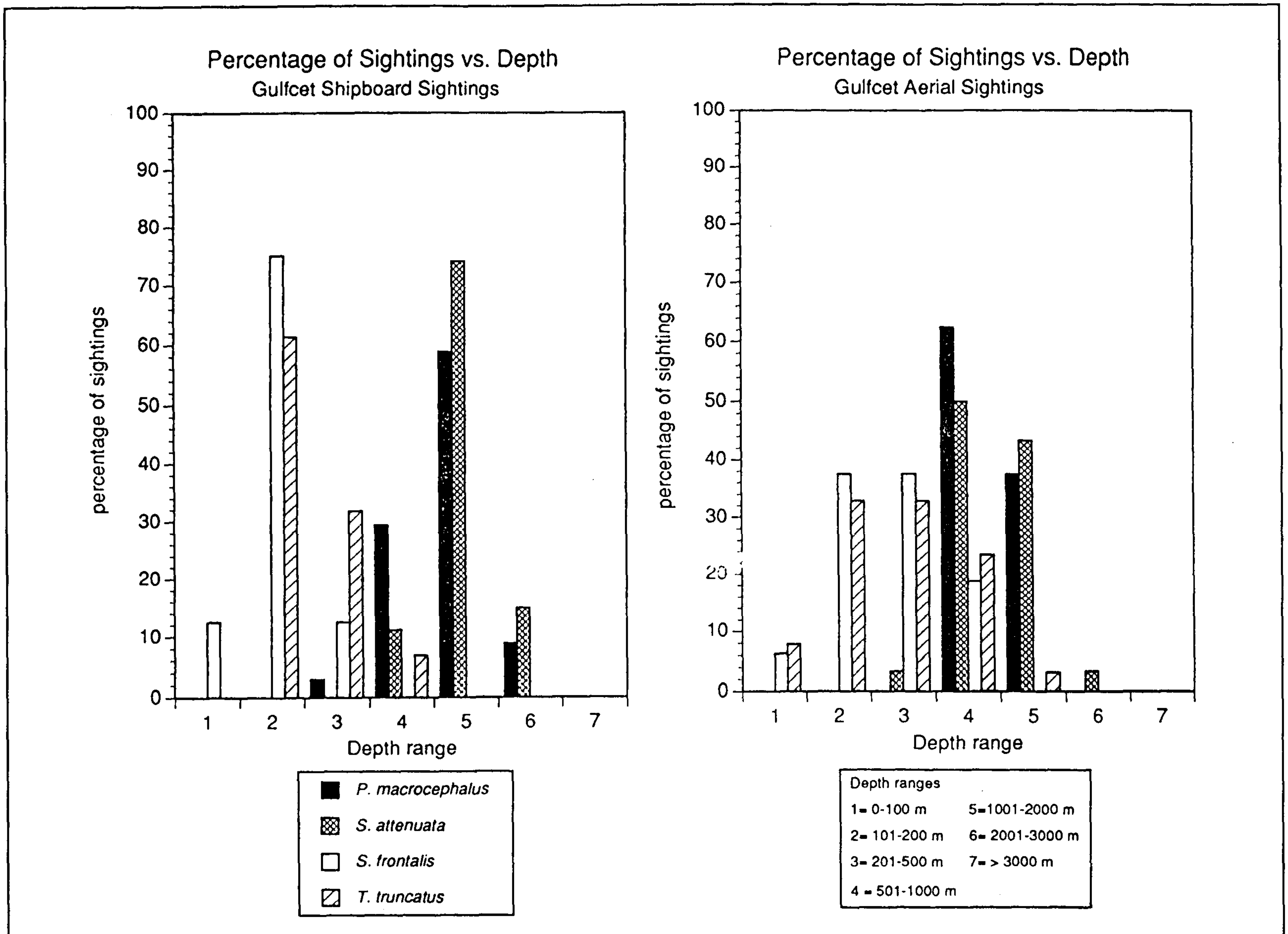
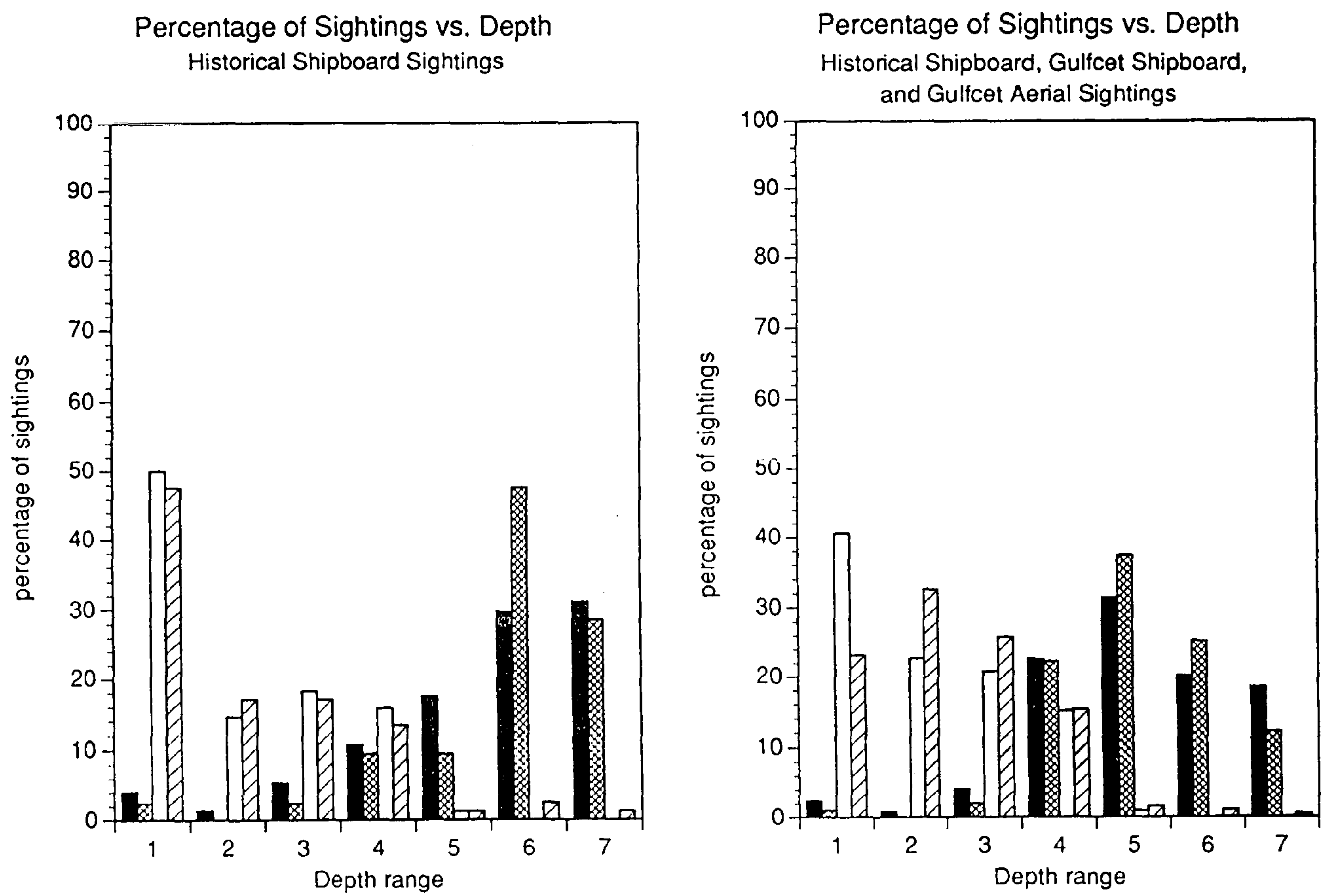


Figure 1D.20. Surface dynamic topography (cm) with respect to 800 m from Cruise 6 (August 1993) with *Physeter macrocephalus* sightings.



Numbers of Sightings

	P. macrocephalus	S. attenuata	S. frontalis	T. truncatus
historical data	74	42	82	82
GC ship visual data	34	27	8	44
GC aerial data	16	30	16	64
all data	124	99	106	190

Figure 1D.21. Percentage of sightings vs depth ranges: GulfCet shipboard and GulfCet aerial data.

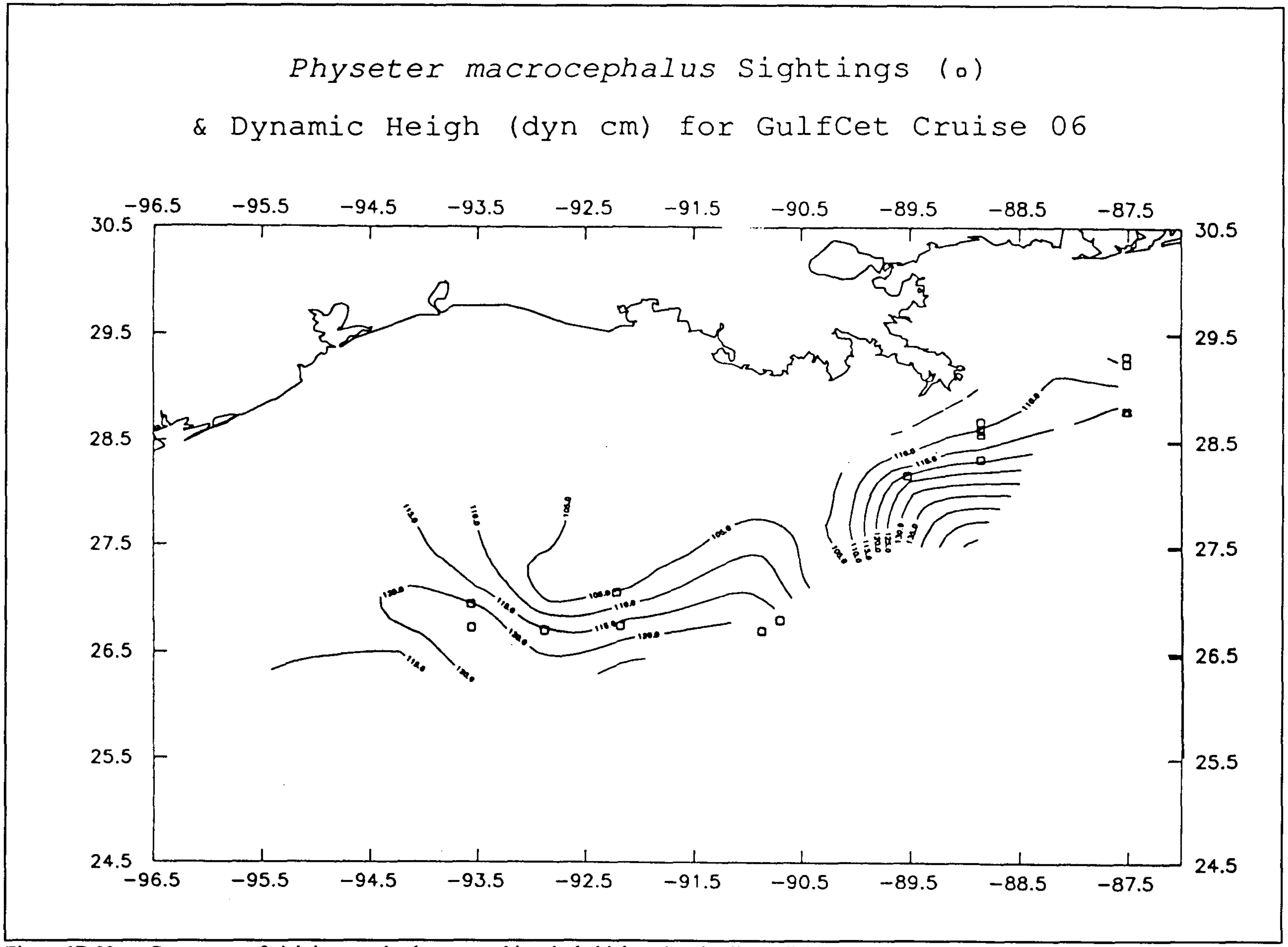


Figure 1D.22. Percentage of sightings vs depth ranges: historical shipboard and "all" available data.

Twenty-eight species of cetaceans have been observed in the GOM. Some of these species are historically rare or have become so as a result of human activities. The GOM is an area of intense human activity, especially in regard to ship traffic and exploration by the petroleum industry. There are over 600 drilling and production platforms in the northern Gulf, mostly located on the continental shelf. The degree to which these human activities impact marine mammals is largely unknown.

To find the depth ranges preferred by cetaceans at each historical and GulfCet sighting point, we extracted depth by longitude and latitude from a bathymetry database. Historical data came from sources including visual sightings from whaling ships (Townsend 1935), sightings from the Smithsonian Institution database prior to 1987, NMFS Pascagoula *Oregon II* sightings from 1990-1991, NMFS Pascagoula research vessel bridge log observations, (Jefferson & Lynn *in press*), D. Fertl's 1990 *Gyre* sightings, and other authors (see Jefferson, Leatherwood, Shoda, and Pitman 1992). Although we combined historical and GulfCet data, the amount of data was sufficient for analysis on only four of the cetacean species. These species were: *Physeter macrocephalus, Stenella attenuata, Stenella frontalis*, and *Tursiops truncatus*.

Figures 5 and 6 show the distribution of these four species based on bathymetry. The Gulf was divided into seven depth ranges and the percentage of sightings was calculated for each species in each range. The data showed that bottlenose dolphins and Atlantic spotted dolphins were found 80 percent of the time in water shallower than 500 m and on or near the continental shelf. Pantropical spotted dolphins and sperm whales were found 70 percent of the time in water deeper than 1,000 m, or over the continental slope and abyssal plan. The mean depths for these two groups are significantly different.

Further analysis will be completed next year and will provide additional insights into the habitats of cetaceans in the Gulf of Mexico.

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REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM SUPPORT FOR THE GULFCET PROJECT

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INTRODUCTION

NMFS-SSC is providing remote sensing and geographic information system (GIS) support for the project. The GIS will be used to integrate and analyze the various data types to explore possible relationships between the distribution and abundance of marine mammals and satellite and shipboard measurements of environmental variables in the Gulf of Mexico.

METHODS AND RESULTS

Support for Ship and Aircraft Surveys

Satellite images are being acquired and processed to provide environmental data concurrently with the shipboard and aircraft surveys during the two-year field effort. The data are collected by the Advanced Very High Resolution Radiometer (AVHRR) carried onboard the NOAA polar orbiting satellites. Each satellite provides partial or full coverage of the study area twice per day (one daytime and one nighttime overflight) depending on the orbital path and cloud coverage. The data are currently being obtained from both the NOAA-11 and NOAA-12 satellites. The National Environmental Satellite, Data, and Information Service (NESDIS) located in Washington, D.C. and the Naval Research Laboratory at Stennis Space Center are the primary sources of AVHRR data for the project. The satellite data are being processed into sea surface temperature (SST) images using the multichannel SST algorithms described by McClain *et al.* (1985), and rectified to fit the GIS base map described in a later section. Each SST image is also being processed into vertical (east-west), horizontal (north-south), absolute magnitude, and directions of SST gradients using 3 x 3 template masks configured as Sobel operators (Gonzales and Wintz 1976) and arithmetic overlay operations (Aronoff 1989). The visible channels of the AVHRR from daytime overflights are also being processed into turbidity images, primarily to examine the areal extent and location of edges of the Mississippi River plume, using the algorithm described by Stumpf (1992). Over 200 AVHRR images have been acquired for the study (through October 1993) and about 60 percent of the images have been processed into the SST and turbidity image products described previously. The satellite-observed environmental data, shipboard and aircraft observations of marine mammals, and environmental data collected aboard the vessels will be included as map layers in the GIS data base.

Support for the Whale Tagging Effort

Satellite images acquired during September-October 1992 were selectively processed into SST images and provided to colleagues at Oregon State University (OSU) attempting to place satellite tracking tags on sperm whales in the northern Gulf of Mexico. A total of three SST images were processed during the two-week field effort and transferred to OSU using Internet. A public domain image processing package described by Leming (1989) that operates on a minimally-equipped personal computer was also provided to enable the OSU investigators to display the images in color and perform simple image manipulation tasks.

The second field effort to tag sperm whales for the project was conducted in June 1993. NMFS-SSC again supported the OSU investigators by providing satellite-observed SST images and a PC-based satellite image display program developed by Miller and

DeCampo (in press) available through the NOAA CoastWatch Program.

Infrastructural Improvements

There were a number of infrastructural improvements within the last year at NMFS-SSC that will directly benefit the GulfCet effort but were completed at no cost to the project. An Internet communications link became fully operational and will enable investigators at NMFS, TAMUG, and OSU to rapidly transfer data (particularly digital maps) back and forth. The personal computers that will be used to support the project have been linked through a local area network and have been upgraded from an MS-DOS operating environment to an OS2/Windows environment. The CoastWatch Program became fully operational in December 1992 and is available as a secondary source of satellite observed SST images for the project. Major software improvements were completed for an AVHRR receiving station last year to streamline day-to-day operations of the unit. In addition to CoastWatch, the station will serve as a backup source for satellite data.

GIS Computer Hardware and Software

The GIS hardware consists of a Silicon Graphics UNIX workstation and peripherals; software is the Advanced Geographic Information System (AGIS)[1]. Other GIS software operating on the SG system includes the Science and Technology Laboratory Applications Software (ELAS)[2] (Beverly and Penton 1989) and WAVE[3]. Although all of the data base development and most of the analyses will be conducted with AGIS, ELAS and WAVE contain complementary software tools that may be useful for analyzing and displaying data.

GIS Base Map Coordinate System

All of the digital map layers used in the GIS data base will be registered to a portion of the Gulf of Mexico master image (GMMI) that includes the GulfCet study area and thus encompasses the area from 25.5° to 31° N latitude and 87° to 98° W longitude. The GMMI is a raster image consisting of three land cover classes: land, water, and land pixels adjacent to water (coastline). The coastline was generated from vector data reformatted from the Digital Chart of the World (U.S. Defense Mapping Agency 1992), a public domain data set released in 1992. The master image is earth located with longitude/latitude coordinates using a simple cylindrical projection (linear longitude/latitude) system (Snyder 1987). The dimensions of each pixel in the GMMI are 0.01° longitude by 0.01° latitude. Longitude and latitude coordinates are being collected concurrently with the cetacean survey observations from aircraft and vessels and with shipboard measurements of environmental variables using Global Positioning System (GPS) or LORAN-C receivers. These earth-located data will later be converted to AGIS map layers and stored as either raster or vector files.

Acquisition of Other GIS Data Sets

In addition to the satellite, survey, and environmental data being collected for the project, other public domain GIS data sets available from the Minerals Management Service and U.S. Geological Survey were tentatively identified for use in the GulfCet data base. These include coastlines, offshore oil field structures, oil and gas lease blocks, boundary of the U.S. Exclusive Economic Zone (EEZ), bathymetry, state and international boundaries, and sea floor maps from the Geological Long-Range Incline Asdic (GLORIA) data.

Raster vs. Vector Data Models

Some of the map layers tentatively identified for use in the GIS data base can be stored as raster or vector data files. The GIS software currently available, with the exception of AGIS, will store and analyze raster

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[1]AGIS is a proprietary GIS software package developed and marketed by Delta Data Systems, Inc., 131 Third Street, Picayune, MS 39466.

[2]ELAS is public domain software developed by the National Aeronautics and Space Administration and is available from the repository for government software maintained by the Computer Software Management and Information Center, The University of Georgia, 382 East Broad Street, Athens, GA 30602.

[3]WAVE is a proprietary data visualization and analysis software package developed and marketed by Visual Numerics, Inc., 9990 Richmond Avenue, Suite 400, Houston, Texas 77042-4548.

or vector maps, but will not handle both data types simultaneously. Thus, depending on the software, mapping projects initiated with both types of data files require conversion from one form to the other, i.e., raster to vector or vector to raster prior to data basing and analysis. If a large number of layers have to be converted for a particular project, the process can require a significant amount of machine and staff time.

Although the AGIS data base supporting GulfCet could contain a mixture of both map types, two important operational concerns have to be considered. First, the vector model is a more compact data structure than the equivalent map stored in a raster form (Aronoff 1989). Since most of the data volume in the GulfCet data base will consist of raster maps (primarily satellite-observed data), there may be slight advantage in storing other data layers (e.g., shipboard measurements of salinity) as vector maps. However, online mass storage requirements for the project were carefully considered when drafting the specifications for the UNIX workstation. The 4.7 gigabytes of online storage (two hard drives and two optical drives) should provide ample room to store and analyze either a mixture of raster and vector maps or all of the data as raster maps. The second and primary operational concern may be processing speed; certain GIS analysis functions, e.g. overlay operations, are more efficiently implemented with raster maps than with vector maps (Aronoff 1989). Some benchmarking will be conducted to compare processing speeds of identical GIS tasks operating on (1) a mix of raster and vector maps and (2) the same maps converted to raster files. Subject to the outcome of the evaluation, it may be more advantageous to convert all of the maps to the raster domain given the anticipated volume of data that will have to be processed for the project.

Processing Protocol

The GIS will be used for qualitative analysis of data structure by using such functions as retrieval and classification and logical operations to create interactive map displays, tabular summaries, and data plots in an effort to visualize relationships between the distribution and abundance of cetaceans and satellite and shipboard measurements of environmental variables. The dimensionality of the data, i.e., the potential number of input variables for multivariate statistical analysis, is expected to be large since GIS analysis tools such as proximity measures will enable analysts to explore the data in ways that would be virtually impossible using conventional analysis methods. The initial exploratory analysis will be followed by a more formal, quantitative analysis of the data using multivariate statistical techniques. Variables to be used in the analysis will be exported from the GIS to one or more statistical software packages: (1) the Statistical Analysis System (SAS)[4] offering a wide range of univariate and multivariate statistical procedures; (2) the Cornell Ecology Programs[5] provide cluster, detrended correspondence analysis, and ordination techniques for ecological research (Gauch 1982); and (3) SpaceStat[6] spatial analysis software (Anselin 1992).

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SATELLITE-MONITORED RADIO TAGGING OF SPERM WHALES IN THE GULF OF MEXICO GULFCET TASKS 5 & 6

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OBJECTIVES

The Minerals Management Service (MMS) funded the GulfCet study to determine the seasonal abundance, distribution and behavior of marine mammals in the Gulf of Mexico. Oregon State University (OSU) was contracted to develop depth-sensing radio tags to tag and track sperm whales in the Gulf. The data could be used to determine areas and depths used by sperm whales.

INTRODUCTION

Very little is known about the population of sperm whales in the Gulf of Mexico. Much of our knowledge of numbers and distribution comes from aerial and shipboard surveys (Collum and Fritts 1985; Mullin *et al.* 1991). Participants of a 1989 workshop sponsored by the Minerals Management Service (MMS), "Sea Turtles and Marine Mammals of the Gulf of Mexico," considered the sperm whale to be the most common endangered cetacean in the Gulf. It was proposed that, given their size, even a small resident population would play an important role in the ecosystem of the Gulf (Tucker & Assoc. 1989). At one time, the Gulf of Mexico was a whaling ground for the sperm whale (Gosho *et al.* 1984), but much of the information on catches there has been lumped with data from the southeastern Atlantic.

Collum and Fritts (1985) reported the results of aerial surveys and opportunistic shipboard sightings of sperm whales in the Gulf of Mexico from 1979 to 1981. A total of 59 animals were seen (47 presumed adults or sub-adults and 12 calves). Sperm whales were seen in water 104 m to 2,742 m deep, and in waters over areas of high productivity such as the edge of the continental slope. They proposed that these areas could attract cephalopods, the main prey of sperm whales, and thus influence the distribution of sperm whales in the Gulf.

Mullin *et al.* (1991) used aerial surveys from 1989 to 1990 to study cetaceans along the upper continental slope off the Mississippi River delta. Sperm whales were the second most common cetacean sighted during their transects. They sighted 43 herds ranging from one to 11 whales, for a total count of 91 animals. As with Collum and Fritts (1985), most sightings were in the fall months. In general, the sperm whales seen in this survey were concentrated near the Mississippi River delta in water greater than 600 m deep, and most often in 900 m to 1,200 m water. One whale was sighted in water 2,392 m deep. Mullin *et al.* (1991) believe that their estimates of sperm whale abundance were too low because of the whales' long dive times relative to the aircrafts' time over the survey areas.

TAG DEVELOPMENT

Satellite-monitored (Argos) tags that collect depth information were developed using assemblies from Telonics (Mesa, AZ) and Wildlife Computers (Woodinville, WA). OSU developed the packaging, attachments and software. The tags were successfully tested on ten bowhead whales in the fall of 1992 under MMS funding, Alaska office (Mate and Krutzikowsky 1993).

CRUISE CHRONOLOGIES

Three cruises were undertaken in support of the tagging effort. The first cruise was conducted from 30 September-14 October 1992. Of four and a half days at sea during this time, we only encountered sperm whales once, on 9 October. During four hours we saw eight to 10 whales. They demonstrated little reaction to the vessel and produced no alarm responses when the vessel approached within eight meters. The charter vessel, the R/V McGrail, was built for higher speeds and did not maneuver well at the slow speeds required for closer approaches.

The second cruise was from 20-31 March 1993, aboard the R/V Odyssey, a 92' sailing vessel owned by the Whale Conservation Institute. OSU sponsored this expedition as a 'proof-of-concept' for future tagging efforts in the Gulf. MMS contributed three tags to this effort. After several days of searching visually and acoustically, 200+ sperm whales were found and tracked for an additional five days and nights. We were able to approach whales closely while using the diesel auxiliary engine. There was no flight response although the whales frequently moved abruptly out of the way of the vessel when the shadow of the boat passed over them or when it came within three meters. On 26 March we applied a satellite-monitored radio tag to a sperm whale. The tag was approximately 0.5 meters from the dorsal ridge of the animal. The deployment appeared to be complete, and there was no startle or flight response by the animal. Unfortunately, no information was returned via satellite from this tag. As the tag had been tested to pressures in excess of 2,000 meters and the same type of tags were very successful on Arctic bowhead whales in 1992, we are at a loss to determine why we did not hear from this animal. Of two other tagging attempts, one glanced off the back of the animal's mid-dorsal ridge and one missed by a few centimeters. Both tags were lost.

The third cruise took place from 6-29 June 1993 in the Gulf of Mexico. Survey efforts were concentrated in an area within 100 kilometers south and east of the Mississippi delta. We were aboard the 58' R/V Acadiana, chartered from LUMCON (Louisiana Universities Marine Consortium). We were able to work at sea for 14 of the 24 days. During the course of the charter, we covered 2,331 kilometers of search track line. We surveyed for sperm whales both visually and acoustically. We sued hydrophones from sonabuoys to determine whether whales were present in the survey area. We stopped approximately every 10 miles (based on an effective hydrophone range of five miles) along our track to listen. Two observers were on watch during daylight hours.

RESULTS OF THE THIRD CRUISE

A total of approximately 90 sperm whales were seen during the course of our third cruise. Animals were sighted seven of 14 days at sea and heard on 11 days. On the days whales were sighted, four to 22 individuals were seen. On average, whales were seen at a rate of 0.04 whales per kilometer of track line. Distribution of animals was very patchy. We regularly found animals in an area 70 - 100 km directly east of the southern tip of the Mississippi delta.

The whales we found were surprisingly small; only two were slightly more than eight meters long. This is atypical of sperm whale school structure (see Best 1979). An examination of stranding data supplied by Jim Mead of the Smithsonian Institution suggested that sperm whales in the Gulf are as large as those found elsewhere in the world. We do not think that this was an example of a naturally small-sized population but believe that we were seeing mostly subadult animals. On several occasions we remained in areas with these small whales for several hours but never saw larger animals arrive or surface.

We tagged two sperm whales during this cruise. A satellite-monitored depth-sensing tag was applied to an 8 m animal on 7 June 1993. The tag was applied near the dorsal ridge but was very poorly attached. One message was heard from this tag shortly after deployment. Combined with our previous experience in the Galapagos, when an attempt to tag in this region of the back resulted in a deflected tag, we now conclude that the dorsal ridge is particularly tough and an area we will avoid in future tagging attempts. We are also concerned that with small animals,the dorsal ridge may not provide sufficient blubber depth for the anchoring mechanisms.

The second tag was developed by OSU for the Office of Naval Research (ONR) and provides location only information. It was applied on 11 June to a 7 m sperm whale. This tag was designed to be virtually implantable. The positioning of this tag was good but attachment was incomplete. Specifically, the penetration was not sufficient to engage wires used as the hold-down mechanism. We believe that this tag, too, was lost very soon after tagging.

During the latter half of our cruise, a seismic vessel, the Acadian Commander, and its backup vessel were in the area in which we had regularly found sperm whales, preparing to start a month-long seismic survey. There operations began on 23 June. During the first two days of their operations, sperm whales were not seen within the active seismic area but only around the periphery. From 25-29 June we surveyed this same area intensively and found no whales in the seismic area and only four whales in 920 km of searching. This sighting rate of 0.004 whales/km was an order of magnitude less than the overall average prior to the initiation of seismic surveying. Within the seismic area, whale abundance changed significantly from a pre-seismic abundance of 0.092 whales/kilometer (Figure 1D.23) to 0.038 whales/kilometer during the first two days of seismic survey activity (Figure 1D.24) to 0 whales/kilometer on days three through seven after seismic operations began (p-value <.001, Figure 1D.25). While we do not view the observations we have made to be proof of a cause-and-effect relationship, the significant correlation of these events suggests that further investigation into the potential effects of seismic surveying on the movements and distribution of sperm whales is warranted.

SUMMARY OF FINDINGS TO DATE

- Sperm whales in the slope-edge waters off Alabama and Mississippi in the Gulf of Mexico have a patchy distribution.
- Animals observed near shore (<100 km from shore) were small and considered to be juveniles.
- Sperm whales exhibited no overt signs of disturbance when closely approached by diesel vessels.

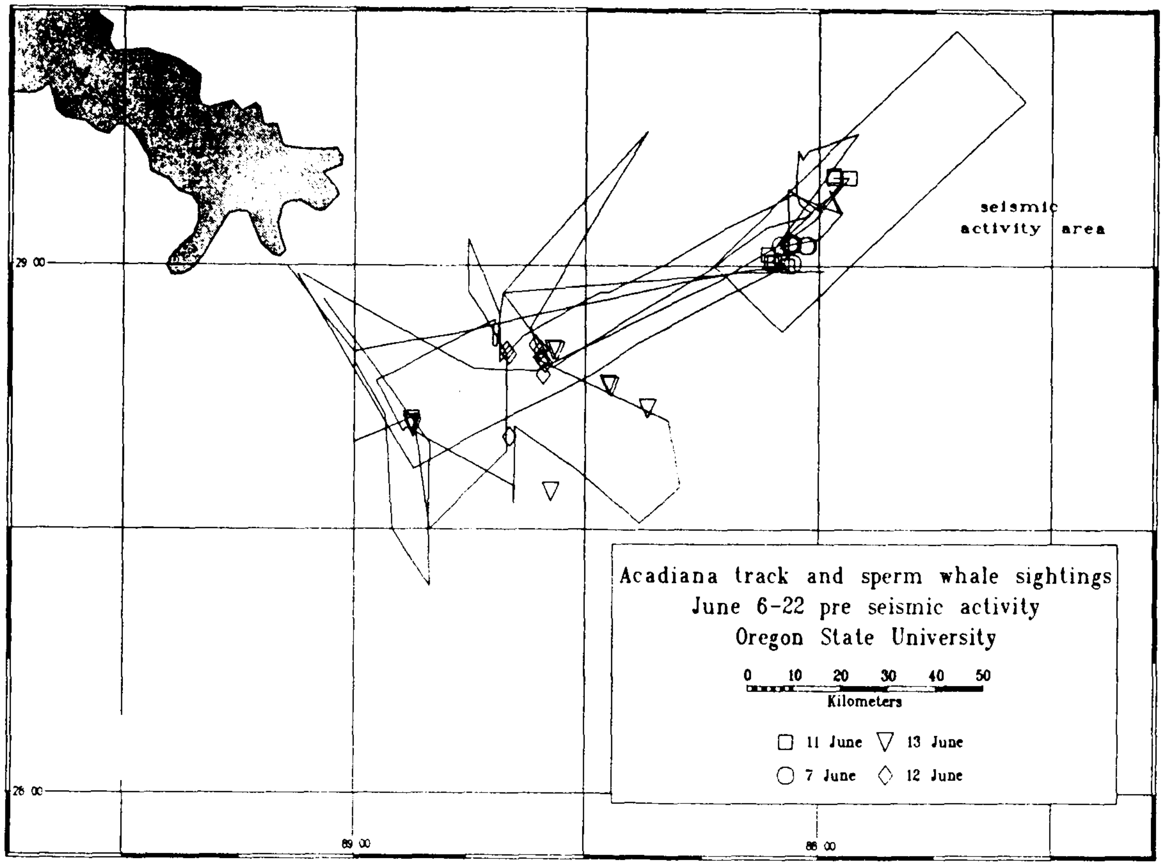

Figure 1D.23. R/V Acadiana track and sperm whale sightings 6-22 June.

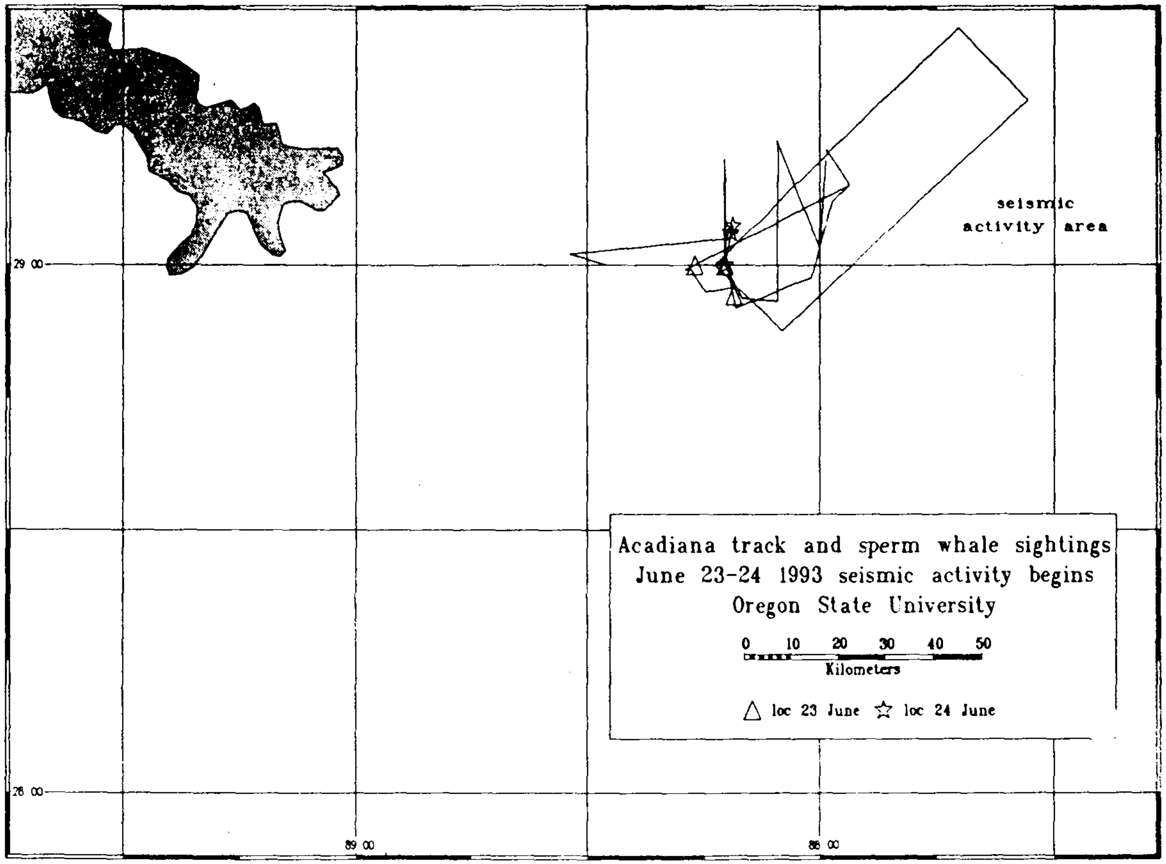

Figure 1D.24. R/V Acadiana track and sperm whale sightings 23-24 June.

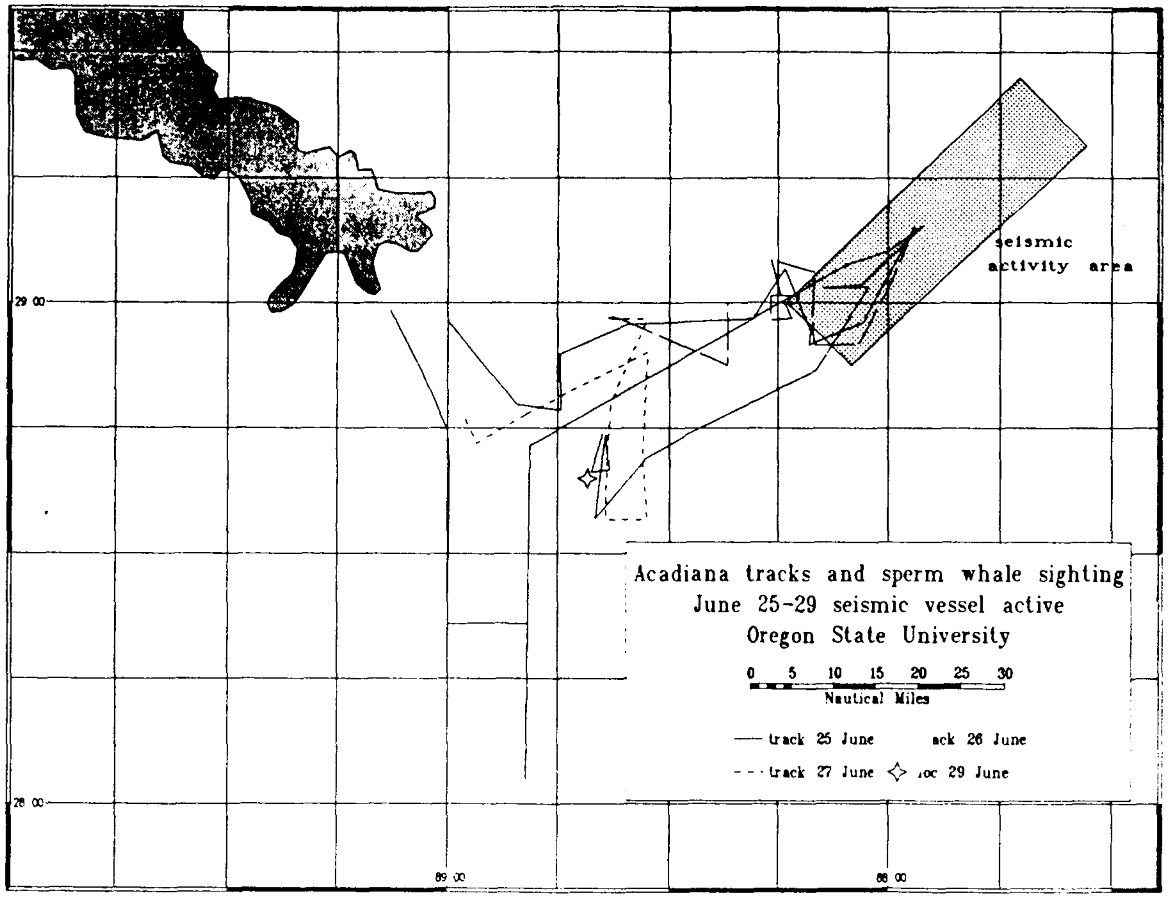

Figure 1D.25. R/V Acadiana track and sperm whale sightings 25-29 June.

- Tag deployment appeared satisfactory when a tag was placed away from the dorsal ridge.
- Active seismic survey vessels may affect the movements and distribution of sperm whales.

FUTURE GOALS

OSU will sponsor an additional field effort on sperm whales in the Galapagos during January-February 1994. We hope to deploy two of each of the depth-sensing and location-only tags. The latter will be modified for a surface attachment, and will have 75 percent less frontal drag than the former. The remaining MMS funds from the GulfCet program will be augmented by OSU Foundation monies to provide a third expedition to tag sperm whales in the Gulf of Mexico.

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Dr. Bruce Mate is a professor of Fisheries and Wildlife at the Hatfield Marine Science Center, Oregon State University. He has studied marine mammals for 25 years and has specialized in the development of technology to track and access behavior of pinnipeds, cetaceans and sirenians. His areas of interest include distribution, behavior, migration and ecology of marine mammals.

Kathleen Stafford is a graduate student at Oregon State University. She has studied sperm whales in the Gulf of Mexico and the Galapagos. Her areas of research interests include dive behavior of sperm whales and acoustic behavior of blue whales.

SESSION 2A

OIL SPILL RESPONSE I

Session: OIL SPILL RESPONSE I

Co-Chairs: Ms. Gail Rainey and Mr. Gary Rutherford

Date: December 15, 1993

Presentation	Author/Affiliation
Introduction	Ms. Gail Rainey Minerals Management Service Gulf of Mexico OCS Region
Document not submitted	Captain Jim Calhoun Eighth Coast Guard District
Document not submitted	Field Operations Representative Minerals Management Service Gulf of Mexico OCS Region
Document not submitted	Mr. Bill Cook Minerals Management Service Headquarters
Document not submitted	Mr. Tim Hebert Louisiana Oil Spill Coordinator's Office Mr. Tim McKenna Texas General Land Office Ms. Debra Prebles Florida Office of Coastal Protection

SESSION 2B

UNIVERSITY RESEARCH INITIATIVE PROGRESS REPORTS I

Session: UNIVERSITY RESEARCH INITIATIVE PROGRESS REPORTS I

Co-Chairs: Dr. Robert Rogers and Dr. Paul W. Sammarco

Date: December 15, 1993

Presentation	Author/Affiliation
University Research Initiative Progress Reports	Dr. Robert Rogers Minerals Management Service Gulf of Mexico OCS Region Dr. Paul W. Sammarco Executive Director Louisiana Universities Marine Consortium
Characterization of Chronic Sources and Impacts of Tar Along the Louisiana Coast	Mr. Charles B. Henry, Jr. Ms. Paulene O. Roberts Dr. Edward B. Overton Institute for Environmental Studies Louisiana State University
Degradation of N-, O-, and S- Heterocycles (NOSHs) in Marine Sediments: Pathway Studies Using Deuterated Tracers	Dr. W. James Catallo[+] Dr. Thomas Junk[++] Dr. Robert P. Gambrell[+] [+]Wetland Biogeochemistry Institute ++Hazardous Substance Research Center Louisiana State University
Experimental Investigation of the Effects of Aromatic Hydrocarbons on a Sediment Food Web	Dr. Kevin R. Carman Dr. John W. Fleeger Department of Zoology Louisiana State University Dr. Jay C. Means Veterinary Physiology Pharmacology & Toxicology Louisiana State University
Hypoxia Vs. Production Activities: Which Influences the Benthic Community?	Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium
Satellite Observations of Average and Extreme Mississippi River Plume Circulation Events	Dr. Nan D. Walker Coastal Studies Institute Louisiana State University

UNIVERSITY RESEARCH INITIATIVE PROGRESS REPORTS

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

Dr. Paul Sammarco
Executive Director
Louisiana Universities Marine Consortium

This session was introduced by Dr. Paul Sammarco, the Executive Director of the Louisiana Universities Marine Consortium (LUMCON) and program manager for the MMS/LUMCON University Research Initiative (URI). The URI is a university-based research program emphasizing the long-term environmental and socioeconomic effects of offshore oil and gas development, one based in the Gulf of Mexico region and the other in California. The purpose of this program is to 1) strategically increase emphasis on long-term effects within the MMS Environmental Studies program, and 2) expand the involvement of universities in the program, while stimulating innovative research and training students in areas relevant to effects of oil and gas development.

The Gulf of Mexico URI was initiated on 1 June 1989 through cooperative agreement with LUMCON. The MMS contract was awarded as a five-year, $2.5 million agreement providing for cost sharing by Louisiana (or other participating) universities. Projects proposed by university researchers were selected for funding following a review and approval process patterned after that of the National Science Foundation. Research projects under this program complement MMS' larger, multi-investigator studies within its Environmental Studies Program by enhancing understanding of important impacts, providing technological innovation, and testing concepts which ultimately may be addressed by larger MMS programs.

The URI continues into its fifth year with a total of 22 projects having been awarded. Eleven projects have been completed with final reports approved and distributed. Eleven other projects are ongoing in various stages of completion. Three new projects were awarded during the summer of 1993.

The objective of this session within the MMS Information Transfer Meeting (ITM) was to report on the progress of eight ongoing environmental projects. A number of other URI socioeconomic studies were presented in a parallel session emphasizing current and recent social studies.

As an integral part of this session, a workshop was held emphasizing the evolution of the URI program and recommendations regarding possible future related programs. The workshop centered on improvements that could be made in the URI approach to environmental studies. Discussions included whether the original framework issues were still valid and how they might best be addressed by URI researchers. Other discussions centered on the optimal length of time recommended for proposal preparation, the adequacy of funding levels, timings on release of Request for Proposals (RFPs), composition of the Technical steering Committee the value of and need for quarterly progress reports, and streamlining administrative procedures.

Dr. Paul Sammarco is the Executive Director of LUMCON. His major research interests include coral reef ecology, chemical ecology, bioerosion, larval dispersal and recruitment processes and stable isotope geochemistry. He received his B.S. in Zoology from Syracuse University in 1970 and Ph.D. in 1977 from State University of New York at Stony Brook. His research centered on the effects of grazing as a controlling factor on coral reefs. Dr. Sammarco has been involved in research in Australia and served as Director of Environmental Research for the Resource Assessment Commission, the Prime Minister's special commission on key natural resources and related environmental issues in Australia.

Dr. Robert Rogers is an oceanographer with the Environmental Studies Section, MMS, Gulf of Mexico OCS Regional Office. He 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. His research interests have included the ecology of coastal meiobenthic organisms and trophic interrelationships. He has been involved in the MMS/Bureau of Land Management Environmental Studies Program since 1977.

CHARACTERIZATION OF CHRONIC SOURCES AND IMPACTS OF TAR ALONG THE LOUISIANA COAST

Mr. Charles B. Henry, Jr.
Ms. Paulene O. Roberts
Dr. Edward B. Overton
Institute for Environmental Studies
Louisiana State University

At the current rate of oil transportation in the Gulf of Mexico, when oil spills occur it is not a simple case of petroleum found upon the shores from the spill incident. Stranded oil and tar balls are frequently deposited along the southern coast of Louisiana, without the cause and effect relationship of a reported petroleum release. Many potential sources of accidental or illegal discharges exist. The petroleum transportation off Louisiana shores ranges in the millions of barrels, with the Louisiana Offshore Oil Port (LOOP) receiving more than 200 million barrels per year. Also contributing to this transportation system are the Outer Continental Shelf production activities, transporting 98 percent of their production by pipeline and 2 percent by barge. Illegal bilge cleaning and dumping and oil seeps may also add to the tar along Louisiana beaches. The distribution, frequency, and composition of this stranded oil was assessed at nine study sites, covering an approximate range of 200 miles along the Louisiana coastline.

OBJECTIVES

This study presents preliminary values for a baseline estimate of the chronic oiling of Louisiana beaches. We hope that this survey will provide a better understanding of coastal impacts related to oil production and transportation in the Gulf of Mexico. The objectives for this study included the following:

1. To assess the abundance, distribution, and composition of stranded oil and tar at nine stations along the South Louisiana coast.

2. To investigate tar balls collected for specific source-biomarkers and source-indexes by a detailed GC/MS source-fingerprint technique to identify related sources. We tried todetermine the sources of the stranded oil and tar found upon the beaches and whether they are caused primarily by small unrelated events or by chronic discharges from identifiable sources.

DESCRIPTION

Nine study sites were selected in the spring of 1992 along the southern coast of Louisiana (Figure 1). These stations were 50 meters wide, running parallel to the beach face and covering the distance between Grand Isle on the east to Martin's Beach on the west, approximately 200 miles. The stations were sampled in the spring and fall for petroleum deposition. The samples found within the stations were removed and taken to LSU for morphological characterizations and GC/MS analysis.

STUDY RESULTS

There was no statistical difference between the spring and summer periods, indicating a constant deposition and removal of petroleum. The visual appearance of the petroleum was 80 percent black and pliable; with 10 percent brown and the remaining 10 percent various colors of petroleum products. The gross number of tar balls for the various stations and average weight distribution per meter indicated a greater petroleum abundance for the western stations. A total of 480 samples were collected in the west compared to 48 in the east and can be expressed as 40 tar balls/station in the west compared to 9.6 tar balls/station in the east. Between the backshore and foreshore beach zones, there were more tar balls collected in the upper beach region than the lower with 18.8 backshore tar bars/station compared to 12.2 foreshore tar balls/station. A total of 4,416.42 g were collected in the west compared to 627.65 g in the east during the Spring 1992 sampling period. A similar trend was observed during the Summer 1992: 4,573.6 g in the west compared to 125.2 g collected in the east. In comparison to other shoreline studies within the Gulf of Mexico, the concentration of tar balls along the Louisiana coast was low. The range of stranded tar as reported in g/m for the Wider Gulf of Mexico Region was 0 to 4,366.61 g/m (the highest value was reported in Discovery Bay, Jamaica by Jones 1990); during our study, the quantity of tar collected ranged from 0.53 to 47.77 g/m. If the estimated threshold concentration of 100 g/m is considered a good guide in determining the degradation of beaches for tourist purposes, the beaches studied were below a level of social-economic concern, although any stranded oil on a

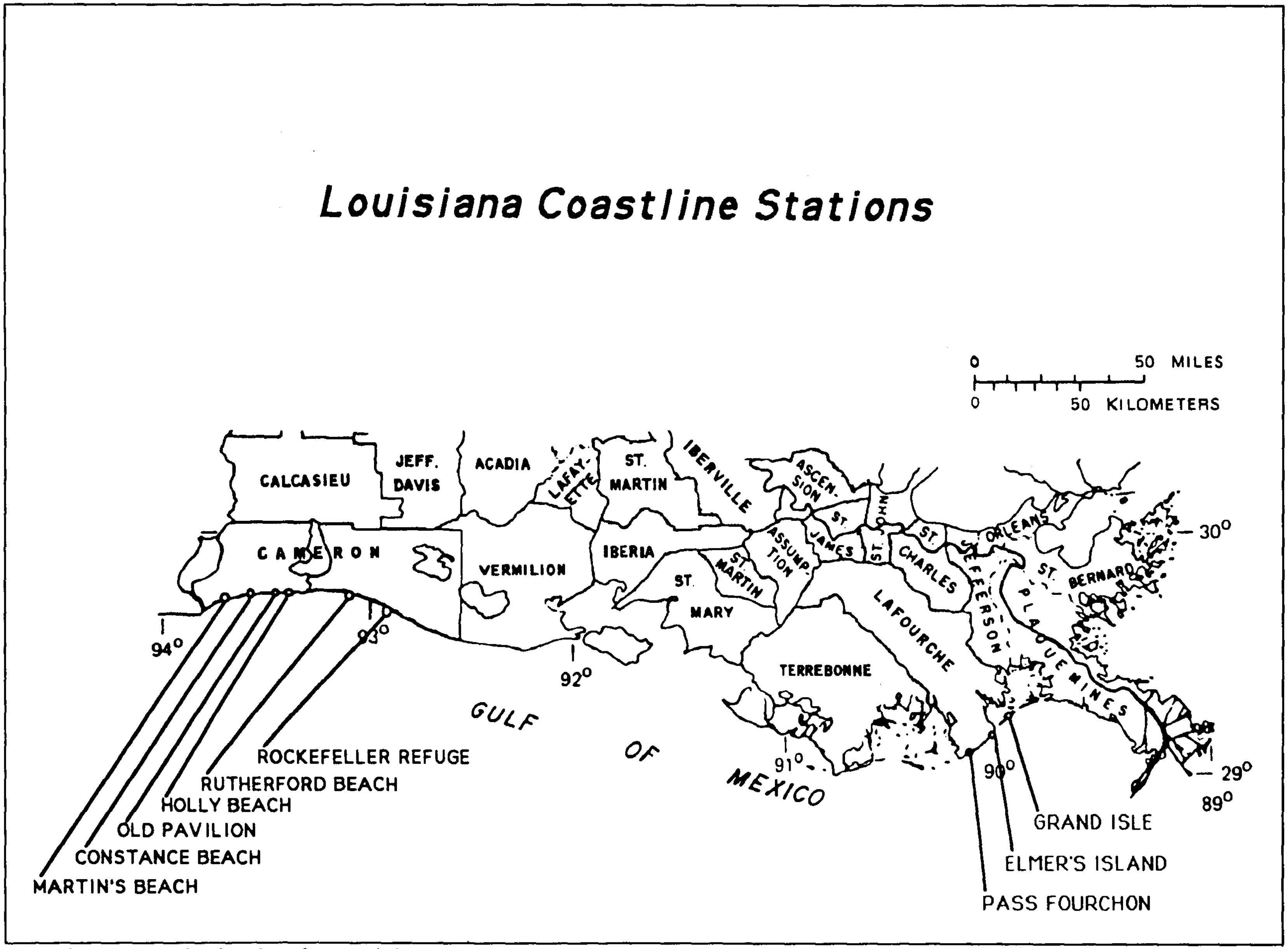

Figure 2B.1. Station locations for stranded oil and tar survey, 1992.

Table 2B.1. Classification comparison for total sample population analyzed.

	No. of Samples*	% of Total
Relatively unweathered:		
high aromatic	6	5
high paraffin	38	32
bimodal wax	7	14
Weathered:		
high aromatic	17	14
high paraffin	2	2
bimodal UCM	2	2
bimodal wax	20	17
bimodal UCM and wax	3	3
Unclassifiable	23	19

*n=118

beach is aesthetically unpleasant and the presence of oil reduces the value placed on that beach as a resource.

Of the 118 samples analyzed by detailed GC/MS, 32 percent were indicative of high pour point, heavy oils (most likely bunker or heavy heating oils), closely followed by tanker washings or sludge discharges at 26 percent. Therefore, greater than 50 percent of the samples collected can be associated with transportation activities. The persistence of the spilled heavy petroleum oils, enriched with asphaltene and high molecular weight residuum hydrocarbon components was considered greater than for many crude oils and light refined petroleum products. Often, light oils spilled in the marine environment spread very thin on the water's surface and disperse by natural processes, such as storms, never forming tar balls. Heavy oils, which are more viscous and less affected by physical processes, persist longer. Microbial degradation, the ultimate fate of most tar balls in the marine environment, is limited by the available surface area of the petroleum and by the recalcitrant petroleum constituents.

Source-fingerprinting by manual comparison of the available GC/MS data was effective in identifying 66 different sources from a sample population of 118. Cluster plot analyses are effective in screening a large population of GC/MS data to determine which samples may be related. The possible matches would then require confirmation by a qualitative comparison of all chromatographic data. Mathematical, or statistical, techniques were limited by the lack of replication and range in index values. The use of statistical principal component analyses my provide a higher degree of separation of suspected sources. More work is required to fully develop a statistical approach to source-fingerprinting.

Several of the sources appear to be derived from the discharge of tanker washings containing crude oil and high molecular weight paraffins. Biomarker signatures typical of Middle East and Alaskan North Slope crudes have been identified in the tar balls analyzed. This is not surprising since approximately 30 percent and 8 percent, respectively, of the crude oils transported into the Northern Gulf of Mexico are from these two sources.

SIGNIFICANT CONCLUSIONS

There existed an extreme difference in petroleum distribution, with 9.6 tar balls per 50 meter station in the east compared to 40 tar balls per station for the west. The samples collected from these stations were analyzed by detailed GC/MS and compared for similarities using a source-fingerprinting data synthesis process. The data indicates a wide range of petroleum sources with unweathered high paraffin heavy oil and weathered oil with a bimodal wax component as the most abundant. The latter are generally associated with bunker and crude oil washings or sludge discharges and represented 26 percent of the tar balls analyzed. An assessment by detailed GC/MS characterization and source fingerprinting utilizing selective ion monitoring (SIM) was completed for 124 of the 528 samples collected. The results indicated 18 sources with multiple occurrences and 47 unrelated sources of which 55 percent of the samples were sourced from the 18 multiple sources and 45 percent from the unrelated sources.

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Charles B. Henry has been a Research Associate at the Institute for Environmental Studies, Louisiana State University for nine years. His research activities involve environmental pollution issues for coastal regions, specifically oil spill mitigation and cleanup techniques, tracking and identifying oil sources by 'source-fingerprinting'. Mr. Henry received his B.S. in Environmental Science from Louisiana State University in 1985.

Paulene O. Roberts is a Research Associate at the Institute for Environmental Studies, Louisiana State University. Her current research areas are in GC/MS analytical techniques and oil degradation processes. In 1990 she received her B.S. in Chemistry from the University of Alaska, Anchorage.

Dr. Edward B. Overton has been Director of the Institute for Environmental Studies at Louisiana State University for seven years and Professor of Chemistry for 23 years. Rapid high resolution analytical techniques involving field portable instruments are his research interests. He has been an active participant in major oil spill and chemical incidents in the coastal environments and has acted in an advisory capacity to NOAA's Hazardous Materials and Response Assessment Division. Dr. Overton received his B.S. and Ph.D. form the University of Alabama.

DEGRADATION OF N-, O-, AND S-HETEROCYCLES (NOSHs) IN MARINE SEDIMENTS: PATHWAY STUDIES USING DEUTERATED TRACERS

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[++]Hazardous Substance Research Center
Louisiana State University

INTRODUCTION

The purpose of this work was to examine degradation rates and pathways of N-, O-, and S- heterocycles (NOSHs) in marine sediments. NOSH compounds are found in petroleum, produced waters, coal chemicals, and pyrogenic mixtures [1]. Several NOSHs and their oxidation products are mutagenic, carcinogenic, and/or teratogenic [1, 2].

Relative degradation rates were determined for prominent NOSH compounds (Figure 2B.2) under oxidized (aerobic) and reduced (anaerobic/methanogenic) electrochemical conditions in three marine sediments. In the course of work, degradation pathways for several NOSHs were inferred from analysis of transformation products using gas chromatography-mass spectrometry (GC-MS). Sediment microbes capable of degrading NOSHs were isolated during these experiments.

To facilitate accurate identification of the NOSH degradation products, methods were developed to synthesize several compounds in deuterated form for use as tracers.

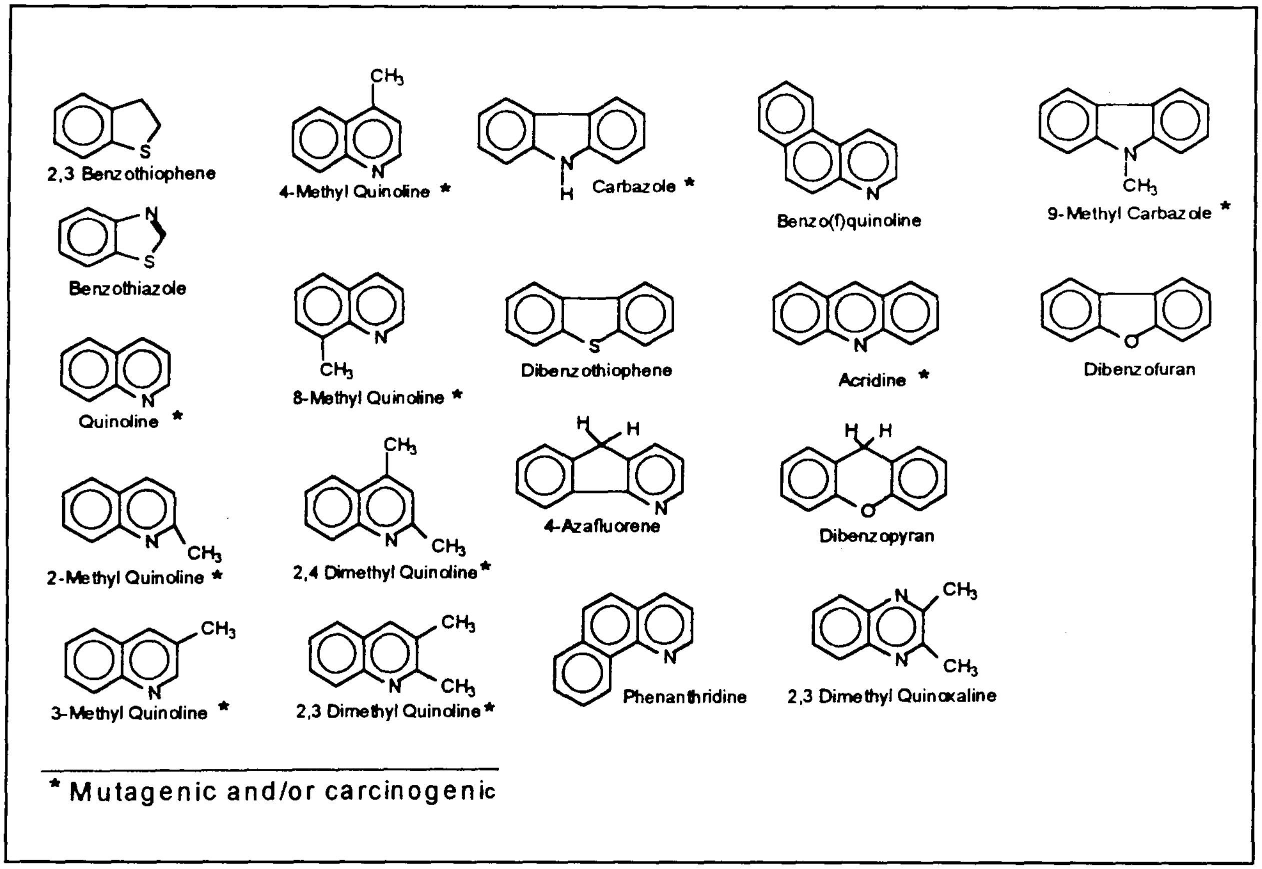


Figure 2B.2. NOSH Compounds Examined in This Work.

DEGRADATION OF NOSHs

The relative rates of NOSH degradation were examined in three marine sediments of different grain sizes: i.e., clay (< 2 um i.d.), silt (2-16 um) and sand (> 16 um). These sediments were maintained under oxidized (+150 - +270 mV vs. SCE) or reduced (-250 - -500 mV vs. SCE) electrochemical conditions in microcosms, and the rate of NOSH degradation was monitored over time using gas chromatography (GC) and GC-MS. It was expected that differences in grain size and redox conditions would alter observed NOSH degradation rates.

Data in Figure 2B.3 show the linear and sigmoidal degradation profiles typical of the NOSHs examined. In general, relative degradation rates were influenced by electrochemical conditions and grain size: oxidized sand > oxidized silt > reduced sand >/= oxidized clay > reduced silt >/= reduced clay.

MICROBES

Microorganisms were collected from the microcosms after acclimation periods (196 - 700 h) and grown in liquid buffers on mixed and single NOSHs as substrates. Cultures showing growth and metabolic activity (increased optical density and iodonitrotetrazolium reduction) were examined using visible and scanning electron microscopy. The NOSH-degrading microbial community was comprised of facultative anaerobes and aerobes including at least one *Psuedomonas sp.*, a *Bacillus sp.*, a filamentous bacterium (probably *Nocardia sp.*) and, in some cultures, a filamentous fungus. The metabolic specificity of this community was broad: the microbes were able to degrade mixtures of aromatic and polycyclic hydrocarbons and NOSHs (e.g. carbon black).

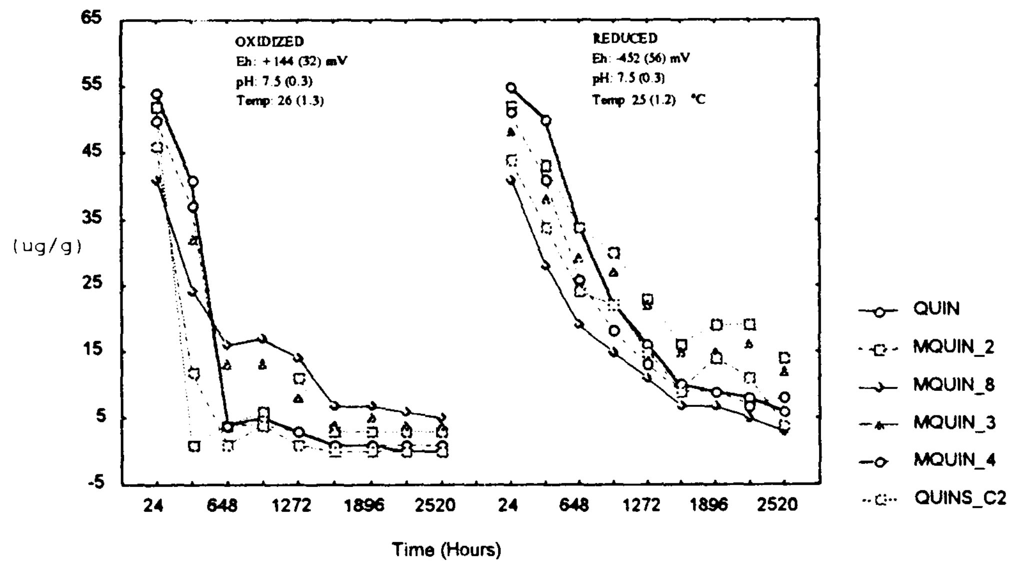


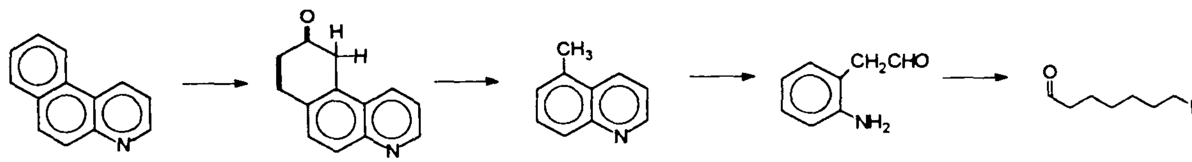
Figure 2B.3. Degradation of Quinoline and Alk Homologs in Oxidized and Reduced Marine Sand.

NOSH DEGRADATION PRODUCTS

To characterize the degradation of NOSHs by the microbial community, metabolic pathway studies were conducted on representative compounds vs. killed controls. Quinoline and other light azaarenes were metabolized with accumulation of few intermediates. Other compounds, e.g., benzothiazole and phenantridine were degraded sequentially, with accumulation of stable products in the medium (Figure 2B.4).

In general, product determination became more difficult as degradation of the NOSH compounds proceeded. This was due mainly to interference from biogenic materials in the matrix (either sediment or bacterial culture). As cultures matured, highly degraded NOSHs could not be differentiated conclusively from biological compounds. As a result, it was necessary to develop ways to confirm preliminary pathway data. Compounds labeled with deuterium offer unsurpassed advantages in this respect: there are no deuterated compounds in nature, and it is possible to distinguish transformation products of deuterated tracers from biogenic compounds in the matrix using GC-MS. The commercial availability of deuterated compounds is limited, so it was necessary to develop specific methods for synthesis and purification of deuterated NOSHs in quantities sufficient for these experiments. The synthetic approach used for most NOSHs exploited stimulated H-D exchange at Pt catalysts at elevated temperature and pressure (250 - 270 °C/35 - 50 atm) [3]. An example of deuterated tracers in degradation pathway determination is given below for benzo (f) quinoline (BfQ).

GC-MS analysis of BfQ degradation products generated by marine microbes gave the following pathway:



1. 2. 3. 4. 5.

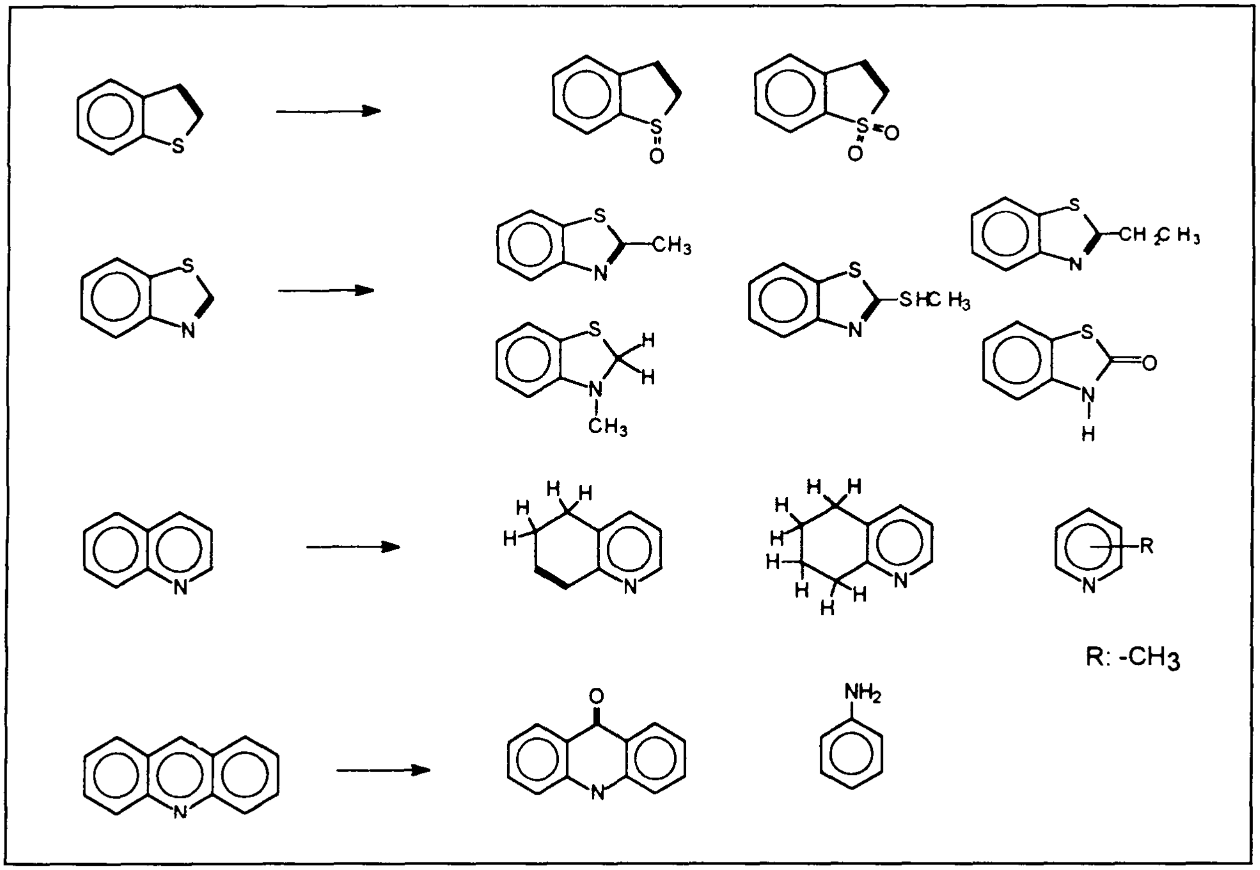


Figure 2B.4. Examples of NOSH Degradation Products Identified.

The pathway suggests that BfQ metabolism in this system generated products of greater toxicity and availability than the starting material (compound 2 is structurally similar to known teratogens and compound 3 is a carcinogen) [1,2]. To test this pathway, deuterated BfQ (d-BfQ) was synthesized and added to cultures containing the NOSH-degrading bacterial community. The uniqueness of d-BfQ isotopic clusters relative to protonated chemicals (shown in Figure 2B.5) was used to confirm the identities of degradation products.

The results of the d-BfQ degradation study helped to clarify the results of previous work with BfQ: deuterated analogs of compounds 2 and 3 (above) were identified in culture extracts after approximately 500 h of incubation. Figure 2B.6 shows a mass spectrum of the deuterated analog of compound 2 above, with distinct isotopic structure (cf. Figure 2B.5.B) in the molecular ion cluster and low mass fragments. With conclusive pathway data in hand, we attempted to decrease the accumulation of toxic BfQ degradation products (compounds 2 and 3 above) in the medium. Aquenous BfQ was treated with a crude microbial inoculum from a marine sediment, and a second treatment received an optimized culture with the ability to degrade a wide range of NOSHs. It was found that the optimized culture eliminated the accumulation of alkyl quinolines resulting from BfQ degradation, whereas the crude inoculum showed significant accumulations of alkyl quinolines. Interestingly, the rate of BfQ degradation was not significantly enhanced by the optimized culture vs. the crude inoculum.

SUMMARY

A fundamental goal of biodegradation research is to understand the transformation pathways of toxic chemicals under conditions found in nature. Once understood mechanistically, the system can be manipulated in ways that may promote the removal of inhibitory or toxic products. The experiments summarized here and those ongoing for MMS have

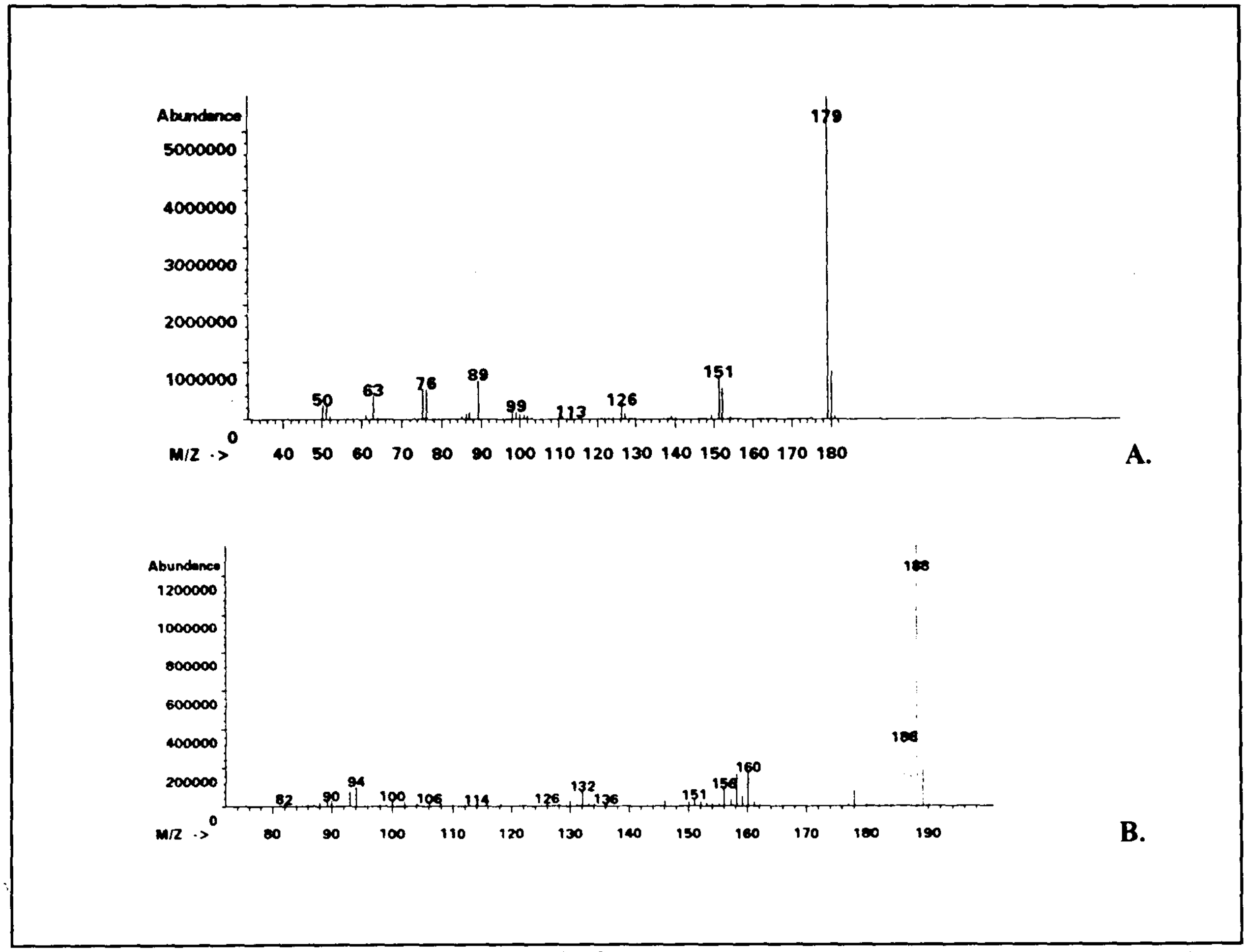


Figure 2B.5. Mass Spectrum of BfQ (A) and d-BfQ (B).

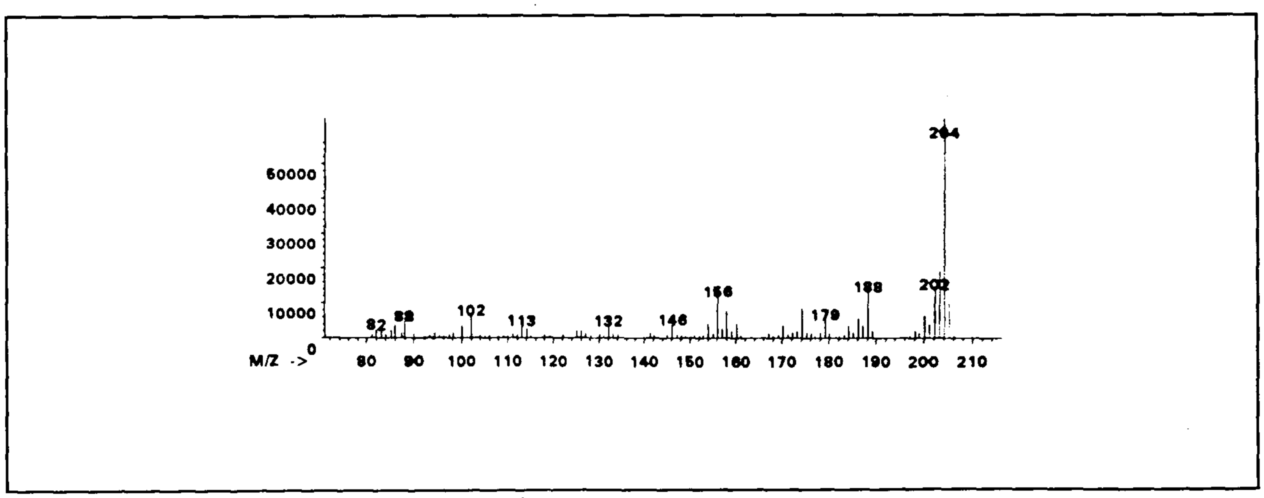


Figure 2B.6. Mass Spectrum of Deuterated 5 (H) -BfQ-6-one.

provided a) data on relative degradation rates for NOSHs in natural marine sediments with different physicochemical properties, b) collection and preliminary characterization of marine microbes involved in degradation of NOSHs and other toxic chemicals, c) protocols for synthesizing tracer compounds in deuterated form (NOSHs, aromatic hydrocarbons, and polycyclic aromatic hydrocarbons) for marine biodegradation and bioremediation studies, d) analytical protocols for extracting and identifying NOSHs and their transformation products in marine systems, and e) approaches for using data from basic pathway studies in applied research.

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EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF AROMATIC HYDROCARBONS ON A SEDIMENT FOOD WEB

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We investigated the biological impact of non-lethal, environmentally realistic doses of polycyclic aromatic hydrocarbons (PAH) on an important food web within the shallow, muddy, estuarine sediments of a Louisiana salt marsh. Specifically, a sedimentary food web with three trophic levels was used as an experimental system to determine the ecological impacts of (PAH). The food web of interest is the microbial - meiofaunal - juvenile fish interaction, typical of Atlantic and Gulf-Coast estuaries. Microbial activity and grazing by meiofauna on microbes were measured in a microcosm experiment in which PAH concentrations were experimentally manipulated over a range of concentrations. In separate experiments, predation by juvenile fish on small metazoans was quantified in contaminated and non-contaminated sediments. Indicators of metabolic condition for the microbes and meiofauna were employed and these indices were related to long-term biological impacts.

The objective of this study was to determine, for the estuarine benthos, the ecological effects of PAH in sestuarine sediments. The results will provide information necessary to develop ecologically meaningful policies concerning the potential impact of aromatic hydrocarbons on estuarine food webs.

The 28-day microcosm experiment to examine the influence of PAH on sedimentary microbes and meiofauna was successfully completed in June 1992. One-hundred and forty (140) six-inch diameter cores of sediment were collected from the salt marsh near the LUMCON facility at Cocodrie, Louisiana. Each core represented a microcosm in the experiment. The cores were immediately transported to a wet lab at LUMCON and distributed randomly among four wet tables with flowing seawater (each table represented a block in the statistical design). Within each table, seven microcosms were subjected to one of three PAH treatments or two controls. PAH was introduced into microcosms by adding PAH-contaminated sediment to the overlying water such that a calculated layer of 1 mm of contaminated (or control) sediment was deposited on the sediment surface. Nominal dosages were 12 ppm, 2.4 ppm, 0.48 ppm, and 0 ppm (no PAH added to sediment), and an unmanipulated control. The PAH-contaminated sediment used in the experimental treatments was from field samples collected form sediments near Port Fourchon; the 12 ppm dosage was chosen as it represents the actual PAH concentration at the Port Fourchon site. Four replicate microcosms (one from each wet table) of each of the five treatment levels were collected at each of seven time points: 0, 1, 3, 7, 14, 21, and 28 days (total of 20 microcosm sampled at each time point). From each microcosm, 12 different core samples are collected: four cores for meiofauna grazing, four cores for microbial activity, one core for nile-red analysis of meiofauna, one core for chlorophyll a concentration, one core for bacterial abundance, and one core for PAH concentration. After each time point, samples were transported back to LSU for processing.

Our analyses indicate that PAH concentration had no significant effects on bacterial physiological condition, microalgal abundance, microalgal physiological condition, copepod grazing on microalgae, copepod physiological status. PAH concentration did not significantly influence overall meiofaunal abundance or most aspects of meiofaunal community composition. There were, however, significant impacts of PAH on the relative abundance of nematodes and copepods (relatively higher abundance of nematodes at high PAH concentrations).

We speculate that the apparent lack of response of this benthic community may be because the meiofaunal community is adapted to relatively high ambient concentrations of PAH. Our observations indicate that PAH concentration in Cocodrie sediments is surprisingly high and at levels that have been reported in the literature to be toxic. Further, there is compelling experimental evidence from the literature that benthic invertebrates can adapt to the presence of elevated contaminants in only a few generations. We plan to address this question in future work by comparing the response of benthic organisms to elevated hydrocarbon concentrations at pristine and a chronically contaminated sites.

Dr. Jay C. Means, Professor of Environmental Chemistry and Aquatic Toxicology at Louisiana State University (LSU) School of Veterinary Medicine, is recognized nationally for his work on the fate and transport of hydrocarbons and other hydrophobic contaminants such as polychlorinated biphenols and chlorinated hydrocarbons in aquatic environments, including estuarine and coastal marine systems. His laboratory group pioneered the research on the predictive modelling of sorption/desorption processes on sediments and also on estuarine colloids. He was the principal investigator responsible for pollutant chemistry and bioavailability of a Cooperative Agreement entitled "Fates and Effects of Nearshore Discharges of OCS Produced Formation Waters", as well as principal investigator of two other projects related to impacts of produced waters in coastal Louisiana. He is also co-principal investigator of a three-year grant under the Minerals Management Service University Research program entitled Biochemical Indicators and Genotoxicity of Produced Waters.

HYPOXIA VS. PRODUCTION ACTIVITIES: WHICH INFLUENCES THE BENTHIC COMMUNITY?

Dr. Nancy N. Rabalais
Louisiana Universities Marine Consortium

Natural variation in space and time has been one of the greatest problems encountered in assessments of effects of petroleum production activities in a field setting. In the extensively developed oil and gas production areas of the northern Gulf of Mexico, a major confounding effect is seasonally intense and widespread hypoxic (dissolved O_2 < 2 mg/l) bottom waters. The zones of hypoxic bottom water may cover 8,000 to 9,500 km2 during mid-summer on the inner continental shelf from the Mississippi River delta to the upper Texas coast. Critically depressed dissolved oxygen conditions may occur in near-bottom waters nearly continuously from April through October on the inner shelf of southeastern and southwestern Louisiana. On the southeastern shelf, the zones of hypoxia are continuous, widespread, and persistent, and may include up to 40 percent of the lower water column in 10-30 m water depth.

Several investigations of the impacts of oil and gas development in the coastal and offshore regions of Louisiana have been complicated by the effects of hypoxia on the benthos. The most notable examples are the Offshore Ecology Investigation, the Central Gulf Platform Study, and an API produced water discharge study. Other studies of either the impacts of operational discharges or the effects of hypoxia have demonstrated that the effects of either hydrocarbon contamination or hypoxia can be identified in the sediments and associated communities. One additional study of produced water discharges in a shallow, erosive water column on the Louisiana inner shelf off Atchafalaya Bay (Rabalais *et al.* 1991) indicated that production platform effects were detectable even where large-scale natural processes (albeit not hypoxia) were expected to obscure patterns. Based on these prior investigations and concerns related to confounding effects on impacts studies, we hypothesized that the effects of offshore petroleum development in the form of a production platform discharge could be identified on the Louisiana continental shelf and placed in the context of natural, temporal variability as caused by hypoxic bottom waters.

Several assumptions guided our research: 1) it is likely that an area of the southeastern Louisiana inner shelf, where there are extensive oil and gas production activities, will experience hypoxic bottom waters during the summer; 2) the dissolved oxygen levels at two or more sites will be similar throughout the season of hypoxia in concentration and duration; 3) benthic communities can be identified as being impacted by hypoxia; and 4) concentrations of contaminants can be identified in the sediments adjacent to a production platform and will be correlated with distance from the discharge. Based on these assumptions, we hypothesized that differences in the benthic fauna can be identified as a gradient in distance from the production platform, that these differences will be consistent across time, and that the relative importance of environmental variables that affect benthic community variability can be identified.

This summary outlines results presented in Rabalais *et al.* (1993).

STUDY DESIGN

A substantial problem evolved early in the determination of adequate study sites that would provide the suitable experimental setting to answer the original research questions. The eventual selection was two platforms in the South Timbalier area in 20 m water depth, 3 km apart, one production (Unocal ST53A) and one non-production (Unocal ST53B); and a production platform in the West Delta area (WD32E) in 20 m water depth, 74 km from ST53B. The South Timbalier area was characterized by sandy silty sediments (less likely to adsorb hydrocarbon contaminants), and the produced water discharge volume from ST53A was 5,550 bbl/d. The West Delta area was characterized by silty sediments (more likely to adsorb hydrocarbon contaminants) and a produced water discharge volume of 20,000 bbl/d. ST53B was the site of a permanent instrument mooring with a continuously recording oxygen meter; a continuously recording oxygen meter was placed at the WD32E platform for a portion of the study period (mid-June through mid-October).

Results from the reconnaissance cruise in April 1990 indicated that the original study design was complicated by 1) dramatic variability in sediment characteristics with distance from the platform at two potential study sites, and 2) the lack of a clear chemical contaminant signal (concentration and expected gradient away from the platform) at two study sites. One platform (Chevron ST52C) was dropped from the study design in July 1990. At this point, however, we were compelled to continue focusing on the three selected platforms because of limitations of time to complete the study and be underway for the 1990 summer hypoxia season and limitations of resources to conduct further reconnaissance cruises. With data from the three sites, we assumed it would be possible (in the event of minimal chemical signals and confounding effects of sediment variability) at least to characterize the benthic communities from a variety of sedimentary regimes where hypoxia is persistent and severe during the summer months.

Field studies were conducted in April through August at three or four sites (additional collections were made in September and October under the auspices of another funding agency). The focus of the study was refined in July to three sites (ST53A, ST53B, and WD32E). Station distances from each platform were placed as closely as possible to 20, 50, 100, 250, 750 and 1,000 m intervals. The ST53B platform served as a reference station for ST53A; an open-water station in West Delta block 33, as the reference station for WD32E. Collections at each study site included hydrographic profiles, sediment samples for chemical analyses, and benthic organisms. Sediments were analyzed in all months for grain size, total organic carbon; in April-August for saturated hydrocarbons, semi-volatile hydrocarbons and trace metals; in selected months and stations for radionuclides. Standard benthic community analyses were conducted on 0.023-m^2 hand-operated Ekman grabs taken from a larger box corer (five replicates for each station each month). Statistical techniques used were analysis of variance general linear model, Duncan's multiple range test, and multiple regression techniques.

The 1990 season of hypoxia was severe, in that hypoxia occurred early and persistently in the spring, hypoxia was severe in the summer, long periods of anoxia were documented, and the generation of hydrogen sulfide in bottom waters was recorded often. Dissolved oxygen concentrations in bottom waters at ST53A were similar to those at ST53B, where the instrument mooring was located. The oxygen record for WD32E located 74 km away, on the other hand, showed incursions in and out of hypoxic conditions, with no extremely low levels for prolonged periods. Oxygen conditions, therefore, were substantially different between the South Timbalier and West Delta areas. Conditions at South Timbalier were characterized as severe and persistent, with effects expected on the benthic community. On the other hand, conditions at West Delta were characterized as ephemerally hypoxic and not severe, with little impact expected. Thus, another original assumption, that hypoxia would be similar at distant locations, was also not met, and we were unable to characterize the benthic communities from a variety of sedimentary regimes where hypoxia was persistent and severe during the summer.

These numerous problems in appropriate study sites, lack of chemical contaminant signal and lack of a gradient and consistent chemical signal when found, meant that we would be unable to adequately test our original hypothesis. The unexpected differences in the oxygen environment between WD32E and the South Timbalier area also complicated those comparative aspects of the study. However, we did further document, under a set of environmental conditions, the signals of production platforms in various habitats, and the effect of variable conditions of hypoxia on the benthos. Further, we were able to identify the relative differences in environmental factors with regard to explaining the variability in benthic community parameters.

RESULTS

The grain size distributions, as expected, were considerably different between the South Timbalier area (primarily sandy silts) and the West Delta area (primarily silts). The degree of variability among stations within a single study site was high, and not always consistent with time. There were no consistent gradients in sand/silt/clay percentages with time at ST53A. ST53B was the most variable in space and time with non-uniform and high percentages of sand or clay that were not consistent with distance from the platform nor sample period. Sediments at WD32E were composed primarily of silts, with the exception of stations closest to the platform (0, 20 and 50 m) where the sediment surface was impacted by sandblasting operations. At these times, anomalously high percentages of coarse-grained sands were present. These sediment differences complicated the interpretation of chemical contaminant and benthic infaunal data.

Minimal informative data were gleaned from the sediment radionuclide and trace metal samples. Limited surficial sediments analyzed for the radionuclides Pb-210, Ra-226 and Ra-228, indicated concentrations at or below typical coastal sediments. Elevated concentrations of Ra-226 at a few stations were not found in sediments associated with higher levels of petrogenic hydrocarbons. There were no clear gradients in concentrations of metals away from the ST53A or ST53B platform for the four months sampled. Values, in general, were lower for sediments at ST53B than at ST53A. Metal concentrations clearly outside the limits of normalized Al concentrations (Schropp *et al.* 1990) (Pb > 100 ppm and Zn > 100 ppm) were evident within 100 m of the WD32E platform, and were likely related to a platform activity or discharge.

Sediments at ST53A contained hydrocarbons in low concentrations of mostly a weathered petroleum or biogenic nature. There were no clear spatial nor temporal patterns evident in the distribution of hydrocarbons adjacent to the ST53A platform. Sediment hydrocarbons adjacent to ST53B were similar in composition to those of ST53A, but generally lower in concentration. Hydrocarbon concentrations had a greater range at WD32E than the sites in the South Timbalier area. The sediments at WD32E contained hydrocarbons mostly of a mixed weathered petroleum and biogenic nature; there were certain stations, however, where the hydrocarbon composition was distinctly petrogenic. There was also a trend for a greater predominance of biogenic hydrocarbons with distance from the platform. With the exception of the June sampling period, total saturated hydrocarbon concentrations for WD32E were similar to concentrations in South Timbalier, despite the higher percentage of fine sediments at WD32E and the larger volume discharge. There was a general decrease in the concentration of specific analytes and in summed PAHs from April through August. The summed alkylated PAH concentrations at 50 and 100 m in June exceeded the threshold level where negative impacts on benthic infauna have been shown previously (Rabalais *et al.* 1991).

In summary, the greatest range in hydrocarbon concentrations was observed at WD32E, and there were obvious indicators of petrogenic origin hydrocarbons at selected stations during some months. In a few instances at WD32E, analyte concentrations and summed PAH concentrations approached or exceeded the threshold level where negative impacts on benthic infauna have been shown previously. Hydrocarbon concentrations, in general, however, were low for most study sites (even where sediments were silty) and were characterized as weathered petrogenic or biogenic in nature. In general, there were no consistent spatial or temporal trends in hydrocarbon chemistry at the three study sites.

There were significant decreases in summer and fall in species richness and abundance of organisms. Decreases were dramatic at ST53A and ST53B during the period of severe hypoxia/anoxia. The decline in benthic populations was gradual at WD32E throughout the summer and early fall. There was a slight recovery in the benthic community at ST53A and ST53B during October, but the decline in numbers of species and organisms continued at WD32E. Overall, abundance was greater at ST53B in the spring and early summer. As hypoxia/anoxia set up in the South Timbalier area and benthic populations declined, abundance of organisms became significantly greater at WD32E. As populations continued to decline at WD32E into the fall along with the slight recovery at ST53B, ST53B became the study site with the greatest abundance of organisms. At ST53A and ST53B, the most dramatic reductions occurred when bottom water oxygen levels fell below 0.5 mg/l. Oxygen levels seldom approached this level at WD32E, and were never persistently low.

Although ST53A was consistently lower in number of species and individuals than ST53B, these differences were not always significant. It is tempting to attribute these differences to the consistently higher concentrations of produced water hydrocarbons at ST53A; however, a multiple regression model with both study sites combined indicates that only the environmental variables of oxygen concentration, temperature, salinity, sediments, and total saturated hydrocarbon concentrations were significant in explaining the variation in species richness and abundance in the South Timbalier study area.

The benthic communities at ST53A and ST53B were similar to each other with regard to taxonomic composition (predominantly polychaetes) and changes in dominance of species through time. A large component of the benthic community at WD32E, on the other hand, was composed of polychaetes, but a much greater diversity of other major taxa existed than at the stations in the South Timbalier area. Some gradients in benthic community parameters were consistent through time. For example, species richness and abundance were generally lower at the 20 m station at ST53A. The remainder of the stations grouped with 250 m, 500 m, 750 m and 1,000 m having the most species and individuals, and with stations at 50 m and 100 m being intermediate. These trends were not always significant, nor consistent through time. Also, no environmental variable analyzed showed the same consistent pattern with distance from the platform. No gradient with distance from the platform was evident in the benthic community at the non-production platform, ST53B, and there were usually no significant differences with distance from the platform. Hydrocarbon concentrations were also lower at this study site. Benthic community parameters were significantly different (in most cases) by station at the WD32E platform, but these differences were not related to distance from the platform and were not consistent across time. Stations at 20 m and 50 m, in general, had more species and individuals than the other stations, but these differences were probably related to platform effects based on the type of fauna in the samples. In April, higher values for number of individuals at 20 m, 50 m and 100 m were related to abundances of *Mediomastus ambiseta* and Tubificidae A, both indicators of organic enrichment. Tubificids were uncommon in the remainder of the study and at the other study sites.

Variability in the benthic community parameters of species richness and abundance was explained by differing combinations of the environmental variables of oxygen and related water temperature and salinity, sediments, and total saturated hydrocarbons. The environmental variable of bottom water oxygen concentration was important in both models for ST53A and one each for ST53B and WD32E. In the case of ST53A and ST53B, there was more of a threshold effect, whereby numbers of species and individuals were dramatically reduced when the oxygen concentration fell below 0.5 mg/l. Sediment characteristics were incorporated in the models for ST53B but were inconsistent with benthic community paradigms (i.e., percent sand was negatively correlated to diversity and abundance). Contrary to many benthic studies, grain size distributions were not always paramount in explaining the variation observed in the benthos (e.g., ST53A); however, the relationship with oxygen was strong for that site and sediment variability was minimal at ST53A. At only one site, ST53B, were any hydrocarbon variables significant in the models that explained variability in species richness and abundance. The variable of total saturated hydrocarbons was positively related to species richness and abundance, perhaps indicating an enhancement effect of the biogenic-type hydrocarbons present in the sediments at the distal ends of the ST53B transect. As noted earlier, however, the concentration of saturated hydrocarbons at the ST53B study site (non-production platform) was much less than the other two sites (both production platforms). Neither of the variables that would indicate the presence of produced water origin hydrocarbons (summed alkylated PAH and FFPI) were significant in any of the models. The potential for effects within 100 m of the WD32E platform were masked by the platform-related grain size distribution differences and other potential platform effects that would increase diversity and abundance.

Thus, there were some indications for gradients in benthic community parameters at the two production platforms, but these gradients were not always consistent in time, nor consistent with distance from the platform, nor significant. However, there were no clear environmental signals at any of the platforms with distance from the platform. There were indications that hydrocarbon composition and concentrations at the two production platforms were different from the non-production platform. Multiple regression analysis identified oxygen concentration, bottom water temperature and salinity, and sediments as important environmental factors that explained the variation in benthic community parameters of species richness and abundance. Production discharge hydrocarbon concentrations were not significant in any of the models, but there were no clear environmental signals related to these contaminants at any of the study sites.

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SATELLITE OBSERVATIONS OF AVERAGE AND EXTREME MISSISSIPPI RIVER PLUME CIRCULATION EVENTS

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INTRODUCTION

The Mississippi River is a major contributor of sediments, pollutants, and nutrients to the northern Gulf of Mexico's continental shelf and slope. Utilization of satellite-acquired digital data enables a quantitative assessment of the areas most often impacted by such discharges. This investigation uses the extensive archives of NOAA AVHRR satellite data plus ongoing acquisitions (at the Earth Scan Lab, Coastal Studies Institute) to enable a systematic characterization of the Mississippi River discharge plume and its variability in time and space. This project focuses on assessing how plume morphology and shelf circulation is affected by storm events, seasonal fluctuations in river flow, and interannual modulations of the annual cycle. The results will lead to a better understanding of the time and space scales of riverine/oceanic interactions and surface circulation pertinent to pollution monitoring and oil spill contingency planning. The primary objectives of this project are

1. to determine which areas of the continental shelf are most influenced by riverborne sediments, pollutants, and nutrients by examining the Mississippi River's discharge plume with five years of synoptic digital satellite data obtained by the Advanced Very High Resolution Radiometer (AVHRR) aboard the NOAA environmental satellites.

2. to assess the relationships between the morphology of the Mississippi River discharge plume and environmental forcing parameters including river discharge, local wind forcing, tidal range and phase, and shelf/slope current phenomenon (such as Loop Current intrusions).

METHODS AND RESULTS

This study utilizes digital data acquired by the Advanced Very High Resolution Radiometer (AVHRR) of the NOAA environmental satellites. This satellite data type was chosen as the main source of data for several reasons. It provides the best available temporal resolution, at least four scenes/day, which enables assessments of daily changes in plume morphology under clear-sky conditions. The spatial resolution (1.1 km) and regional coverage are optimal for studying the surface morphology of the river plume and simultaneous circulation features seaward of the river mouths. These data have been archived daily since July 1988 by the Coastal Studies Institute's Earth Scan Laboratory at Louisiana State University. The AVHRR provides five channels of information, two in the visible (yielding information on suspended sediment concentrations) and three in the thermal infrared range (for computing sea surface temperatures). The Mississippi River plume is revealed very differently by the visible and thermal infrared channels of data. Reflectance information provides a quantitative means of defining the Mississippi River sediment plume, and, therefore, is used as the primary data source of information. The main drawback to its use is that once the sediment drops out of suspension, the plume is no longer detectable by the satellite sensor. The plume is often trackable for longer distances with the thermal infrared channels as river temperature, particularly during autumn and spring, contrasts with that of adjacent shelf water. Thus, the sea surface temperature signal is used in this study to assess the maximum spatial extent of the Mississippi plume.

The visible channels of the AVHRR, when properly processed, can provide important information on surface suspended sediment distribution and variability. Suspended sediment distribution patterns also provide information concerning the distribution of pollutants in the northern Gulf of Mexico, as many pollutants are carried on fine-grained river sediments. It is desirable to be able to relate the satellite radiance information to in-situ concentrations of suspended sediments, and for this reason a field component was included in the project. In April 1992, two field trips were undertaken via helicopter to collect "surface-truth" data on suspended sediment concentrations within the Mississippi plume. Approximately 25 samples were obtained during each overflight by lowering a 500 ml bottle from the helicopter to the surface. During each trip a range of turbidities was sampled, ranging from turbid river water to Loop Current water, which during the first trip was found within 10 km of Southwest Pass. Concentrations of suspended sediments were calculated from laboratory fliltration analyses of the samples (U.S. Geological Survey 1987). The suspended sediment concentrations and the corresponding atmospherically corrected satellite reflectance values were used to establish a non-linear calibration equation which was applied to all NOAA-11 satellite imagery (methodology followed that of Stumpf 1988, 1992).

In addition to the satellite imagery database, ancillary information on daily Mississippi River discharges and hourly winds was obtained to investigate the forcing mechanisms responsible for variations in plume morphology.

The spatial structure of the Mississippi River sediment plume was investigated in relation to river discharge and wind behavior. In general, the size of the sediment plume was found to be a function of river discharge, higher discharge generally yielding larger plumes. The satellite image datasets were composited according to "low," "medium," and "high" discharge conditions. Results of these analyses revealed that under medium discharge conditions, the "mean" sediment plume covered 2,200 km^2 of the continental shelf. Under high discharge conditions, the area of the "mean" plume doubled. The spatial extent of the "maximum" composite plume under high discharge conditions covered an extensive area of the continental shelf and slope (13,207 km^2), extending from 88°20' W to 90°50 W and offshore to the 1,000 m isobath. This information is synthesized in Figure 2B.7. Detailed analyses of individual satellite images revealed that the Mississippi sediment plume undergoes dramatic changes in areal extent and surface morphology on time scales as short as hours. Much of this variability can be attributable to wind speed and direction. The individual images revealed plume areas ranging from 450 km^2 to 7,700 km^2. Plume areas varied by as much as 2,000 km^2 in 24 hours. The areal extent of the Atchafalaya plume, to the west, is even more susceptible to wind behavior as a result of the shallow shelf onto which the Atchafalaya River discharges (Walker *et al.*, 1992).

Although the results of the compositing analysis yielded valuable information on the average and extreme morphological characteristics of the Mississippi River sediment plume, analyses of individual satellite images yield more detailed information on circulation processes on the continental shelf and slope. Extreme circulation events which occurred in October 1992 and August 1993 aptly demonstrate the influence of wind and shelf/slope currents in determining the fate of river water in the northern Gulf of Mexico. During October 1992, a storm off the Mississippi delta caused sustained northeasterly winds for several days resulting in the generation of a 200 km long by 10 km wide cool plume of combined river/coastal waters which moved rapidly to the southwest (Figure 2B.8). An Ensearch Corporation semi-submersible rig, anchored in the Mississippi Canyon, was forced to curtail operations for several days as a result of strong currents, estimated at 1-2 m/s, within the high speed "jet." Subsequently, the cool, low salinity plume was influenced by circulation associated with two large warm core Loop eddies in the northwestern Gulf of Mexico. This event may be one of the first documented cases of high speed currents generated by atmospheric forcing of Mississippi discharge and coastal waters, separate from the Loop Current and its eddies.

Almost one year later in August 1993, when river discharge was anomalously high for summer (as a result of the Great Flood of Summer 1993), the Mississippi River's surface sediment plume was observed extending towards the east at least 150 km, with a surface area in excess of 7,000 km^2 (Figure 2B.9). The presence of westerly winds and persistent anticyclonic flow over the outer shelf and slope appear to have been the main driving forces for the eastward transport of river water. Drifting buoy data, obtained by Texas A&M University as part of the Louisiana Texas Physical Oceanography Program (LATEX) suggest that circulation was favorable for the transport of river water at least as far as the Florida Keys.

The following general observations can be made from the satellite imagery. Under conditions of easterly and southeasterly winds, the Mississippi River

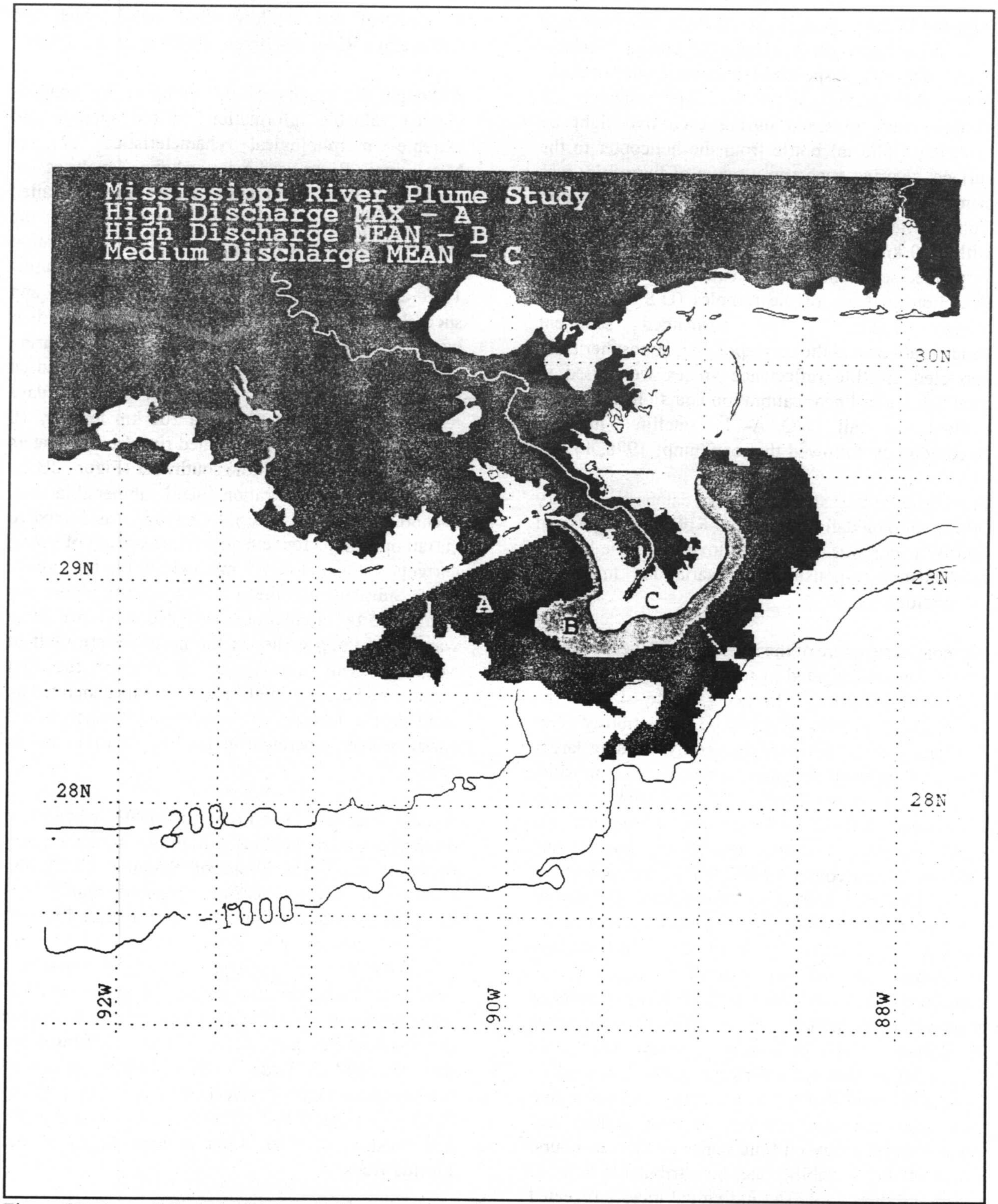

Figure 2B.7. Mississippi River sediment plume composite map summary depicting the mean plume under medium discharge conditions (C), the mean plume under high discharge conditions (B), and the maximum spatial extent of the sediment plume under high discharge conditions (A) (from Walker and Rouse 1993).

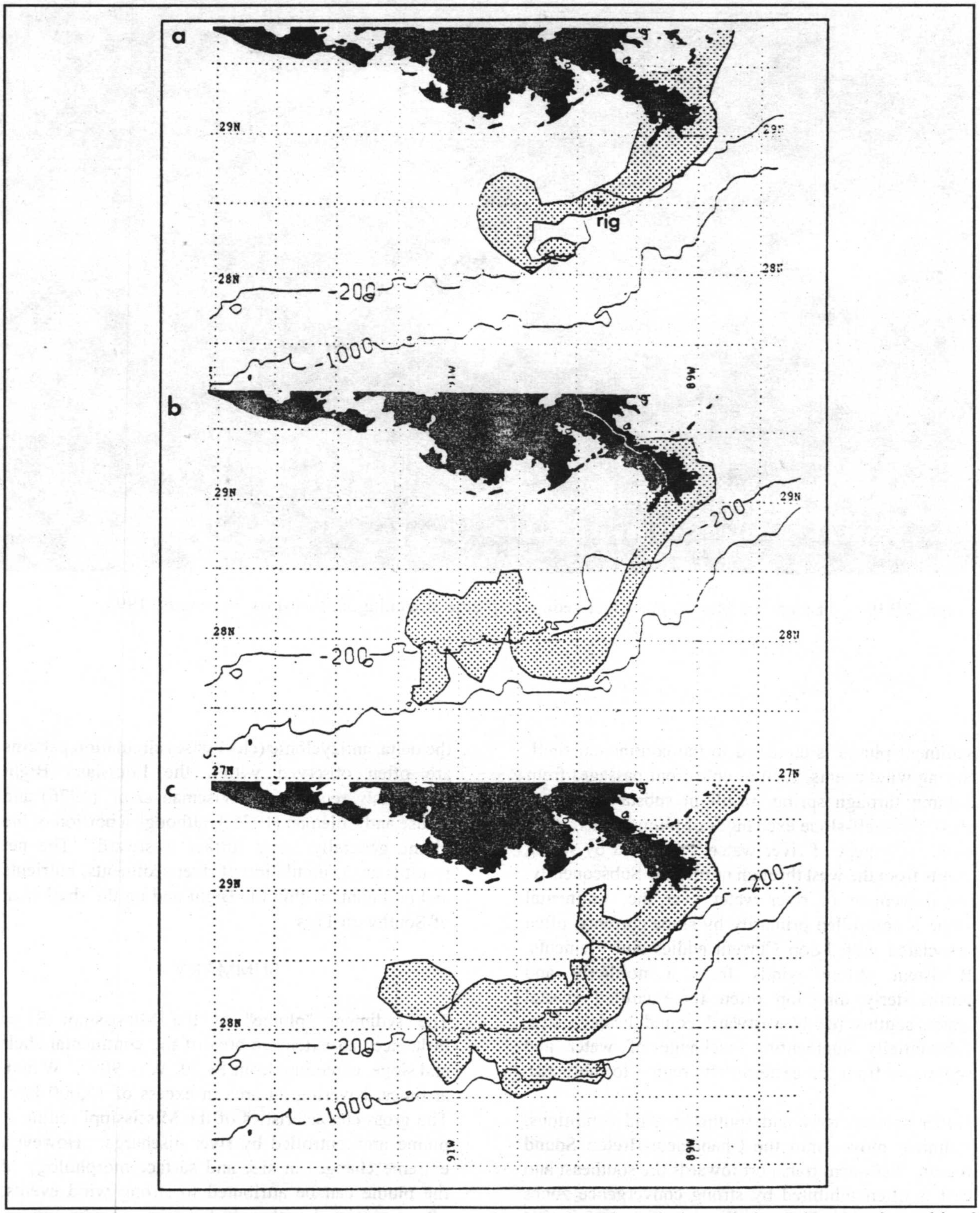

Figure 2B.8. Schematic diagram depicting the spatial extent and evolution of the "plume" of combined river/shelf water as observed in sea surface temperature data of the NOAA satellites on a) 4 October 1992, b) 11 October 1992 and c) 13 October 1992 (from Walker and Rouse 1993).

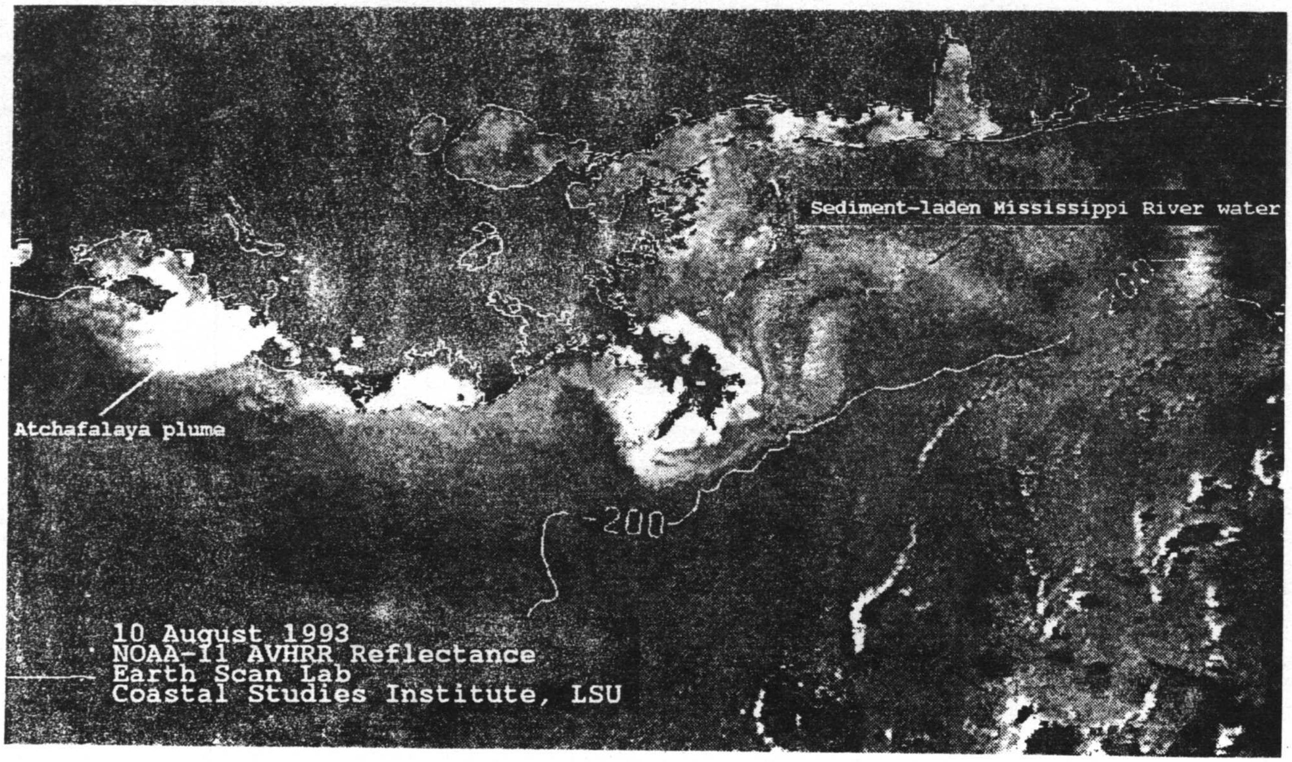

Figure 2B.9. Extensive Mississippi River sediment plume streaming eastward on 10 August 1993.

sediment plume is confined to the continental shelf. Strong wind events, such as cold front passages from autumn through spring, result in substantial cross-shelf and shelf-slope exchanges of plume water. Off-shelf movement of river water is initiated by strong winds from the west through northeast. Subsequently, the movement of river water over the continental slope is controlled primarily by slope currents, often associated with Loop Current eddies and filaments. Persistent strong winds from a northerly and northeasterly direction often force chilled coastal waters southward and westward around the delta face, substantially augmenting exchange of water and sediments from the eastern delta region to the west.

Under southeasterly and southerly wind conditions, sediment moves into the Chandeleur-Breton Sound region. Sediment transport towards the southeast and east is often inhibited by strong convergence zones associated with the prevailing southeasterly wind regime as well as by intrusions of the Loop Current water onto the shelf east of the delta. To the west of the delta, anticyclonic (clockwise) circulation patterns are often observed within the Louisiana Bight (previously reported by Wiseman *et al.* (1976) and Rouse and Coleman (1976)), although a portion of the plume generally flows further westward. The net result is an accumulation of river sediments, nutrients and pollutants within the Bight and on the shelf west of Southwest Pass.

SUMMARY

The sediment "plume" of the Mississippi River influences an extensive area of the continental shelf and slope, extending from 88 20' W to 90 50' W and, at times, covering an area in excess of 13,000 km^2. The gross characteristics of the Mississippi sediment plume are controlled by river discharge. However, extreme changes in size and surface morphology of the plume can be attributed to strong wind events, often associated with cold-front passages in winter.

Dramatic changes in plume orientation can occur in a matter of hours as a result of altered wind forcing.

This satellite-based assessment of the Mississippi River plume has suggested that the proportion of water flowing westward increases during winter and possibly also under high discharge conditions. Under the influence of strong northeasterly winds, river water from the eastern passes and ambient coastal waters flow southward hugging the eastern delta region. They subsequently turn westward to join the discharge emanating from South Pass and Southwest Pass. To the west of the Balize delta, anticyclonic (clockwise) circulation of the plume is often observed within the Louisiana Bight, although a portion of the plume may also continue flowing westward.

This investigation has revealed that river discharge, wind forcing, and shelf currents are the major factors controlling the distribution of Mississippi River water, sediments, and pollutants on the continental shelf. Significant off-shelf transport of plume waters occurs only in association with strong northerly or westerly winds. Subsequently, the movement of river water over the continental slope and deep Gulf is controlled mainly by ocean currents, often associated with Loop Current eddies and filaments.

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SESSION 2C

RECENT AND CURRENT SOCIOECONOMIC STUDIES IN THE GULF OF MEXICO

Session: RECENT AND CURRENT SOCIOECONOMIC STUDIES IN THE GULF OF MEXICO

Co-Chairs: Mr. John Greene and Ms. Vicki Zatarain

Date: December 15, 1993

Presentation	Author/Affiliation
Introduction	Mr. John Greene Minerals Management Service Gulf of Mexico OCS Region
A Social Science Research Agenda for the Minerals Management Service in the Gulf of Mexico	Dr. Robert Gramling University of Southwestern Louisiana Dr. Shirley Laska University of New Orleans
Social and Economic Impacts of Oil "Boom and Bust" Cycles	Dr. Ruth Seydlitz University of New Orleans
OCS Development and Coastal Income Inequality: A Comparative Analysis	Dr. Charles M. Tolbert, II Department of Sociology and Rural Sociology Louisiana State University
A Socioeconomic Outer Continental Shelf Issue Analysis of Stakeholders in the Central Gulf of Mexico	Dr. Robert Gramling University of Southwestern Louisiana

INTRODUCTION

Mr. John Greene
Minerals Management Service
Gulf of Mexico OCS Region

The long history of oil and gas development on the Outer Continental Shelf (OCS) of the Gulf of Mexico (GOM) has left its imprint on the land and peoples of the region. The Gulf of Mexico OCS region has had a long-standing commitment to the understanding of the environmental impacts of this activity. In recent years, the lack of a focused socioeconomic research program has been highlighted (NRC,1993). In response to the identified gaps in our understanding of the social and economic impacts of OCS oil and gas activity, the GOM region has begun to develop a robust socioeconomic research program to fill data gaps and to gain understanding of these impacts.

The papers presented in this session represent results and status of recent and current socioeconomic research in the region. These research projects are seen as important bases in the formation of a focused socioeconomic research program in the region. They will provide, in conjunction with other studies already in process or planned, an understanding of relationships between economic and social behavior in the area and OCS oil and gas activity in the region.

A SOCIAL SCIENCE RESEARCH AGENDA FOR THE MINERALS MANAGEMENT SERVICE IN THE GULF OF MEXICO

Dr. Robert Gramling
University of Southwestern Louisiana

Dr. Shirley Laska
University of New Orleans

BACKGROUND

The northern Gulf of Mexico is easily the most developed offshore area in the world. Today there are over 3,9000 production platforms on the federal waters (beyond three miles offshore) of the Outer Continental Shelf (OCS) alone, with over 18,000 development wells in place linked to these platforms.[1] Production platforms are in place in water depths of over 1,700 feet and over a hundred miles offshore. Very little of OCS oil and none of the gas is tankered ashore, which means that virtually the entire offshore production system is connected to onshore facilities via a network of thousands of miles of subsurface pipelines. Unlike some of the new offshore regions of the world,[2] because offshore development evolved in the Gulf, almost all of the fabrication of offshore facilities was done locally. The end result of this massive development scenario, and of its evolution over almost 50 years, has been to significantly alter the physical, social, economic, and cultural environment of the coastal Gulf of Mexico (see National Research Council 1992; Gould *et al.* 1991).

Since the passage of the Outer Continental Shelf Lands Act in 1953, offshore oil and gas leasing on the Outer Continental Shelf (generally beyond three miles offshore) has fallen to the Department of the Interior. Initially this task was divided between the Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS). The two primary impetuses for social science research came from the passage of the National Environmental Policy Act (NEPA) in 1969, which requires "utilization of a systematic interdisciplinary approach which will ensure the

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[1] In contrast, as of 1988, on the Pacific Outer Continental Shelf there was a total of 21 production platforms and 669 development wells. There is no other production on the remainder of the U.S. Outer Continental Shelf.

[2] Because offshore platforms must be constructed onshore and be moved offshore, they are inherently mobile and can theoretically be constructed in virtually any coastal region of the world and moved to any other. For example, of the 21 production platforms in place on the Pacific OCS in 1988, nine were constructed in Japan, two in Malaysia, and one in Korea. Even more remote, Mobil considered constructing the platform for the development of the Hibernia field (located off the coast of Newfoundland) in Taiwan. Political rather than technical considerations were probably more important in the decision to construct the platform locally.

integrated use of the natural and social sciences" (42 U.S.C. 4321 *et seq.*) for analysis of the impacts of proposed federal actions and projects and amendments to the Outer Continental Shelf Lands Act in 1978, which required assessment and monitoring of the impacts of OCS activities on the "human, marine, and coastal environments" (43 U.S.C. 1802 *et seq.*).

In response to these requirements the Environmental Studies Program was created in the Department of Interior to provide needed information for decision making and monitoring. In 1982 the offshore leasing and regulatory functions performed by BLM and USGS were combined, and Minerals Management Service (MMS) was created, which included the Environmental Studies Program. Since its inception, the program has spent approximately $539 million on targeted research. Approximately 12 percent of the funding has gone to studies in the Gulf of Mexico. Socioeconomic research has accounted for approximately 4 percent of the ESP research budget, and over 70 percent of that was spent in Alaska. In addition, part of that 4% was spent on the funding of scientific meetings that had more ecological and oceanographic content than socioeconomic, and some of the studies specifically identified as socioeconomic had substantial components (sometimes a majority) that were natural science in content (National Research Council 1992). This has meant that only a small percentage of this research has addressed impacts in the Gulf of Mexico, where all but 21 of the approximately 4,900 OCS production platforms are sited, and only a small percentage of this has addressed impacts on the human environment.

In 1989, a report prepared by the National Research Council found that socioeconomic information in the Gulf of Mexico Region's Environmental Impact Statement (EIS) for Sale 116 off southwestern Florida was not sufficient for informed decisions concerning OCS oil and gas activities. Briefly stated, the report found that "[S]tandard social and economic analyses have been inadequate" and that "[S]ignificant types of social and economic impacts have been ignored." (National Research Council 1989: 56).

Other sources also began to question the adequacy of the Gulf of Mexico Region's socioeconomic analyses for informed decision making. For several years the Scientific Advisory Committee of the MMS has urged funding of more social and economic studies in order to understand more fully long term social and economic implications of the OCS oil and gas program. In 1991, the State of Louisiana sued the Department of the Interior to stop leasing of blocks off the Western Gulf of Mexico (Lease Sale 135). One basis for this lawsuit was the alleged lack of adequate information of social and economic impacts of the OCS oil and gas program (State of Louisiana versus Lujan).

In response to the growing concern for socioeconomic issues in the Gulf of Mexico Region, the MMS began taking certain steps toward solving the problem. Among the steps taken by the MMS were expansion of the issues analyzed in the EIS to include impacts on public services and infrastructure and impacts on social patterns; the creation of a "Socioeconomic Working Group" within the region; the funding of some socioeconomic research through the Universities Research Initiative established three years ago with the Louisiana Universities Marine Consortium (LUMCON); and the funding of the "Socioeconomic Research Agenda Workshop" described in this document to recommend studies which will assist in the understanding of socioeconomic impacts of OCS oil and gas activities.

The intent of the workshop was to recommend a social science research agenda for the MMS's Environmental Studies Program for the Gulf of Mexico, at a sufficient level of detail to describe specific studies, the justification for those studies, and the methods required to perform the stated objectives of each project.

DESIGNING AND RUNNING THE WORKSHOP

The workshop was funded through the MMS Universities Research Initiative. Once the workshop goals were agreed on, the two co-conveners and representatives from MMS and LUMCON met periodically to design the workshop. The two primary areas of discussion were the workshop participants and the schedule and structure of the workshop. The ultimate selection of structure and participants--a small workshop composed of researchers expert in the impact of extractive development--was based on the objective of accomplishing a detailed description of key and appropriate studies.

Workshop Participants

From the onset, the goal for the selection of participants was to end up with a pool of individuals which had four characteristics: 1) the group represented the disciplinary diversity within the social sciences; 2) within that diversity the group contained significant expertise for each of the germane research traditions (resource economics, social impact assessment, marine policy, etc.) within those disciplines; 3) to the extent possible (with the limited past focus on the impacts of offshore energy production), participants had familiarity with the specific OCS development activity in question, and 4) the group was small enough to be manageable and still meet criteria 1-3 above. The discussions made it evident that in addition to these academic scholars, MMS socioeconomic specialists, and other Gulf of Mexico officials responsible for the development of the socioeconomic research initiatives should participate fully in the workshop as well. Two objectives required this: first, the research agenda proposed by the workshop be practical, i.e. one which would serve the needs of MMS as they increase their consideration of socioeconomic impacts of OCS activity. Second, MMS personnel needed to benefit from exposure to new perspectives offered by the academic researchers and the academic researchers likewise needed to be exposed to new perspectives from agency personnel. The list of participants and a short biographical sketch of each are included in Appendix A.

Workshop Structure and Schedule

There were five main elements agreed upon for the scheduling and structure of the workshop (see Appendix B for a detailed schedule of the workshop). First, approximately one month before the workshop each of the participants received an information packet prepared by the co-conveners and MMS personnel. The packet contained:

1. Background and rationale for the workshop
2. Agenda
3. A brief overview of MMS social and economic data needs
4. A history of OCS activity in the Gulf of Mexico and its socioeconomic impact, by Bob Gramling
5. A bibliography of existing research on socioeconomic impacts of OCS activity in the Gulf
6. A review by Ruth Seydlitz of the availability of secondary data for analysis of OCS socioeconomic impact
7. An example of a Request for Proposals from MMS for use by the workshop participants in modeling their proposal
8. A list of the participants

Second, the workshop itself was run by professional facilitators (see Appendix A). Use of facilitators allowed the co-conveners to become participants in the intellectual work of the meeting and provided the necessary skills to ensure that the group remained focused and that the sessions ran smoothly. Once the facilitators were chosen, they also became part of the planning process. In addition, five local professionals—three University of New Orleans graduate students and two Louisiana state officials—were trained as auxiliary facilitators.

Third, the facilitators interviewed (by telephone) about a third of the workshop participants, and produced extensive notes on the background of the participants, their ideas for research themes, and their general concerns about and advice for, the workshop. These interviews provided information for planning the workshop. Some of the concerns expressed in the phone conversations were addressed in the plenary sessions; in addition, the ground rules proposed to the group reflected some of the concerns expressed in the phone interviews.

Fourth, a field trip was planned as the first on-site experience of the workshop. It was designed to immerse the participants in the OCS oil and gas industry. The field trip took the participants by boat through the coastal environment of Louisiana (where most of the support activity for OCS activity exists) and then offshore to see some of the development. Not only did this give the participants an opportunity to see how unique the OCS resource extraction activities are, but also it allowed the participants to meet one another, to begin networking and to discuss the OCS activities that would be the focus of the workshop. By the first day of actual workshop activities, the participants were prepared both interpersonally and topically to begin collaboratively to develop the agenda.

Fifth, three plenary sessions were established. The beginning session introduced the project, set the ground rules and determined the broad sub-area topics for the four or five breakout groups. No attempt was made to set the themes of the breakout groups beforehand. To do so would have caused the workshop co-directors to have interjected their perceptions of the broad topics. It was the intent of the project to have the workshop participants--key experts in the field--do that. This was recognized as a risky design but essential to have the workshop product be truly the result of the workshop.

In practice, establishing the broad subtopical areas proved problematic, as had been anticipated. The first attempt to do so resulted in a list of over 30 ideas, many of which were individual projects as opposed to components of an overall organizing system for a full research agenda. After extensive dialogue and listing of relevant research issues, several typologies for organizing the work groups around the research issues were discussed. Gramling presented a typology of socioeconomic impacts and methodologies, which was discussed extensively (Appendix C). Eventually, a simple typology that focused on scale of analysis (see methodologies, Appendix C) was agreed on. It was proposed that organizing the work into breakout groups was not necessarily the same task as developing a definition of the subareas of socioeconomic research important to assess OCS impact. In the last plenary session, more effort was directed toward grouping and linking the projects according to different criteria. See below for the results of this effort. Finally, in addition to a simple typology to divide the labor between the work groups, a set of guiding principles emerged from the first plenary session to provide focus across groups.

These principles were:

1. Be practical. Focus on issues that are significant--to the agency, to affected publics, and/or as identified in the existing social science research literature. Provide the kinds of information that, according to scientific standards, ought to be included in an EIS and the kinds of information called for under the Outer Continental Shelf Lands Act Amendments (OCSLAA) of 1978.

2. Use a long-term perspective. In doing studies, take advantage of the time frame of accumulated experience in the Gulf (e.g., the ability to consider the full boom-bust cycle, the changing levels of government capacities over time, etc.) to understand the underlying processes, and to provide useful input to other communities and OCS regions. Focus on compiling what we know, but doing so in a way that helps us have a better idea of what to expect in the future.

3. Identify the generic vs. the specific. To the extent possible, identify underlying causes and processes in such a way as to be able to separate out the experiences that are unique to the time (e.g., pre-1969, post-1973, etc.) or region (e.g., coastal Louisiana, Morgan City, etc.) from those that can be expected in other times and places.

4. Learn from surprises as well as from "the expected." Discuss the lessons to be learned from strategies that were thought to be adaptive but failed; from cases where planning was helpful in ameliorating impacts; from unexpected changes in price, technology, industrial practices, even global politics (e.g., the sudden eagerness for oil development in the former Soviet Union).

5. Be realistic. Explicitly consider technology, changes taking place in the industry, influence of commodity/price trends, federal approaches to leasing, and other "external" factors that affect socioeconomic impacts.

6. Be balanced and thorough. Consider positive as well as negative impacts; deal with the full range of significant socioeconomic impacts, not just those that fall within the traditional subject-matter interests of one or more social science disciplines.

7. Focus on distribution of impacts. Explicitly consider who wins and who loses and whether impacts that are negative (or positive) in the short run may prove to be positive (or negative) in the long run.

8. Ascertain the ways in which OCS activities have a socioeconomic impact. Consider the

process whereby the extraction activity results in impacts. Such considerations will facilitate impact assessment and mitigation.

Following a review of these guiding principles, the breakout work groups were formed. The groups ranged in size from five to seven members and contained a variety of participants from different socioeconomic disciplines (e.g., an economist, anthropologist, sociologist, geographer--and representative of MMS). Each group met in an individual room, with a local facilitator, to design what they felt were the most immediately relevant projects for the research agenda. The professional facilitators moved from room to room to assist in inter and intra group communication.

Three of the work groups focused on the research needed to assess and monitor impacts on 1) individuals and families, 2) communities, and 3) regional/state entities. The fourth group examined the needed research concerning the role of policy in monitoring and mitigating socioeconomic impacts, and the fifth group (other) worked on the issues that had been raised in the plenary session, but that did not fit neatly into the typology. After deciding what the most important projects were within their specific charge, the work groups broke into smaller groups or assigned individuals to provide the first draft of the proposed project description.

A second plenary session was planned to assess the progress of the breakout groups and to determine how to address any problems being encountered. This session clarrified the expected project description outcomes. Additionally, some groups discovered that they were producing similar proposals. Two of the breakout groups combined for the final breakout effort and other smaller groups evolved with members from more than one group. At the end of the workshop a third plenary session evaluated and ranked the projects (see below for description of the last plenary session).

Format of the Project Descriptions

To ensure that the work groups considered and provided input for similar project elements, a structure for the write-up for individual projects was suggested and agreed upon. The elements were

Title
Region
Proposed Period of Performance/Level of Effort
Applicable Planning Areas
Description of Proposed Project
  Objectives:
  Methods/Study Design:
Products
Justification
Current Status of Information on this Topic
Applicability of Information to Issues of Regional or Programmatic Concern
Qualifications

RESULTS

Proposed Projects and Their Rankings

The number of project descriptions produced by each breakout work group ranged from two to five. The project descriptions were collected and copies were reproduced for each of the workshop participants. On the last day of the workshop each of the 18 proposed projects was presented by a member of the work group that had designed that project.
Following the presentations, criteria for ranking the projects were developed (concerns and issues surrounding the ranking process are discussed below). After a number of suggestions were proposed by the workshop participants, the facilitators suggested three criteria for ranking them:

1. Immediacy/time sequence. How important is it to get the project under way?

2. Practicality/fit with MMS needs. How important is the project for MMS's decisionmaking and monitoring responsibilities?

3. Scientific importance. How important is the project for understanding and/or monitoring the phenomena.

Other criteria which included

4. Mix of methodological approaches. Will the findings be more encompassing if a variety of research methods is used?

5. Utility of findings to governmental entities in the Gulf of Mexico region in addition to MMS. Does OCSLAA permit consideration of needs of

regional and local governments when research is conducted on social impacts?

6. Marketability of research idea. What initial research projects will be seen as central to the MMS mission and thus constitute a good base for establishing a socioeconomic research program in the Gulf of Mexico region?

7. How the research findings will be used in the preparation of EISs.

Voting Procedures

Each participant was given a ballot with the projects listed in the order of presentation. Each participant had a total of ten points that could be allocated among the 18 projects, with no more than three points to any one project. Following voting, the results were tallied and the projects were ranked as follows:

Proposed Studies and Their Rankings by Participants

1. An Assessment of the Historical, Social and Economic Impacts of OCS Development on Gulf Coast Communities. (31 votes)

2. Consequences of OCS Oil and Gas Activities for Individuals and Families. (21 votes)

3. Socioeconomic Issues Analysis on Gulf of Mexico Activity. (20 votes)

4. Case Studies of Gulf Communities. (17 votes)

5. Mitigation Strategies for Addressing Socioeconomic Impacts. (16 votes)

6. MMS Policies and Processes Affecting Socioeconomic Impacts. (15 votes)

7. Estimates of OCS Development in the Gulf of Mexico Since 1954: Comparison Between Two Accounting Methods. (14 votes)

8. Decline. (13 votes)

9. Local Government Capacity to Manage Development. (11 votes)

10. Regional Forecasting/Simulation Model. (10 votes)

11. Monitoring Socioeconomic Impacts of OCS Activities in the Gulf of Mexico Region. (9 votes)

12a. (tie) Perceptions of Risk. (8 votes)

12b. (tie) Adaptations of Local Oil-Support Businesses to Change in OCS Activities. (8 votes)

13a. (tie) Factors Influencing Industry Restructuring. (7 votes)

13b. (tie) Development of "Appropriate Technologies" in the Petroleum Industry. (7 votes)

14. Outer Continental Shelf Activities and the Human Environment. (6 votes)

15. A Comparative Analysis of the Socioeconomic Impacts of Mineral Extraction Communities. (5 votes)

16. Socioeconomic Survey of the Gulf of Mexico. (2 votes)

CONSTRUCTING A RESEARCH PROGRAM FROM WORKSHOP RESULTS

The ultimate success of using a workshop of experts to "quick start" a socioeconomic impact research program for the MMS will not be known for several years. While the response to the workshop on the part of both the researchers and MMS staff who participated was very positive, the contribution of the workshop will rest on how the recommendations are implemented. Conference participants saw several more steps as necessary. The implementation of several of these recommendations is presented below in a prescriptive fashion for succinctness to demonstrate how important the participants felt how important they were in producing a successful socioeconomic impact research program. Without serious consideration of these issues, the contribution of the workshop toward beginning a socioeconomic impact research program might be minimal. The issues fall into the categories of funding, packaging, and capacity building.

Selecting Projects For Funding

Considerable concern was expressed to the co-conveners publicly and privately that the ranking of the proposals be kept in perspective.

There are several issues here:

1. The process of ranking individual proposals does not necessarily result in a balanced program of research. As one participant wrote afterwards, "There needs to be a much smaller group of people who look at the array of possibilities, the relative costs involved, the type of balance that would be appropriate and then work up, in interaction with one another, an appropriate game plan."

2. The ranking process does not necessarily address how the studies are to be used. In order to select projects based on this criteria, it would be necessary to ascertain MMS specific objectives with regard to implementing a socioeconomic impact assessment research program. Determination of program objectives could also be "quick started" by holding an in-house workshop similar to this one which was held with the scientists and by producing a similar document which can then be referred to as the program is implemented. The reason for the importance of this effort is that the projects proposed in this document will serve different MMS objectives.

In the final plenary session some attempt at combination of the projects was discussed. The group reached a number of conclusions:

1. The group noted that no clear interval separated the higher ranked studies other studies; they rejected the idea of setting a line between top-ranked studies and other studies.

2. The group noted that more broadly stated baseline studies tended to get more support than more specialized studies. Several members noted that while there is a need for basic projects, there are important, more focused, studies in the pool of those recommended.

3. The group also noted that some of the more specialized studies could be linked methodologically or topically with some of the higher-ranked ones, and therefore might be included with them in establishing a program of study.

4. The group agreed that some of the more specialized studies might be given a higher priority because they would help achieve a balanced research program, or because they might have a high promise of developing new methodologies, answering specific relevant questions, or facilitating administrative decisions or policy considerations. It was also noted that some of the more focused studies were very innovative and that MMS does not have a history of funding innovative studies.

5. The group agreed that some of the studies overlapped and might be combined.

6. But the group reached no consensus on alternative ways to cluster the projects, other than noting that the rank order or scores of the projects should not be considered as the sole criterion in establishing a research program.

A number of participants have written suggesting possibilities for combining projects, and reducing overlap. While some of these appear to have considerable merit, the co-conveners have refrained from including them in the report or from interjecting their own suggestions for combinations. We will note that there is some overlap and that possibilities for combining some of the projects are good. This should be carefully considered as implementation proceeds.

Packaging the Projects

In addition to concerns about funding priority, workshop participants suggested that MMS consider carefully the packaging of the project components, using both theoretical and methodological criteria as well as practical criteria in place at MMS with regard to preparing and distributing RFPs. "How things have always been done" for the biophysical environmental studies projects may not work for the socioeconomic impact assessment research. Carefully considering what should be changed in the way the projects are packaged--while difficult to do because the process is well in place--may have a very positive payoff in terms of implementing a socioeconomic impact research program.

Certain projects may be easily packaged with others (e.g., #6 and #13a). Certain projects may be of sufficient magnitude to warrant a single project. Consideration must be made of the utility of bringing together various researchers and research activities and whether they must be brought together within the research project or by the MMS social scientists who will oversee the program's implementation. Again, deliberate consideration of the implications of the way in which the projects are implemented may be crucial to a successful socioeconomic impact research program.

Capacity Building

A final concern of the workshop participants was that MMS did not currently have the capacity to implement the recommendations of the workshop. Several specific recommendations were made:

1. MMS needs to increase staff to successfully administer a social science research agenda. The specific recommendation was made that MMS add two Ph.D.-level social scientists in the Gulf region. It should be noted that one participant specifically objected to the limitation of the recommended positions to Ph.D level. However, many felt the research and theoretical training associated with the doctorate were necessary for the management of a research program. Additionally, the people should be trained and have experience in the application of social science research to social problems and issues; they should have the management skills to draw on the resources of the in-house social scientists for advice about developing a clear sense of the objectives of the program and how to implement them.

2. MMS needs to respond to requests for proposals from academic researchers. While consultants play an important role in the biophysical environmental studies program, this may be possible because the research issues are much better defined. In its first years, the program will benefit from funding academic researchers who have, as a constant requirement of their craft, theoretically and methodologically robust research. Private consultants have more difficulty implementing such efforts because they are not subsidized by institutions which have peer-reviewed research as an objective. Again, careful attention to the way in which the research is carved into requests for proposals will permit an assessment of which components are best completed by the consultant sector.

One way to enhance academic submissions is to have a longer period of time between the announcement of the RFP and the submission deadline. Due to the way in which the university operates, quick responses are difficult because a funding procurement component is not fully in place in the academic setting as it is in the consulting firm. The responsibility for almost all of the proposal preparation often falls on the researcher.

3. Develop a sound, systematic process of obtaining reviews, from both in-house and academics, of the research proposals. Other federal agencies do not select the reviewers until after the submissions are made; as a result, individuals who do not submit proposals can be utilized as reviewers. By ascertaining how these other agencies have developed their review processes, MMS can modify its system. A credible systematic review process is paramount for keeping the best researchers in the research game. Recent problems with RFP announcements and reviews have badly soured some of the key researchers of resource extraction and economic development.

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SOCIAL AND ECONOMIC IMPACTS OF OIL "BOOM AND BUST" CYCLES

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The focus of this paper is on the social and economic impacts of offshore petroleum extraction and production in the Gulf of Mexico on communities in Louisiana. Two issues will be addressed. The first is the manner in which offshore extraction leads to impacts. A scenario of impacts will be presented. The second is the implications of the scenario for intervention and mitigation strategies.

A SCENARIO OF SOCIAL AND ECONOMIC IMPACTS OF OCS PETROLEUM EXTRACTION

The following scenario of impacts was derived from ongoing research concerning the effect of offshore petroleum extraction on social problems, educational attainment and strain, and community economic health of parishes in Louisiana. The data measuring petroleum industry activity, social problems, education and community economic health were obtained annually from diverse federal and state governmental sources. Several indicators of social problems, educational attainment and strain, and community economic health were used. Two indicators of petroleum extraction activity were used—the average price per barrel and the number of developmental wells off the coast of Louisiana. All variables in dollars were converted into 1983 dollars. All variables measuring impacts were calculated for four groups of parishes: 12 parishes highly involved in petroleum extraction and production, 11 parishes minimally involved in such activities, five parishes highly involved in extraction only, and five parishes highly involved in activities related to extraction and production (e.g., refining, fabrication, and wholesale trade). Time series regression was used to calculate the effect of the measures of extraction activity on each measure of social problems, educational attainment and strain, and community economic health for each group of parishes separately. (For further information concerning the data and methods, see Seydlitz and Laska 1993).

The results varied by degree (highly or minimally involved) and type (extraction or related activities) of involvement. There were fewer significant impacts in the minimally involved and related activities groups of parishes than in the highly involved and extraction groups. The results in the highly involved and extraction groups were very similar; therefore, the scenario is based on the findings for these two groups (see Tables 1 and 2).

The chain of events begins with an increase in extraction activities. As extraction operations increase, average per capita income, sales taxes, criminal court cases, and school expenditures rise and enrolling in college may decrease, while transfer payments and unemployment decline. Based on theory, the increase in income may lead to an increase in parents' educational aspirations for their children and the increase in high school completion, although the

Table 2C .1. Summary of Impacts in the Highly Involved Parishes[a]

Impact Variable	Oil Activity increases	One Year Later	Two Years Later	Three Years Later	Four Years Later
homicides (.145)					decrease
criminal cases (.510)	**increase**		decrease		
suicides (.508)				**increase**	
high school completion (.093)				**increases**	
going to college (.302)	**increases**	decreases	**increases**	decreases	
per pupil expenditures (.256)	**increase**			decrease	
per capita expenditures (.100)	**increase**				
income (.383)	**increases**	**increases**	decreases		
transfer payments (.509)	decrease		**increase**		
unemploy. rates (.527)	decrease		**increase**		
per capita unemploy. (.544)	decreases		**increases**		
net migration (.648)		**increases** (inmigration)		decreases (outmigration)	
sales taxes (.240)	**increase**		decrease		

[a] Numbers in parentheses are the R^2s for the effect of petroleum activity.

increase in high school completion in the extraction parishes appears to be too early for this explanation. The increase in income allows people to spend more money so sales taxes collected also rise. Housing values rise (based on decennial data not shown in tables), which increases property taxes. The rise in sales and property taxes means that schools have more funds, thus school expenditures increase. High school graduates see the advertisements for lucrative positions in resource extraction companies and forego

Table 2C .2. Summary of Impacts in the Extraction Parishes[a]

Impact Variable	Oil Activity increases	One Year Later	Two Years Later	Three Years Later	Four Years Later
homicides (.188)					decrease
criminal cases (.443)	**increase**		decrease		
suicides (.261)			**increase**		decrease
high school (.096)	**increases**				
going to college (.176)	decreases			decreases	
per pupil expend (.596)	**increase**	**increase**		decrease	
per capita expend (.464)	**increase**	**increase**	decrease	decrease	
avg. number pupils (.042)			decreases		
income (.532)	**increases**	**increases**	decreases		
transfer pay. (.351)			**increase**		
unemploy. rates (.275)			**increase**		
per capita unemploy. (310)			**increases**		
net migration (.633)		**increases** (inmigration)		decreases (outmigration)	
sales taxes (.445)		**increase**		decrease (P) **increase** (W)[b]	

[a] Numbers in parentheses are the R^2s for the effect of petroleum activity.
[b] The effect of price at the third lag was negative while the effect of wells at the third lag was positive.

college; therefore, the enrolling in college decreases. As more people have jobs with more income, transfer payments and unemployment decrease. However, some residents lack the skills needed to gain employment in the extractive industry and feel deprived. Their perception of deprivation and their attendant feelings of frustration due to their inability to gain from the rising economic affluence in the community as a whole leads to outwardly directed anger and the number of criminal court cases rises.

One year later, income, school expenditures, sales taxes rise and inmigration occurs. The rationale for the increases in income, school expenditures and sales taxes the same as above. The increase in inmigration occurs because people from other communities discern that lucrative positions are available in the highly involved and extraction communities; thus, they move into these communities in hopes of obtaining these positions.

The second year after the increase in resource extraction activities, the scenario begins to reverse. Income, sales taxes, criminal court cases and school expenditures decrease and suicides may increase while unemployment and transfer payments rise. The problem is that too many people have arrived. Some of these newcomers do not have jobs; therefore, average per capita income and sales taxes decrease and unemployment rates, per capita unemployment and per capita transfer payments increase. Since per capita income is less, many people do not have money to spend on discretionary or expensive items; thus per capita sales taxes are lower. Lower sales taxes reduce the proportion of the money that goes to the schools from sales taxes and the total amount schools can spend. Residents and newcomers who do not have lucrative jobs may now know many other people who also are not benefitting from the resource extraction. These people may feel despair and turn the anger inward resulting in an increase in suicides and a decrease in criminal court cases.

The third year after the increase in activity, school expenditures decrease, sales taxes may decline, suicide rates may increase, high school completion may rise, enrolling in college drops and outmigration occurs. Again, the decrease in per capita sales taxes may be associated with the drop in school expenditures since schools would have less money to spend. The newcomers and some long-time residents may realize that they have no hope of obtaining positions in the extractive industry and that they cannot afford to live in the community; therefore, suicide rates increase and outmigration occurs.

The increase in high school completion and the decrease in enrolling in college was unanticipated. It may be possible that parents still aspire for their children to complete high school hoping that there will be an increase in resource extraction activities in the future from which their children can benefit. Freudenburg (1992) discusses how volatility in the price of the resource extracted is similar to intermittent positive reinforcement, which is the most effective reinforcement schedule. He points out that people in a community do not quit hoping that the extractive industry will become active again, because they have seen upturns and downturns in the industry previously and have learned to wait for the next wave of activity.

In the final year for which lags could be included due to the number of observations in the time series analysis, homicide rates decrease and suicide rates may decrease. It is possible that, because almost all of the other relationships have reversed by the fourth year after an increase in activity, the situation in the community has reached a new equilibrium. Therefore, social disruption has decreased, which has decreased both suicide and homicide rates. Another potential explanation for the decreases in homicide and suicide rates may be the outmigration that occurred in the previous year. Thus, some unattached young males at high risk for homicide and suicide may have left the community.

The scenario proposed would be difficult to test and would require that a path analysis with time series data be used. Such a test is only possible in communities that have had a long-term involvement in resource extraction and there are very few such communities. Also, portions of the scenario include individuals' perceptions and feelings, which would require ongoing surveys and indepth interviews to collect the data. Such a test was beyond the scope of the present study and can only be conducted well in future resource extraction projects due to the need for survey and indepth interviews throughout the phases of resource extraction activities - opportunity-threat, predevelopmental, developmental and postdevelopmental. Finally, although employment was not included in this current study, the scenario purports that jobs are a major factor in the causal chain leading from resource extraction to impacts. Thus, jobs and the idea that there is an increase in employment opportunities due to increases in extraction activities need to be included in tests of the scenario.

IMPLICATIONS FOR INTERVENTION AND MITIGATION STRATEGIES

Social problems. The results concerning the relationship between petroleum industry activity and social problems were not clear, consistent or strong; hence, it is difficult to suggest possible mitigation strategies. However, it may be possible to use programs that have reduced similar problems in other contexts. These strategies include suicide prevention programs, employment counseling, anger management training, mental health counseling, and substance abuse prevention and treatment for both newcomers and long-time residents.

Education. The outcome of the study implies that there is a need to monitor and mitigate the impacts of energy extraction on educational attainment. A mitigation strategy to encourage high school graduates to invest in college when the industry is very active is necessary as is a policy to stimulate high school students to complete high school when the industry is less active. Both mitigation activities would reduce overspecialization of the community in the energy extraction industry, which would enable the community to take advantage of or even create future economic development opportunities when the extractive industry is less active or has ceased operations entirely.

High school graduates could be encouraged to continue their education when the industry is active if employers would allow employees to work flexible hours or even part-time so employees could obtain additional education. Employers could also offer credits toward promotions for completing college courses. These incentives should be offered not only to managerial employees, but also to workers in manual labor positions. Employers could have meetings with employees, community leaders, and the media to discuss the inevitability of the bust and the need for individuals and communities to develop other skills to attract new economic development opportunities to protect the community against the economic problems associated with the decline in the extractive industry. Presentations could be made at the high schools showing students the possible jobs available with different levels of education, including information about working conditions, type of work and salary ranges. Such information may entice some high school graduates to continue their education despite the availability of positions that do not require additional education.

Although the data demonstrated that high school completion increases when industry activity increases, incentives by employers could further elevate high school completion. For example, employers could require a high school degree for more jobs and job training, especially for lucrative employment. Employers could visit high schools in the communities and discuss the employment opportunities available if students obtain their high school degree. In fact, employers could present material on the range of possible employment and show students the potential salary ranges and working conditions of positions available with and without the high school degree. If no attractive jobs are available without the high school degree and some are available with this degree, at least some students should be encouraged to complete high school.

Educational strain may be dependent on migration. It may be possible to set aside some money from the industry, the state (e.g., severance taxes), the community (e.g., unexpected additional income from sales and property taxes), and the federal government (e.g., money from lease sales) to offset additional demands for educational services that initially occur with increases in activity. Because the benefits of resource extraction are national while the impacts are local, it is logical for the federal government to set aside some money to mitigate impacts in both the highly involved communities and surrounding affected communities.

Community Economic Health. The findings demonstrate the need for a diversified economy. Economic improvement, even when the extraction industry is doing well, is not assured, but economic problems when the industry is doing poorly are highly probable. The economic decline due to the downturn in the industry can be mitigated somewhat if the community has a more diversified economy. In fact, even a more diversified involvement in the extraction—such as producing products from the extracted resource, constructing equipment needed for extraction activities, transporting the raw material and its products, wholesaling the raw material and products—may be economically beneficial, particularly when the industry is less active. On the other hand, it is possible that the economic survival of the related parishes was due to the importation of oil from other countries. If this is the case, then the economic survival of these communities would not be generalizable to other similar communities where importation of the raw resource is not possible.

If a community is undergoing rapid economic development through resource extraction and the extracted material could be obtained from other regions when it is not available in the host community, then it may be possible to ensure a more diversified involvement in the extractive industry. The creation of a more diversified involvement could be accomplished by requiring companies that are extracting the resource to site plants that add value to the material in the community from which the resource is extracted. These plants cannot be those that do low-level processing that adds little value, such as cutting lumber to make it easier to transport. To mitigate some of the negative impacts, the plants must be those that truly add value to the material, such as refining petroleum for use as gasoline and heating fuel as well as producing industrial chemicals and consumer use plastic items from the petroleum.

Another possible method of mitigating some of the negative impact on community economic health may be to set aside money from sales taxes collected by the community, severance taxes collected by the state, lease sale proceeds collected by the federal government, and the profits earned by the companies involved in extraction for job training and employment counseling of long-time residents and newcomers. However, some prior research shows that long-time residents are unwilling to undergo job training to obtain employment at power generating stations (Little and Lovejoy 1979; Lovejoy 1983). Such money could also be used to mitigate the increase in transfer payments that occurs when unemployment increases.

It might also be possible to reduce the economic rollercoaster of improved economic health succeeded by decreasing economic health by regulating the speed with which the extractive industry is allowed to develop. In the context of offshore petroleum extraction, this could be accomplished by monitoring economic impacts and adjusting the number of tracts leased and number of wells allowed to control the economic changes. Unfortunately, this strategy may have the effect of increasing the anticipated duration of extractive endeavors in the community and elongating the period of prosperity associated with the extraction which may result in a greater risk of overspecialization to the extractive industry (Freudenburg and Gramling 1992).

Another potential approach to mitigation would be to control a variable early in the causal chain leading to the impacts. Unfortunately, most of the variables in the causal chain cannot be regulated. For example, the price of oil is a powerful variable and is associated with many of the impacts. However, the price is determined by international factors beyond the control of the United States or the petroleum-producing companies themselves.

The number of developmental wells in a region could possibly be controlled. On the one hand, it is unrealistic to expect companies to lease tracts for oil extraction and not allow them to develop wells quickly when there is strong economic incentive to do so. On the other hand, the government does supervise leasing and the pacing of leasing. The political difficulty of this strategy is that there is currently no evidence that shows that slower growth would mitigate some of the impacts of resource extraction. Also, Freudenburg and Gramling (1992) suggest that the longer the anticipated duration of resource extraction, the greater the risk of overspecialization, assuming that all other factors are held constant.

Based on the scenario, migration is another important variable in the causal chain. However, it is politically infeasible to control this factor. It may be possible to reduce migration if companies were required to hire a particular portion of their employees at all levels from the host community. Also, there could be a portion assigned for the surrounding area. The regulation of this mitigation strategy would be difficult, but not impossible.

The rest of the factors in the causal chain are either late enough that control of them would not reduce the impacts or very difficult to regulate, if not impossible. Thus, with the possible exceptions of managing the development of wells and requiring that particular proportions of the employees come from the host community and the surrounding area, it is not possible to break the causal chain suggested in the scenario. Thus, mitigation appears to be necessary.

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OCS DEVELOPMENT AND COASTAL INCOME INEQUALITY: A COMPARATIVE ANALYSIS

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SUMMARY

This report summarizes preliminary findings from a comparative analysis of family income inequality that employs parish- and county-level data from the 1970, 1980, and 1990 Censuses. The focus of the analysis is trends in family income inequality in coastal Louisiana parishes adjacent to the substantially developed Outer Continental Shelf (OCS). The comparative analysis design permits inequality trends in Louisiana parishes to be compared to inequality trends in coastal counties of the Florida panhandle where there has been no significant OCS development. In addition to these spatial comparisons, the analysis design permits a temporal comparison across key decades in the recent history of the offshore oil and gas industries. While the decade of the 1970s was one of rising oil prices and greatly expanded OCS development, the 1980s saw prices fall and offshore activity generally decline. This change in development patterns is an important reason to study inequality trends in the 1970-1980 and 1980-1990 periods. Following conventions of inequality analysis, trends in family income inequality have been gauged with multiple measures of inequality computed with decennial census data. A descriptive overview of initial findings is contained in this report. In the coming months, inequality will be modeled with pooled time-series, cross-sectional estimators. In these ways, the analysis is designed to gain an understanding of the effects of OCS development on income inequality in coastal areas.

BACKGROUND AND OBJECTIVES

The study of income inequality is a long-standing tradition in sociology, economics, and other social sciences (for reviews of studies and methodologies, see Allison, 1978; Coulter, 1989). Implicit or explicit in most income inequality research is a concern for the fundamental dimension of social stratification in industrial and post-industrial societies. Rather than focusing only on income extremes--say, the very rich and/or the very poor--those who study income inequality assess the *distribution* of income throughout the population. Inequality indices thus gauge the relative *socioeconomic well-being* of all persons.

This research brings state-of-the-art inequality analysis procedures to bear on relative socioeconomic well-being in an area with the most offshore development in the U.S. Despite the rhetoric of concern about the social, cultural, and economic effects of offshore oil and gas development, there is relatively little documentation of socioeconomic effects. In view of the paucity of such research, an income distribution analysis is an undertaking of the highest priority. One reason for the lack of socioeconomic research has been the absence of viable data that span both the expansion and contraction of development off the Louisiana coast. Some coastal parishes are remote, and some are sparsely populated. Consequently, the only reliable and valid available data for such areas are decennial censuses. The recent release of county-level summary data from the 1990 Census makes it possible now to develop inequality measures from three consecutive decennial censuses.

The conceptual framework employed here is industrial restructuring, an inherently multidisciplinary approach. Scholars from a variety of social science disciplines--economics, sociology, geography, urban and regional planning, political science--have begun to adopt this perspective as they study late-industrial and post-industrial changes in spatial and social divisions of labor. The industrial restructuring approach focuses on sectoral employment shifts (e.g., from manufacturing to service), spatial employment shifts (e.g., plant relocations), and resulting changes in local economies that shape the socioeconomic well-being of residents. It is a framework built on industrial life cycle and transition themes such as sunrise industries (e.g., semiconductors), industrial decline (e.g., steel), and industrial renaissance (e.g., craft-based manufacturing). Key proponents of this perspective include Markusen (1985), Storper and Walker (1989), and Sassen (1990). Restructuring in the offshore industry is increasingly apparent in changing ownership patterns, new technologies, and the internationalization of offshore labor. It is very likely that this restructuring will be reflected in onshore income inequality patterns since 1970.

The project now underway has two phases: 1) a comparative analysis of inequality trends, and 2) a modeling of income inequality. The comparative analysis contrasts inequality patterns in coastal Louisiana parishes and panhandle counties of north Florida where there has been no offshore activity. Thus, the Florida counties are treated as a control group contrasted with Louisiana parishes. To maximize the utility and validity of comparisons, efforts have been made to pair and/or match counties and parishes as closely as possible on relevant social, demographic, and economic characteristics. The overriding concern of the comparative analysis is the extent to which patterns of income inequality in coastal parishes diverge across time from patterns in Florida and elsewhere in Louisiana.

The second phase of the analysis will involve modeling of the Louisiana and Florida inequality patterns. Pooled time-series, cross-sectional estimators will be employed that permit the error structures to be varied across time and/or spatial units. Exogenous variables will include measures of community human capital, local industrial characteristics, labor force data, urbanization, population density, and growth. Models will be designed so that separate estimates can be obtained for the Louisiana coastal parishes and the Florida panhandle counties. This will permit comparisons of the sources of income inequality in the two areas and reveal how those sources have changed since 1970. Statewide models will also be estimated to ensure that any distinctive local inequality patterns are not result of state-based factors. This second phase of the project will be carried during the winter of 1994.

OVERVIEW OF COMPARATIVE INEQUALITY ANALYSIS

Data Sources: Various county-level data sources have been relied upon in the proposed research. The primary source for family income data required for computation of inequality indices is summary tape files associated with the 1970, 1980, and 1990 Censuses (Allen, 1991; U.S. Bureau of the Census, 1980, 1990). These data files are part of the extensive holdings of the LSU Center for Life Course and Population Studies.

Measures of Inequality: Because income inequality indices have different properties and strengths, it has become standard practice for researchers to analyze multiple inequality measures. This research employs two inequality indices: the Gini coefficient and Theil's information-theoretic inequality measure.

Based on the Lorenz curve, the Gini coefficient has been the most widely used inequality measure. It will be employed in the proposed research as defined by Treas and Walther (1978):

$$G = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} | x_j y_i - x_i y_j |$$

where n = the number of income categories, x_i = the population share of the ith group, and y_i = its income share. The measure is most sensitive to income transfers that occur in the middle of the income distribution.

Despite its ease of computation and interpretation, the Gini coefficient has been shown to be problematic (Allison, 1978; Coulter, 1989). Based in information theory, Theil's (1967) inequality measure overcomes most problems associated with the Gini coefficient. Following Treas and Walther (1978) and employing natural logarithms, the Theil measure can be defined as

$$T = \sum_{i=1}^{n} y_i \log \left(\frac{y_i}{x_i} \right)$$

with the elements of the equation defined in the same way as for the Gini coefficient. The Theil measure is thought to be most sensitive to changes in the lower tail of the income distribution.

Figure 1 displays our initial findings for the Gini and Theil inequality measures. The results are based on the Louisiana Parishes of Cameron, Vermilion, Iberia, St. Mary, Terrebone, LaFourche, Plaquemines, and St. Bernard. Florida panhandle counties included are Santa Rosa, Okaloosa, Walton, Bay, Gulf, Franklin, Wakulla, Jefferson, and Taylor. The overall inequality data suggest that both coastal areas experienced significant declines in family income inequality between 1970 and 1980. Between 1980 and 1990, however, the patterns diverge. Though the counties and parishes experienced increasing income inequality across the 1980s, the Louisiana parishes saw sharper increases in overall inequality. We strongly suspect that this is due to the diminishing of OCS activities associated with the decline of oil prices during the 1980s. This hypothesis will be tested in the modeling phase of the project.

The overall inequality scores masked some important differences among parishes and counties in Louisiana and Florida. Using a hierarchical clustering algorithm, parishes and counties were matched on a number of key 1970 dimensions, including demographic factors. Demographic variables include population, racial composition, income, households on public assistance, education level, migration, and unemployment rate. Three strongly matched pairs of parishes/counties were derived: LaFourche, Santa Rosa; Vermilion, Walton; and St. Mary, Taylor. Figure 2 details the inequality patterns for these three pairs of matched counties as measured by the Theil coefficient. The results indicate that inequality decreased more sharply in the Louisiana parishes during the offshore boom. Since the Theil coefficient is more sensitive to the lower end of the income distribution, these findings suggest that effects of the OCS development activities quickly reached low-income families. We will attempt to test this hypothesis in the modeling phase as well.

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A SOCIOECONOMIC OUTER CONTINENTAL SHELF ISSUE ANALYSIS OF STAKEHOLDERS IN THE CENTRAL GULF OF MEXICO

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INTRODUCTION

This project will identify the levels of support for, and opposition to, Outer Continental Shelf oil and gas activities by the various stakeholder groups in the coastal central Gulf of Mexico (Alabama, Mississippi, and Louisiana); the social and economic issues and concerns of these groups; and the underlying assumptions concerning the effects of Outer Continental Shelf activities. The project suggests ways to focus research and management efforts effectively on significant issues of public policy.

The current project, an issue analysis of the Gulf of Mexico, was a high-priority recommendation that came out of an MMS-funded workshop (see Gramling and Laska 1993) held in New Orleans in September of 1992. The workshop was designed to produce a recommended research agenda to address the appraisals made by the National Research Council (1989; 1992).

An issue analysis identifying the social and economic issues connected to oil and gas activity in the central Gulf of Mexico is important for two reasons. First, as noted above, the array of various levels of opposition to and support for the Outer Continental Shelf leasing program is not a simple one. The delineation of the various levels of support and opposition and how they are distributed within the central Gulf, is the first step toward understanding this complex phenomenon. Second, and more importantly, an issue analysis will uncover the reasons behind the various levels of support for or opposition to Outer Continental Shelf activities. What are the assumptions that the various stakeholders make about the nature, both positive and negative, of various Outer Continental Shelf activities? This is a critical question not only for understanding the phenomenon, but also for predicting the socioeconomic impacts of various activities that potentially take place on the Outer Continental Shelf. As Gramling and Freudenburg (1992; see also Freudenburg and Gramling 1992) have shown, human social systems respond not only to alterations in the physical environment, such as those produced by various development projects, but also to changes in the social environment, such as those produced by new information concerning proposed actions. While there has been no physical development activity (e.g., exploratory or development drilling) associated with the federal leasing program in the vicinity of the Florida Keys since the 1950s, significant, empirically verifiable changes in the human environment have resulted simply from proposing these activities, changes which have had dramatic effects on the leasing program itself, including a Presidential moratorium. In short, knowing the assumptions that underlie the support or opposition to Outer Continental Shelf activities allows for a better understanding of what the effects of those activities will be, and consequently to more informed decision making.

Specifically, the objectives of this research are

- to identify and describe the various stakeholder groups in the coastal central Gulf of Mexico, define their interests and the degree of their concerns about Outer Continental Shelf oil and gas activities.
- to identify the specific social and economic issues related to the central Gulf of Mexico oil and gas activity considered important by different major stakeholders and other knowledgeable individuals.
- to identify the underlying assumptions on the effects of Outer Continental Shelf activities, which determine stakeholders' positions on the social and economic issues.
- to suggest ways to further enhance research initiatives by ensuring their relevance to stakeholders' concerns.

RESEARCH METHODOLOGY

With an issue analysis, the research strategy is different from standard surveys where the interest is focused primarily on representativeness. With surveys, the researcher wants to be able to statistically generalize to the public at large. The effectiveness of surveys, of course, depends on the quality of the questions asked. Issue analysis targets the issues as they are expressed by those who will later act on the basis of their stand on the issue. In issue analysis, the population becomes the array and positions on those issues rather than the individuals who hold positions on those issues. Whereas with a standard sampling methodology the researcher must be very careful to sample all the elements of the population, with issue analysis the researcher must be very careful to sample across all of the issues and positions on the issues of interest. To do this, a "theoretical" sampling procedure (often called snowball sampling) is used, which allows the researcher to target issues.

Snowball sampling is a method through which the researcher develops an ever-increasing set of sample observations. One respondent in the population is asked to recommend others for interviewing, and each of the subsequently interviewed participants is asked for further recommendations (Babbie 1992). This is the only feasible type of sampling procedure which will fit the requirements of the project to 1) identify various stakeholder groups through a referral process and 2) retain flexibility in the field to identify and sample stakeholder groups as they are "discovered" through the sampling process. Sampling continues until the investigation exhausts the issues (i.e. no new ones are being found). At this point, a content analysis of the interviews will allow the relative strength (i.e. proportionately how many individuals hold particular positions, and how strongly do they hold them), of the positions to be determined.

This type of analysis is most useful in identifying the strength and organization of various stakeholder groups that may support or oppose an activity or in identifying the appropriate categories for use in a type of data collection that uses standard methodology where the interest is statistical generalization.

Specifically, the research has nine major components:

1. A review of existing information on key stakeholder groups and their concerns. This review involves both a literature review and initial telephone interviews with currently known key informants in the central Gulf of Mexico.

2. The creation of a data base that allowed the comparison of employment, industrial sector, occupational, income, and household data at the state, county, and community level across the entire three central Gulf states using the recently available U.S. Census summary tables available on CD ROM. The data base covered the three central Gulf of Mexico states Louisiana, Mississippi, and Alabama, all counties/parishes in these states, and all "places" (cities) reported by the census.

3. The selection of relevant sample communities, and/or regions, based on the information obtained from components 1 and 2 above. After examination of the communities in the data base, initial contacts in the communities, and consultation with representatives from Minerals Management Service the target communities were selected. The area chosen for investigation ranged from Cameron to Gulfshore, and included the communities of Cameron, Lafayette, Morgan City, Grand Isle, Gulfport, Biloxi, Mobile (very limited sampling), Fairhope, Dauphin island, Orange Beach and Gulfshore. Data collection was begun with a letter of authorization to spend funds, in June 1993 using Grand Isle as a test community.

4. The identification of additional key informants: In each of the selected communities key stakeholder informants were identified. In each community these informants were the start of the "snowball" sampling procedure. In each community or region our first key informants were public officials/community leaders who had detailed knowledge about the area. We asked these individuals what groups have interests concerning OCS activities in order to 1) test and potentially expand our initial assumptions concerning stakeholder groups and 2) obtain references on specific individuals within these groups to interview them.

5. Key informant interviews. We interviewed a wide variety of individuals across oil, gas, and support sectors of the economy, commercial fishermen of various types, recreational fishermen

and boaters in the sample communities during July and August of 1993. These interviews solicited information about the important issues and concerns with respect to OCS activity and how it is believed OCS activities will affect the community.

6. Examination and copy of relevant local documents noted by key informants. This was limited to instances where the position(s) of specific stakeholders have been put forth in writing (e.g., position papers, correspondence, reports), or where the documents could provide important information about the group or the community.

7. Transcription of interviews. The interviews are currently being transcribed. When this process is completed the data will be loaded into an analytical software program for analysis.

8. Content analysis of interviews and relevant local documents. Content analysis is a process by which specific concepts that appear in the documents to be analyzed (here the transcripts of the interviews and the local documents) are used to generate coding categories, and the resulting appearance of the concepts across categories of individuals or groups is analyzed. This is not simply a counting procedure. The key to content analysis is the identification of the appropriate concepts embedded in the relevant documents (in this case transcripts), and the analysis of the ways in which the concepts appear across the interviews. For example, a key concept that might emerge is that of "economic development." Once identified in the interviews, a key concept would be identified by a variety of words would be chosen (e.g., economic, jobs, training, etc.) that would allow the researcher to search the interviews electronically for these key words, determine if economic development is an issue in that document and to what extent that issue dominates the transcript. Once instances of economic development have been identified, then the researcher can (for example) see if this concept is more likely to be raised by individuals familiar with OCS activities than those relatively unfamiliar with OCS activities or with certain stakeholder groups and not with others.

9. Analysis of results and report writing.

PRELIMINARY FINDINGS

Although no formal analysis of the data has yet occurred, as the transcription is not complete, several trends seem to be emerging

1. Outer Continental Shelf activities are generally supported in Louisiana for most stakeholder groups. The exceptions to this are several environmental groups and some of the alternative users of coastal waters. Most common among this latter group are shrimpers who contend that some areas (e.g., east of the mouth of Bayou Lafourche) cannot be shrimped due to the amount of discarded oilfield trash on the bottom. Some of these areas appear to be in state waters and some in the vicinity of some of the earliest Outer Continental Shelf development. In general, it is somewhat difficult to tell without more careful analysis of the data the level of problems that shrimpers have with Outer Continental Shelf activities because of the extent of the conflict and opposition that has arisen in the shrimping community over the use of TEDs.

2. Most business interests in coastal Mississippi are not excited about offshore oil, but they are not organized or focused on the issue. Community leaders in Gulfport and Biloxi have in the past opposed Outer Continental Shelf activities, but the current gambling fiasco has them so focused on gambling as an economic activity that Outer Continental Shelf concerns have shifted into the background.

8. Mobile Bay appears to be the dividing line for real opposition to offshore activity. Baldwin county took the state to court to stop the sale of state leases, and community residents in Orange Beach and Gulfshore voice frequent, strong opposition to offshore development. It is probably not coincidental that beach-oriented tourism really begins west of the mouth of Mobile Bay and continues into Florida.

4. In general, most of the people we interviewed were ignorant of Minerals Management Service and its role in offshore development.

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SESSION 2D

LATEX I: LATEX SHELF STUDY PROGRESS REPORT

Session: LATEX I: LATEX SHELF STUDY PROGRESS REPORT

Co-Chairs: Dr. Murray Brown and Dr. Denis Weisenberg

Date: December 15, 1993

Presentation	Author/Affiliation
Introduction	Dr. Murray Brown Minerals Management Service Gulf of Mexico OCS Region
Near-Inertial Oscillations over the Texas-Louisiana Shelf	Dr. Changsheng Chen Dr. Robert Reid Dr. Worth D. Nowlin, Jr. Department of Oceanography Texas A&M University
On the Reversal of the Mid-Shelf Circulation in the LATEX Region During June 1993	Dr. Matthew K. Howard LATEX-A Data Office Geochemical Environmental Research Group College of Geosciences and Maritime Studies Texas A&M University
Effects of LATEX Cyclogenesis on the "Blizzard of the Century" 12-15 March 1993	Dr. S. A. Hsu Coastal Studies Institute Louisiana State University
LATEX Shelf Hydrography in August 1992 and August 1993—A Comparison	Dr. Denis A. Wiesenburg Geochemical and Environmental Research Group Texas A&M University
Waves and Currents During Hurricane Andrew as Seen by the LATEX A Array	Dr. Steven F. DiMarco Dr. Norman L. Guinasso, Jr. Mr. F. J. Kelly Mr. Linwood L. Lee, III Geochemical and Environmental Research Group Texas A&M University

NEAR-INERTIAL OSCILLATIONS OVER THE TEXAS-LOUISIANA SHELF

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Dr. Robert Reid
Dr. Worth D. Nowlin, Jr.
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INTRODUCTION

Wind-induced, near-inertial oscillations over the Texas-Louisiana shelf during spring and summer 1992 are described using the moored current meter and wind data taken by the Texas-Louisiana Shelf Circulation and Transport Processes Study (LATEX A, see Figure 2D.1). First, the spatial distribution of energy and modulation time scale of near-inertial currents over the shelf are presented based on rotary spectra, complex demodulation, and variances. Second, the meteorological field and associated frontal passages are described using daily weather maps and surface wind measurements from surface buoys over the northwest of Gulf. Third, a possible driving mechanism for near-inertial currents is discussed based on the coherence estimate for winds and currents and a simple mixed-layer model. Finally, a summary completes this presentation.

ANALYSIS OF CURRENTS

Rotary spectral analysis was carried out on the 3-h, low-passed records of currents made during the study period of April-October 1992. A sharp spectral peak centered at near-diurnal frequency was found at instruments over the shelf (Figure 2D.2). The energy contributing to this near-diurnal peak decreases with depth and was almost entirely clockwise-rotating motion, with some contribution from counter-clockwise rotation near the bottom. The energy of diurnal tides was removed from the records using the up-dated harmonic analysis program developed originally by Forman (1979), which shows that the energy of diurnal tides was much weaker than the near-inertial motions at all moorings except those nearest to the coast.

In general, the amplitudes of near-inertial currents decrease with depth at each mooring over the entire shelf (Figure 2D.3). Vertical phase distribution of near-inertial currents is characterized by first baroclinic mode-like structure; near-inertial oscillating currents in the deeper stratified layer are approximately 180\degrees out of phase with those in the upper mixed layer (Figure 2D.3). Such phase distributions tended to disappear in cases of weak vertical stratification (Figure 2D.4). This vertical structure is similar to that reported by Wood and Chapman (1989 unpublished manuscripts) at Nantucket Shoal over the New England shelf and by Millot and Crepon (1981) over the continental shelf of the Gulf of Lions, indicating the similarity in near-inertial oscillation over different continental shelves.

The near-inertial oscillations are almost in phase in the cross-shelf direction over the shelf during each individual event (Figure 2D.5). Study of variances shows that the near-inertial energy has a maximum at the shelf break and decays gradually toward the coast, but rapidly offshore (Figure 2D.6).

METEOROLOGICAL FIELD

Generally speaking, the near-surface atmospheric flow over the LATEX shelf was dominated in spring through summer 1992 by a subtropic anticyclone with high pressure centered near 27 degree N east of Florida. This large-scale, high pressure system drives southeast or sometimes south wind in the marine boundary layer over the entire shelf. The synoptic-scale wind field was distorted intermittently during the passage of fronts associated with low pressure cells (Figure 2D.7). From late April to May, the direction of the wind vector turned toward the southeast with the passages of three cold fronts. In June and July, however, the passage of southeast-moving front was restricted to north of the LATEX region. The resulting flow in June was dominated by southeast or southwest winds over the shelf, with occasional northeast winds during strong frontal passages (Figure 2D.8).

Rotary spectra for hourly wind velocities at all meteorological records over the shelf and in the open Gulf show relatively significant clockwise-rotating energy peaks at diurnal periods. This peak energy level is about one order smaller than that of the low-frequency winds (Figure 2D.9). The magnitude of diurnal wind fluctuation was intermittent with a modulation scale of five to seven days, and the

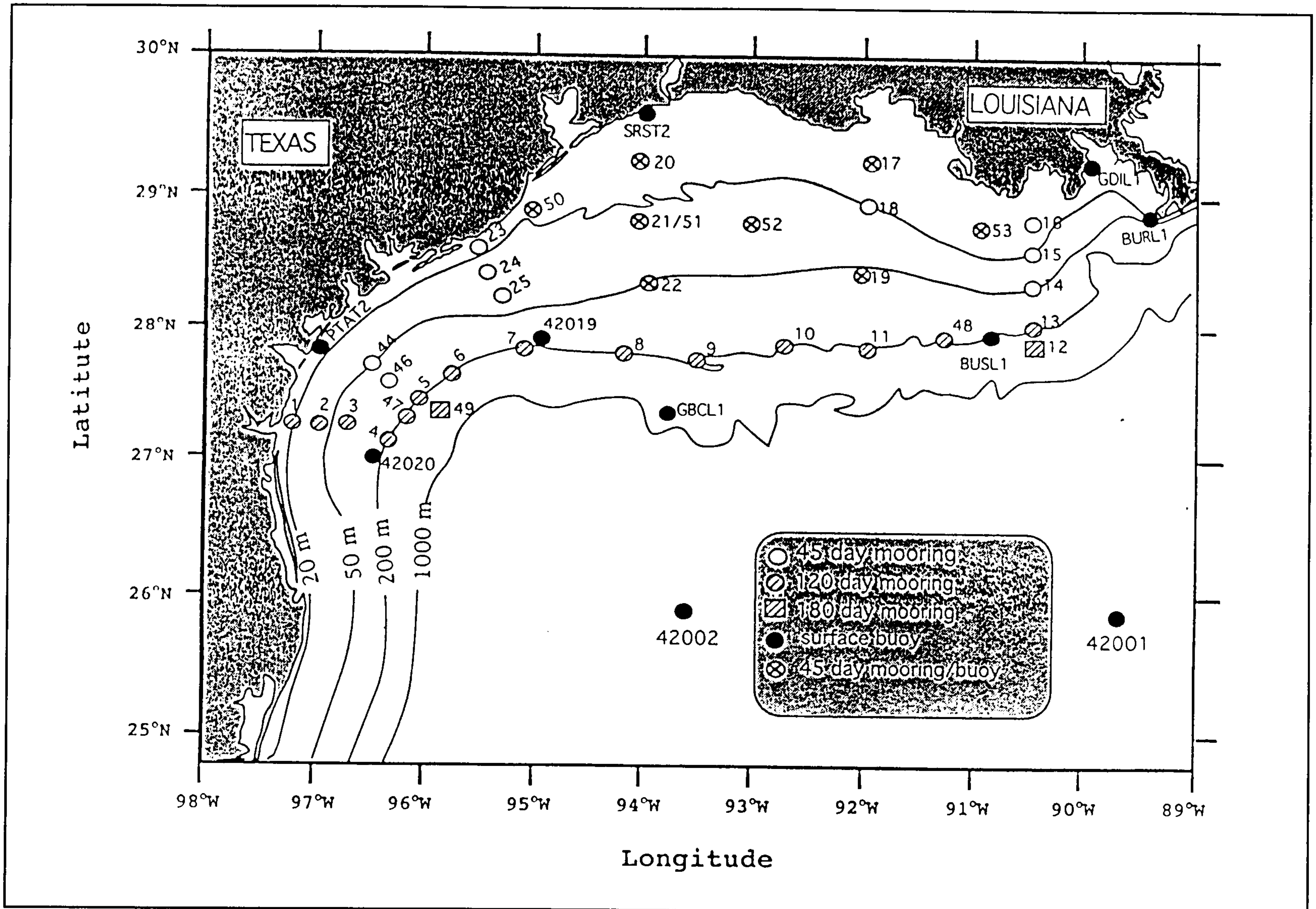

Figure 2D.1. Locations of current meter moorings and meteorological buoys. Current meter moorings are marked based on three maintenance schedules shown in the lower part of the map. The LATEX buoys are placed at moorings 17, 19, 20, 21/51, 22, 50, 51 and 53. The oil platforms, NOAA buoys, and other coastal buoys are marked with filled circles.

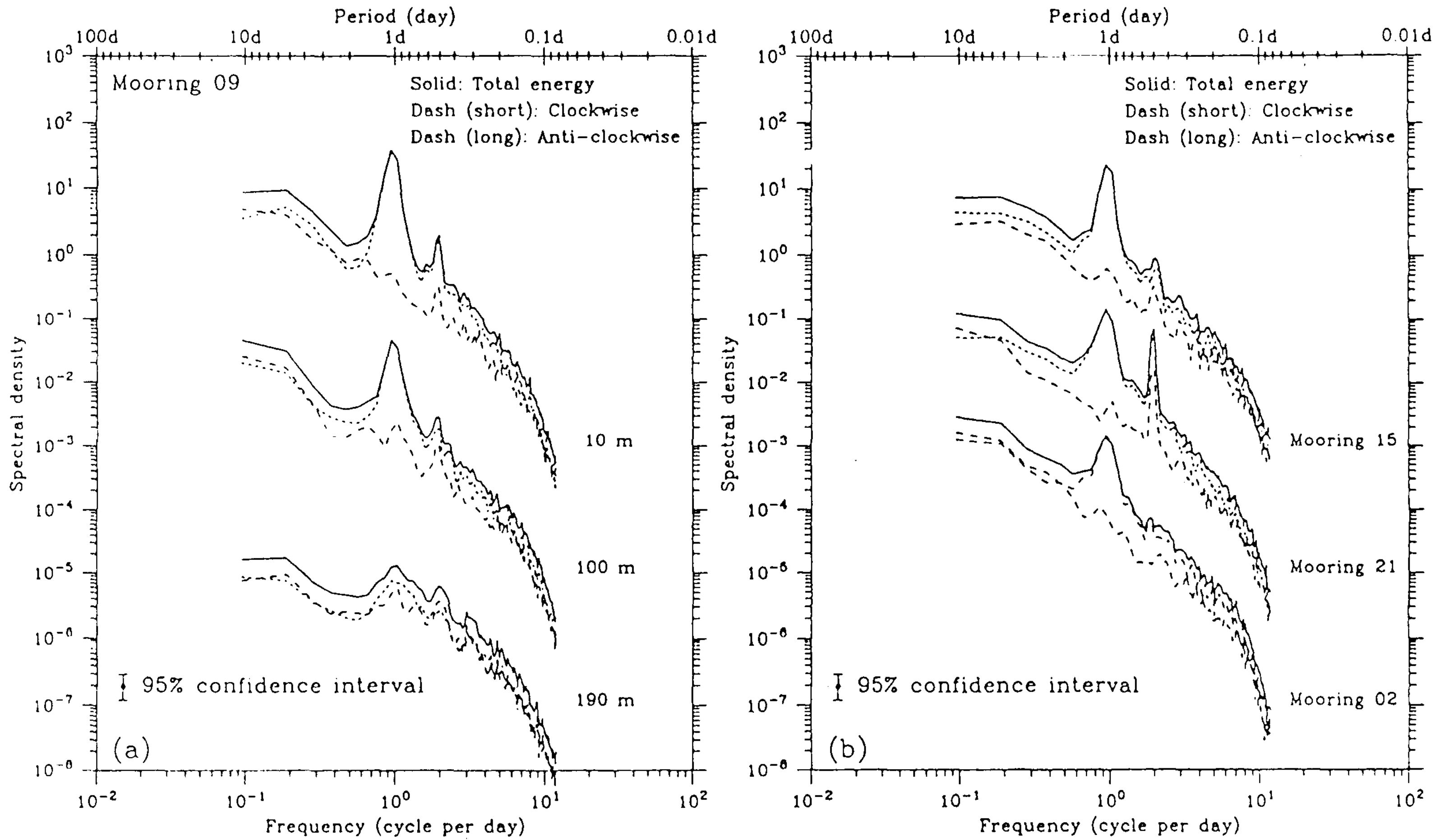

Figure 2D.2. Rotary spectra of water currents at three depths of 12, 100, and 190 m at mooring 09 (a) and at 10-12 m at moorings 15, 21, and 02 along the 20-m isobath (b). Solid, long dash, and short lines are spectra of total kinetic energy, clockwise, and counterclockwise rotating currents, respectively. The spectra at 100 and 190 m in (a) and moorings 21 and 02 in (b) are shifted downward by 10^2 and 10^4, respectively. The unit of special density is $(cm/s)^2$/cpd.

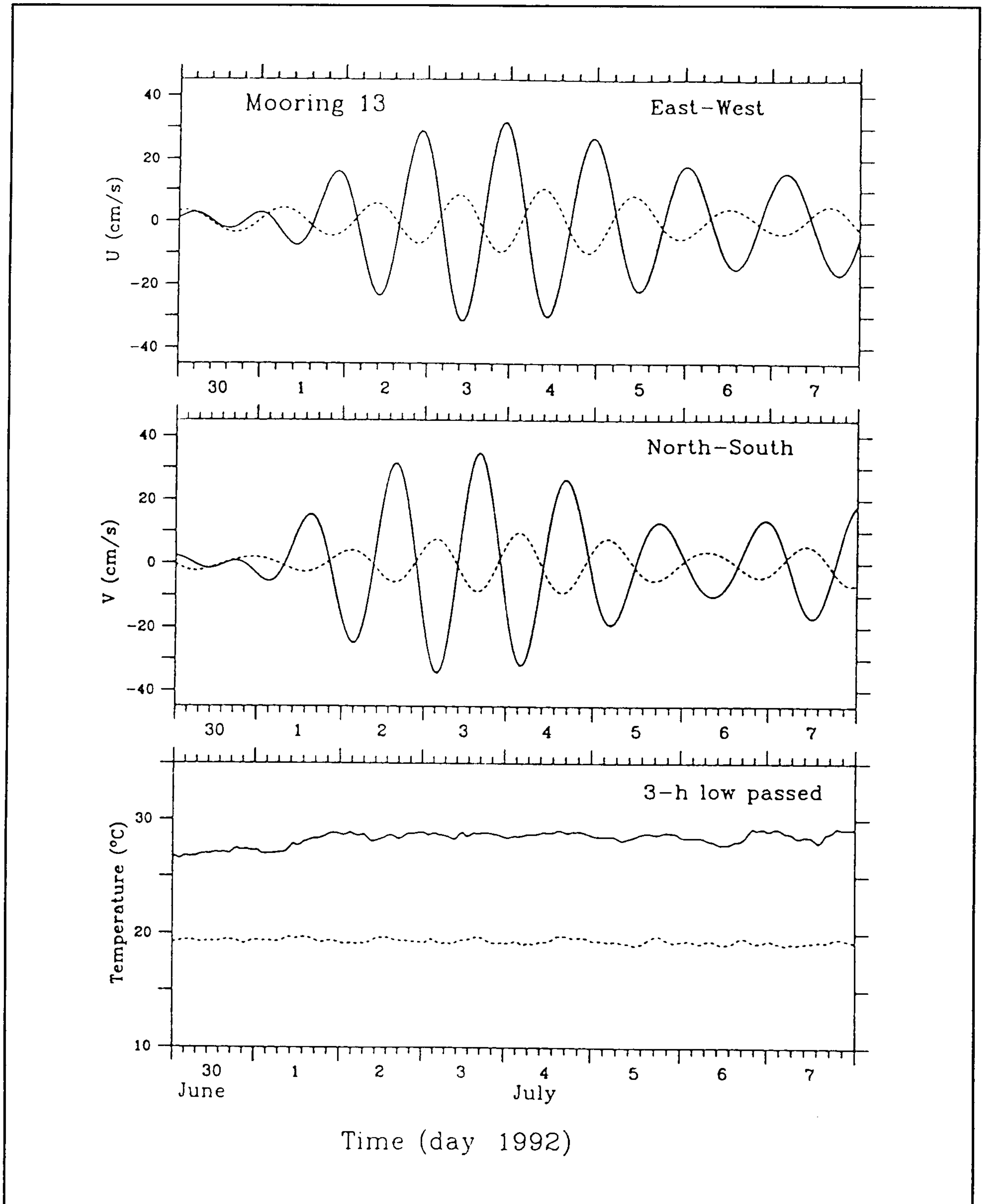

Figure 2D.3. Time series of the band-passed residual currents and the 3-h low-passed water temperature from 30 June to 7 July 1992 at depths of 12 (solid line) and 100 (dash line) m at mooring 13. The width of the band is from 1/29 hours to 1/21 hours.

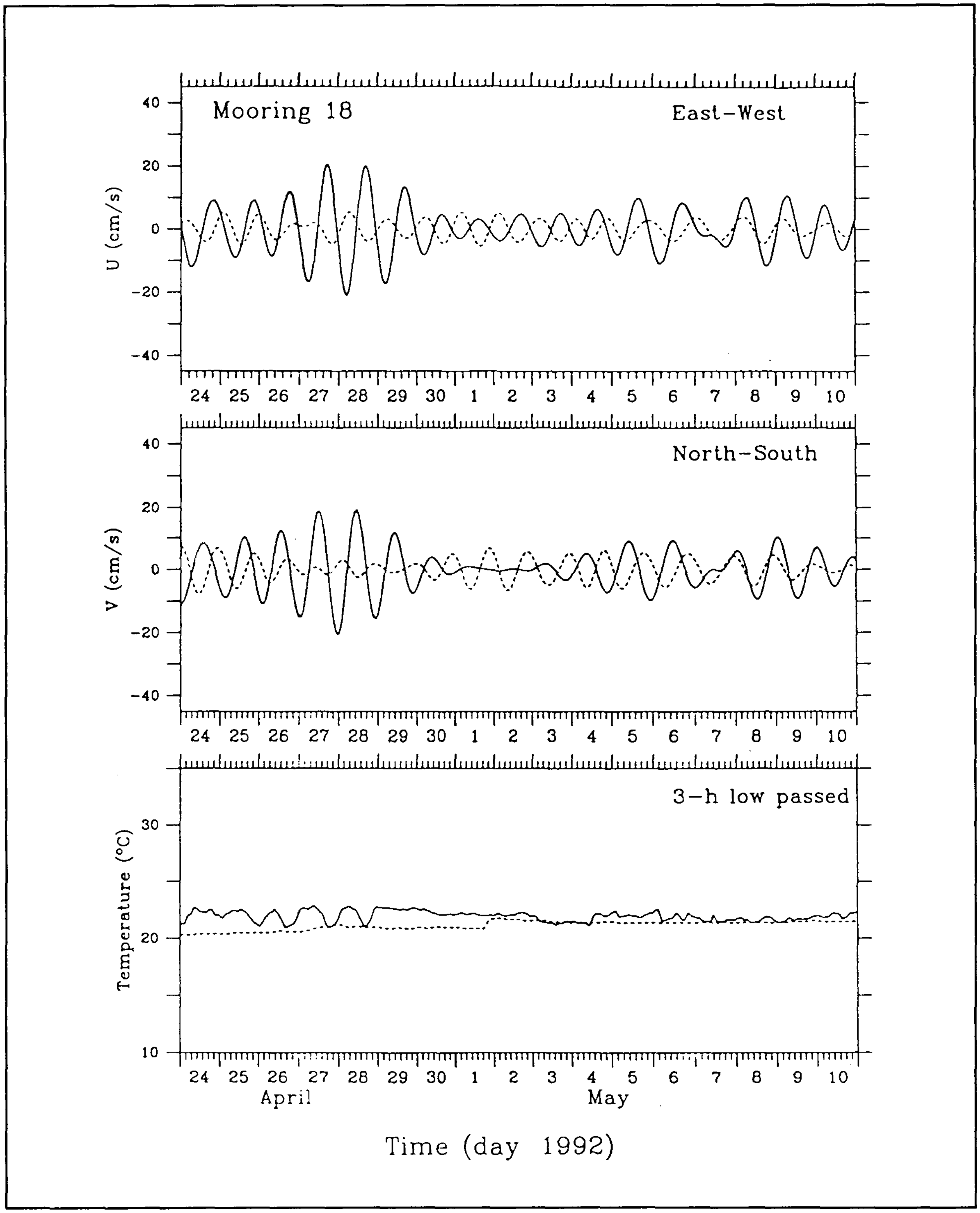

Figure 2D.4. Time series of the band-passed residual currents and the 3-h low-passed water temperature from 24 April to 10 May at depths of 10 (solid line) and 19 (dash line) m at mooring 18. The bandwidth is the same as Figure 2D.3.

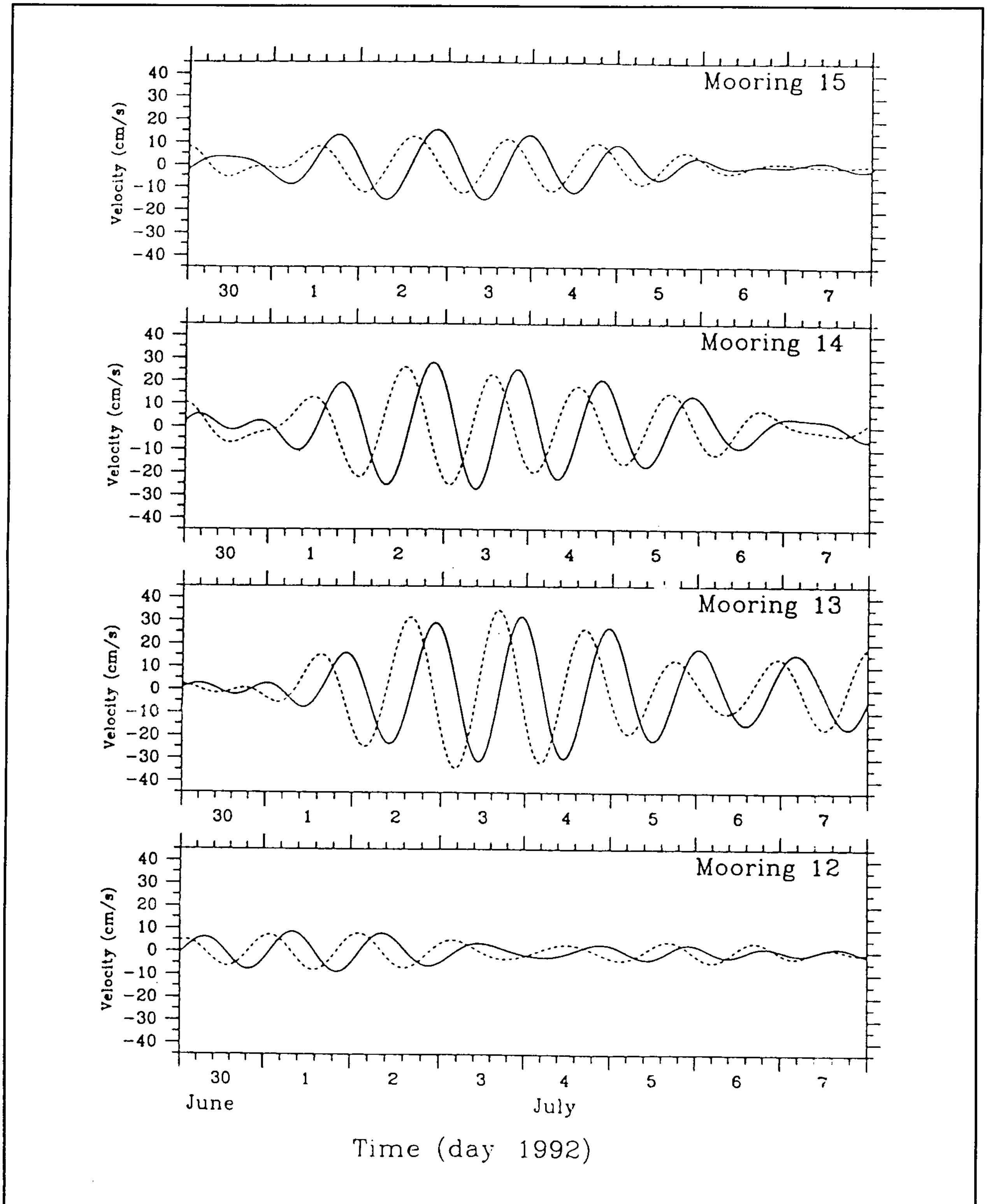

Figure 2D.5. Time series of the band-passed residual currents at top meters of moorings 15, 14, 13, and 12 during 30 June-7 July 1992. Solid and dash lines are the east-west (U) and the south-north velocity (V) components, respectively. The width of the band is the same as Figure 2D.3.

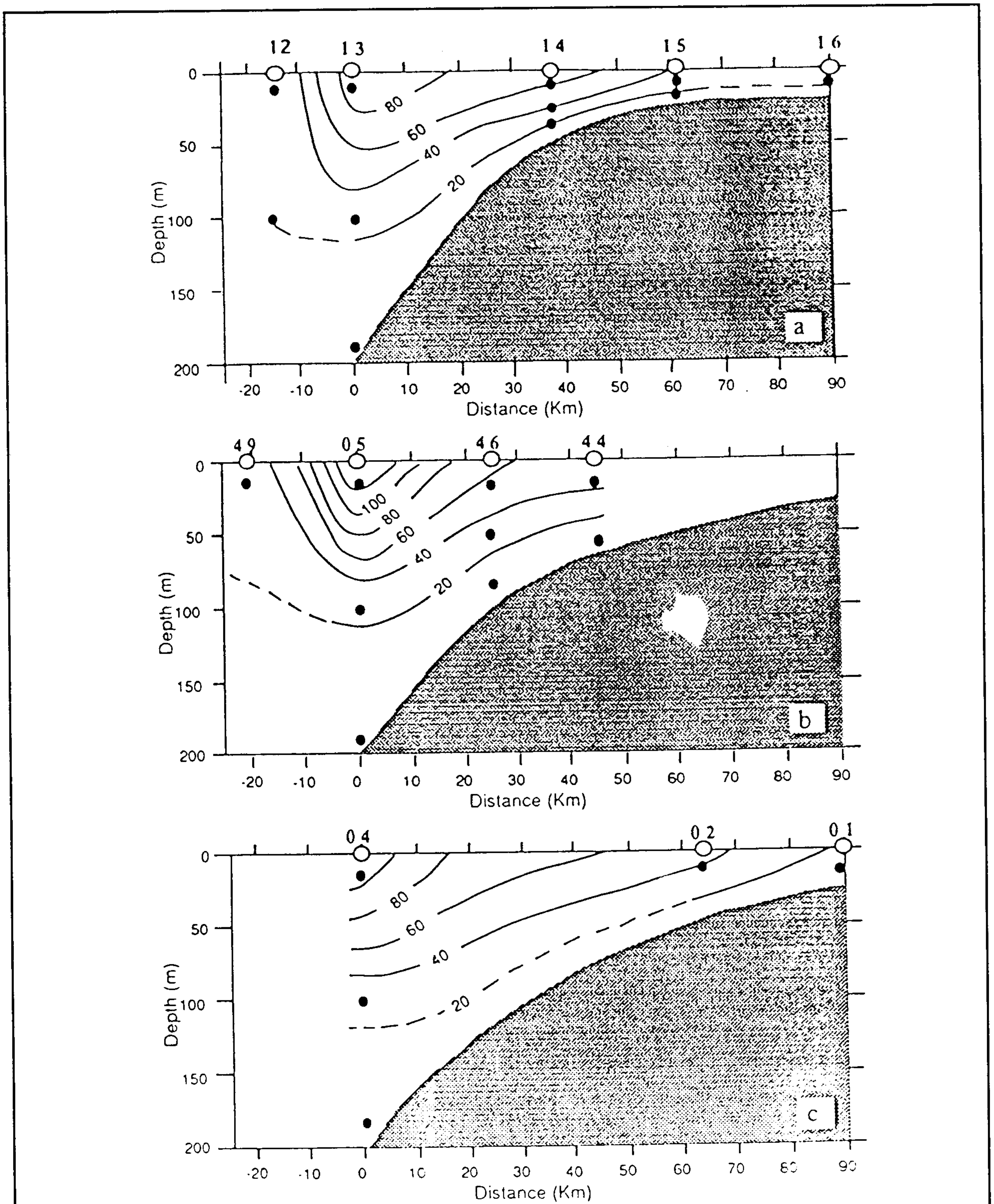

Figure 2D.6. Distributions of the variance of the band-passed residual currents observed from 15 April to 22 July 1992 at three cross-shelf sections from east to west over the LATEX shelf. The number at top in each figure is mooring number. The unit in the contours is cm^2/s^2.

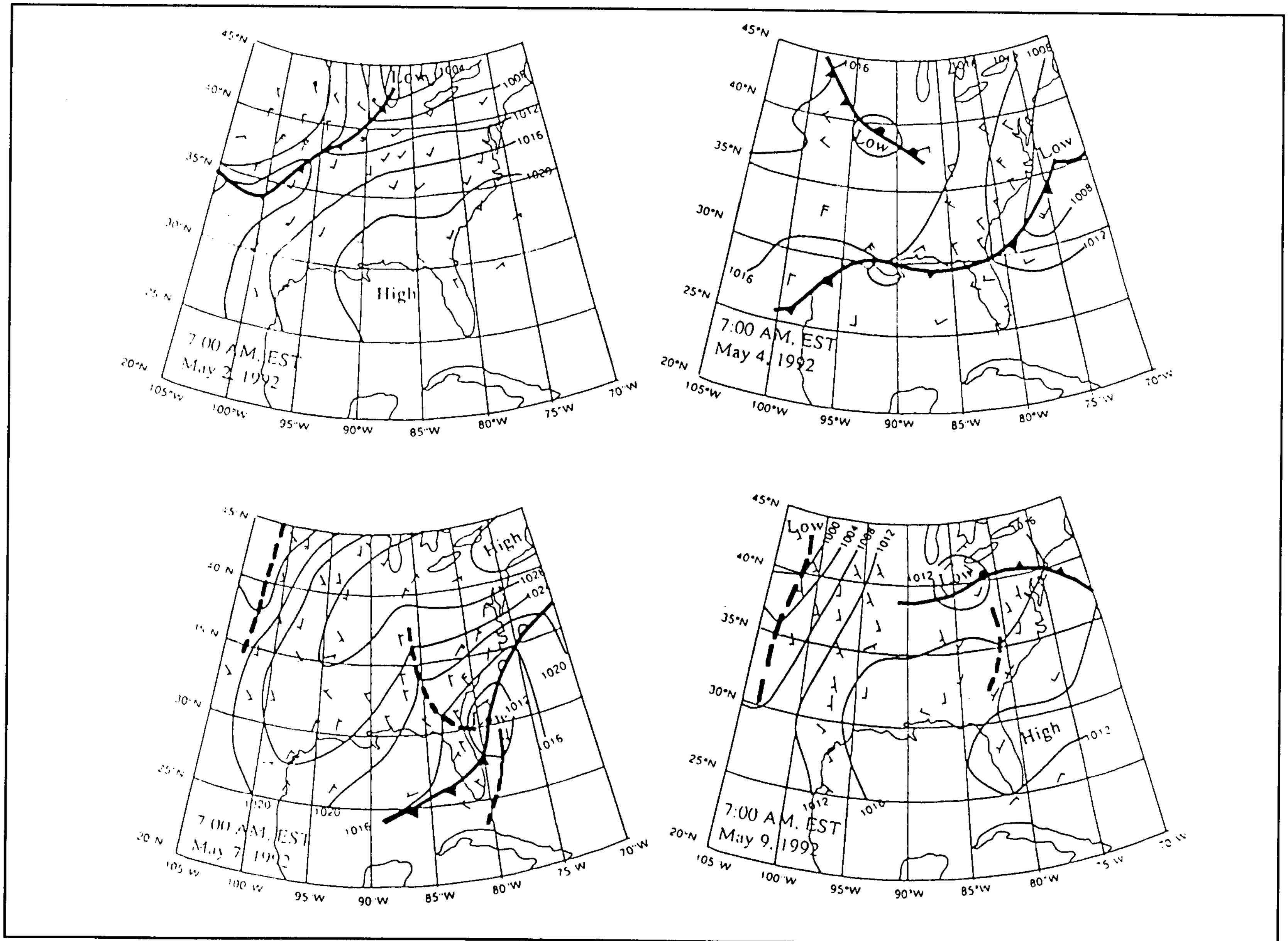

Figure 2D.7. Weather maps at 1000 mb selected at 7:00 AM (EST) on 2, 4, 7, and 9 May 1992.

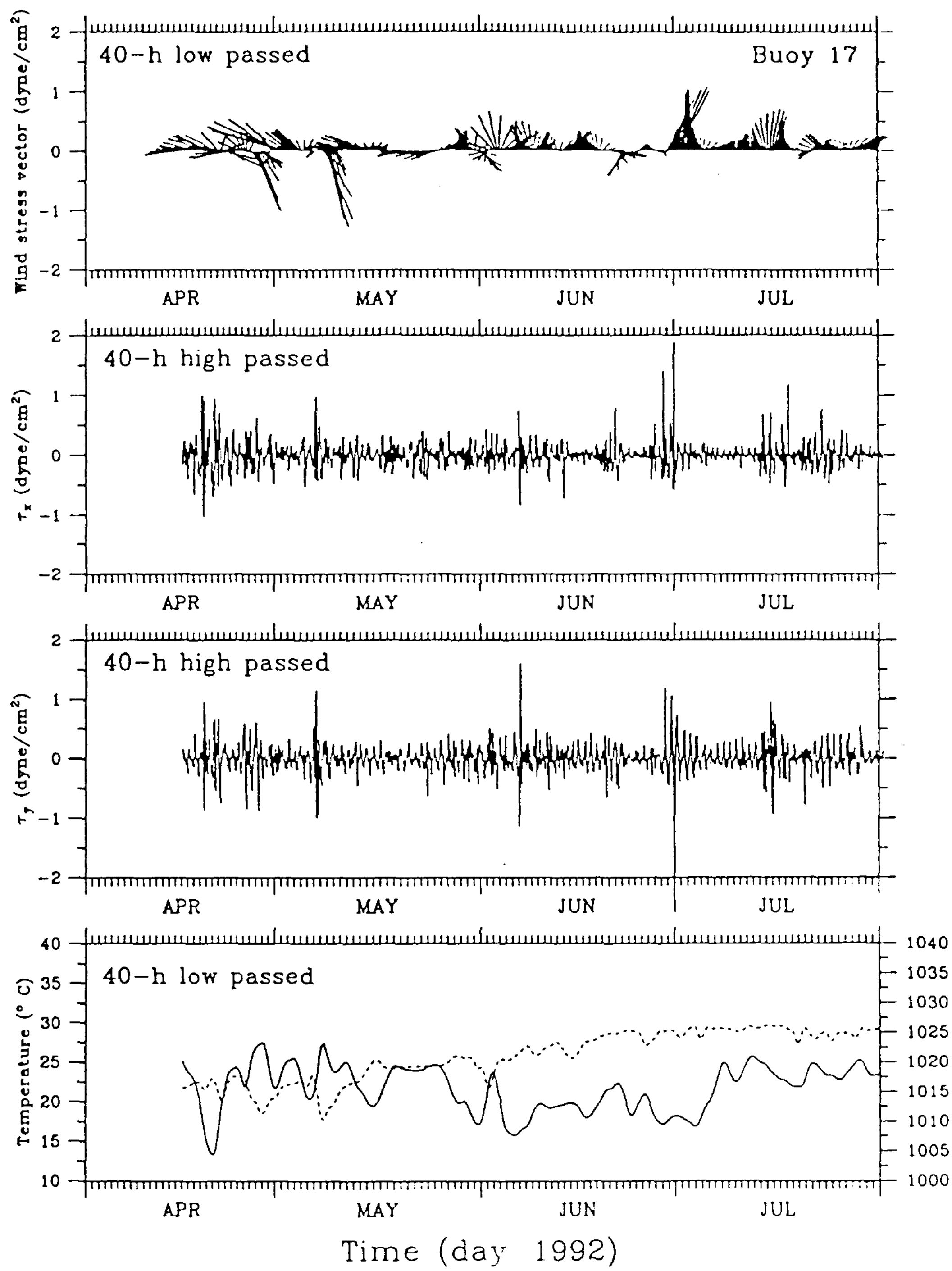

Figure 2D.8. Time series of 40-h low-passed surface wind stress vectors, the x and y components of 40-h high-passed surface wind stress, and the 40-h low-passed air temperature (solid line) and pressure (dash line) at buoy 17 from April to July 1992.

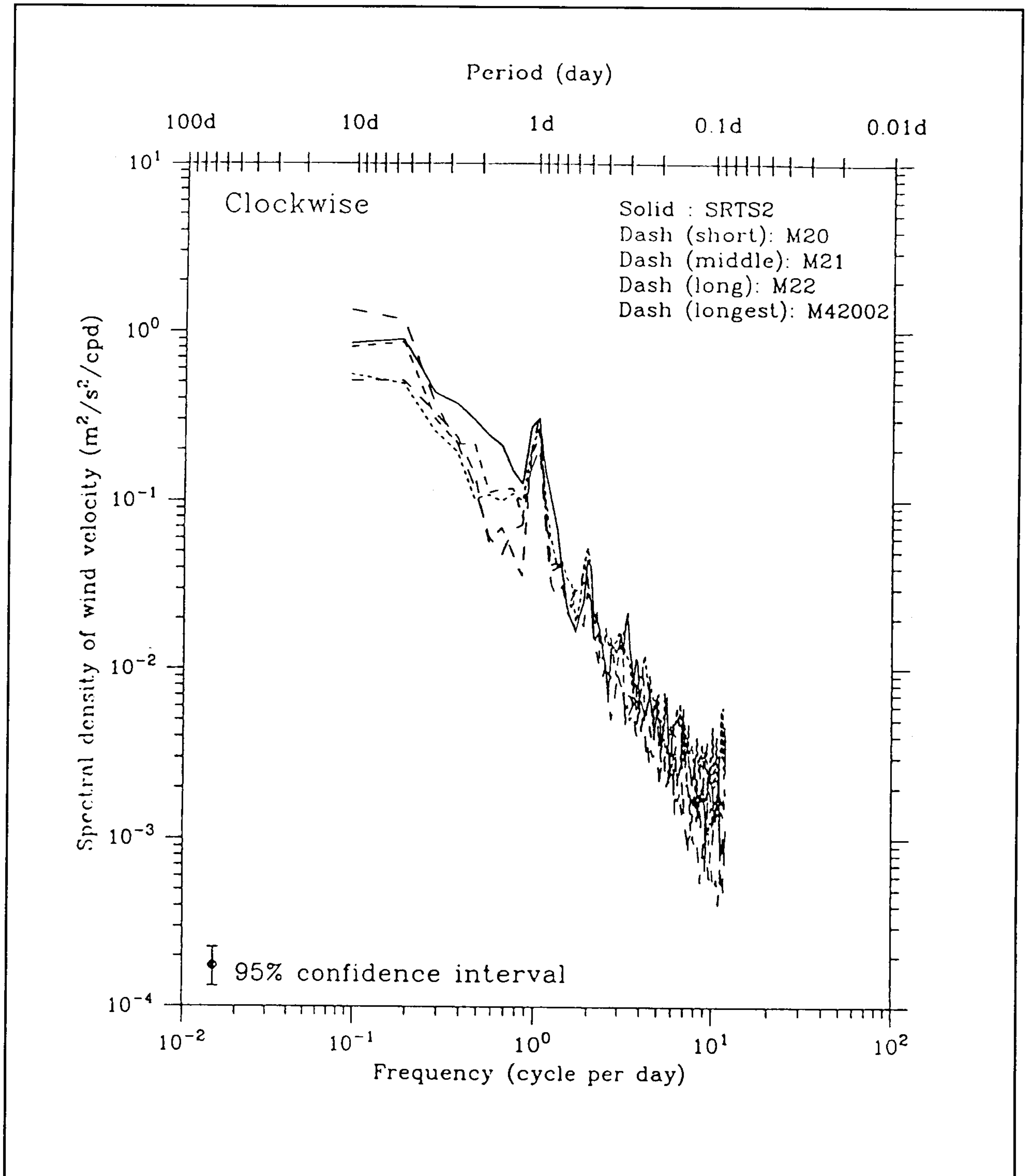

Figure 2D.9. Clockwise-rotating rotary spectra for surface wind velocity at SRST2 (solid line), LATEX buoys 20-22, and NOAA buoy 42002. Spectral densities for LATEX and NOAA buoys are plotted using dash lines with a shortest interval at buoy 20 near the coast and with a longest interval at buoy 42002. Estimates of rotary spectra were made using the hourly-sampled wind data obtained from mid-April to late July 1992. Segment points of 256 with overlap points of 128 were used for spectral analysis, and the unit of spectral density is $(m/s)^2$/cpd.

fluctuations are similar in the cross-shelf direction (Figure 2D.10). The diurnal wind variation is almost in phase with the diurnal variation of air pressure gradient during frontal passages. The seabreeze is restricted to within about 50 km of the coast. The feedback effect of near-diurnal variation of air-sea temperature difference on the diurnal variation of surface winds appears to be small over the shelf, even though both of them are almost in phase.

DRIVING MECHANISM FOR NEAR-INERTIAL CURRENTS

Similarity is found in the near-inertial frequency band of rotary spectra between the surface wind stress and water currents at each mooring where wind data are recorded on either a LATEX mooring or a nearby oil platform (Figure 2D.11). Strong, near-diurnal oscillations of water currents occur during periods of large wind variation (Figure 2D.12). This suggests that the near-inertial currents may be forced by temporal variation of local surface wind stresses during frontal passages.

The results obtained from a simple mixed layer model forced by the real surface wind stress give a reasonable prediction for the near-inertial current in the mixed layer when the downward transfer of the near-inertial energy to the deep stratified layer is weak (Figure 2D.13). Diagnostic analysis for model results suggests that the large, near-inertial oscillations over the LATEX shelf are generated mainly by the temporal high frequency (near-diurnal) variation of the wind stress coincident with frontal passages (Figure 2D.13).

SUMMARY

Wind-induced near-inertial oscillations over the Texas-Louisiana shelf in spring and summer 1992 have been described using the moored current meter and wind data taken by the Texas-Louisiana Shelf Circulation and Transport Processes Study. Rotary spectral analysis show a clockwise-rotating energy peak at near-inertial frequency for water currents on each current meter mooring. Vertical structures of the near-inertial oscillation are characterized by the first baroclinic mode with near 180\degrees phase difference between upper mixed and lower stratified layers. The oscillations are intermittent with a modulation time scale of about five to seven days. They are surface-intensified with maxima near the shelf break, decaying gradually toward the coast but rapidly offshore. Similarity is found between the temporal variation of wind stress and the near-inertial currents. When the downward transfer of the near-inertial energy to the deep stratified layer is small, a simple mixed layer model forced by the real wind stresses provides a reasonable prediction of the near-inertial currents in the mixed layer. Study suggests that the large near-inertial oscillations over the LATEX shelf are generated mainly by temporal high frequency (near-diurnal) variation of the surface wind stress occurring during atmospheric frontal passages.

ACKNOWLEDGEMENTS

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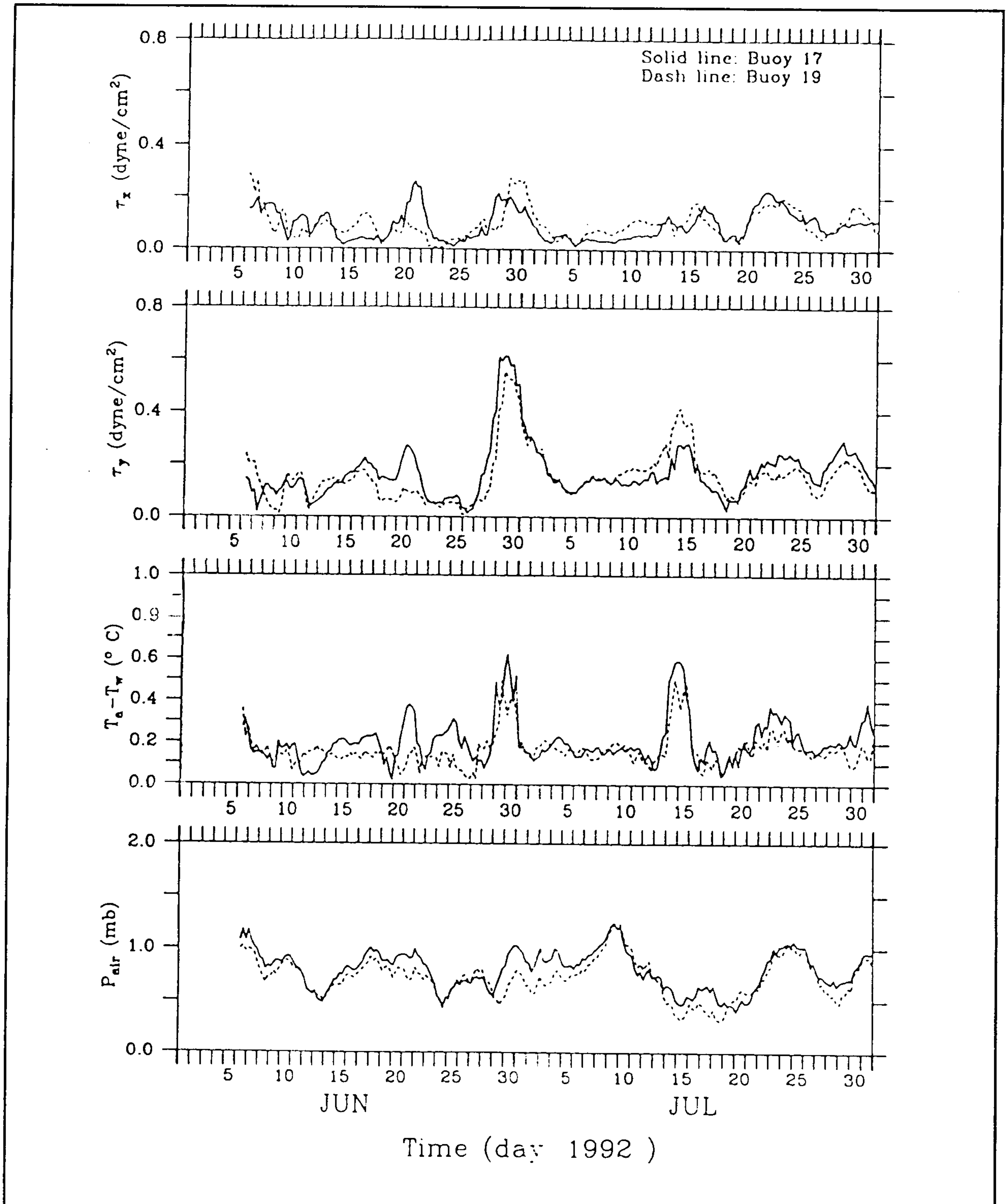

Figure 2D.10. Time series of surface wind stress components, the air-sea temperature difference, air pressure calculated by the complex demodulation analysis at a diurnal period at LATEX buoys 17 (solid line) and 19 (dash line) from early June to the end of July 1992. A least square method was used to fit 48-h segments with a 6-h overlap.

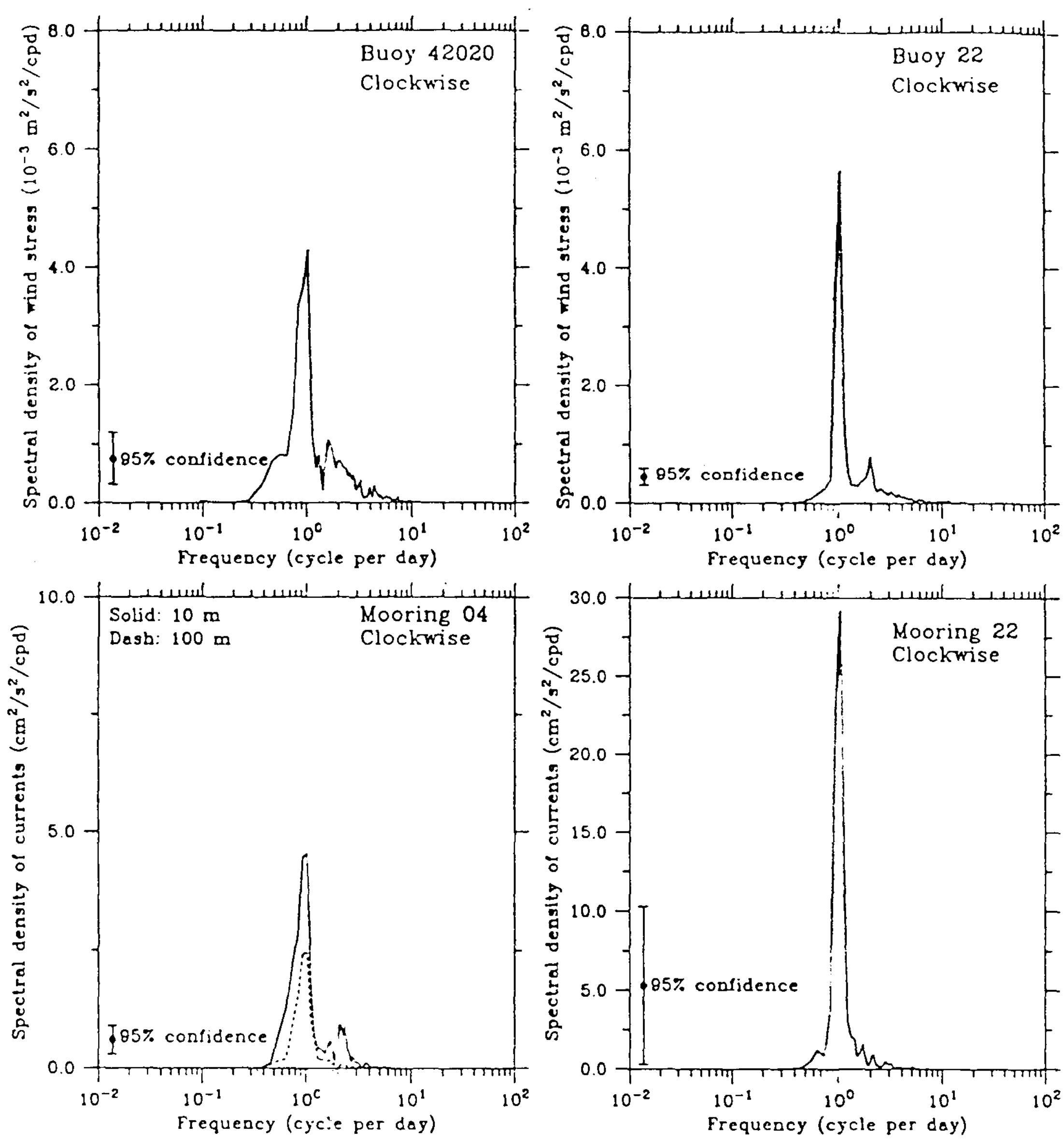

Figure 2D.11. Comparisons of clockwise-rotating spectra between 40-h low-passed wind stress and currents at buoy 42020 and mooring 04 from mid-April to end of May 1992 and at buoy 22 and mooring 22 from early June to end of August 1992.

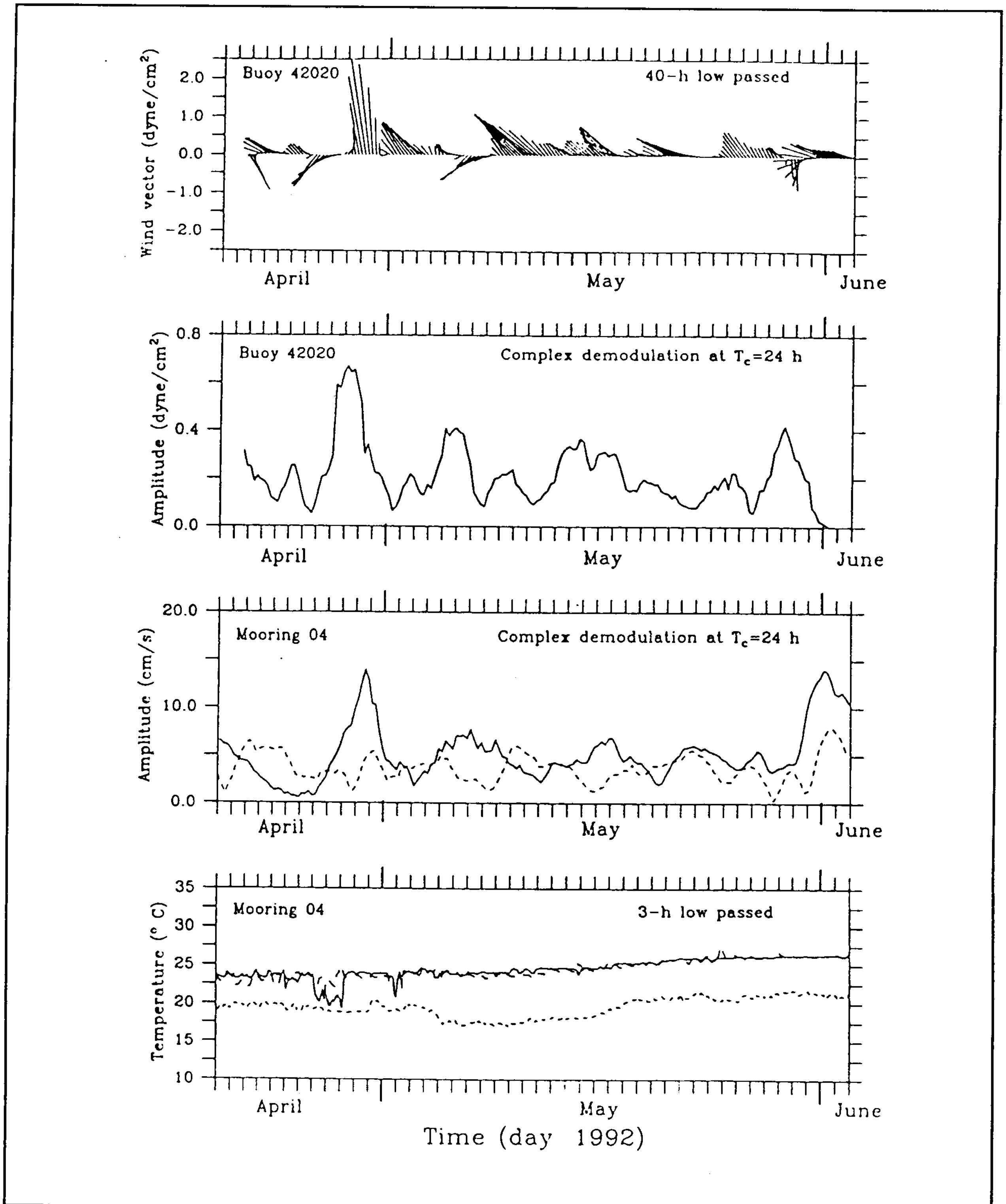

Figure 2D.12. Time series of 40-h low-passed wind stick vectors at buoy 42020, amplitudes of 40-h high-passed wind and currents calculated by a complex demodulation analysis at a diurnal period at buoy 42020 and mooring 04 (solid line: 10 m and dash line: 100 m), and 3-h low-passed water temperatures at the surface (long dash line), 10 (solid line) and 100 (short dash line) m.

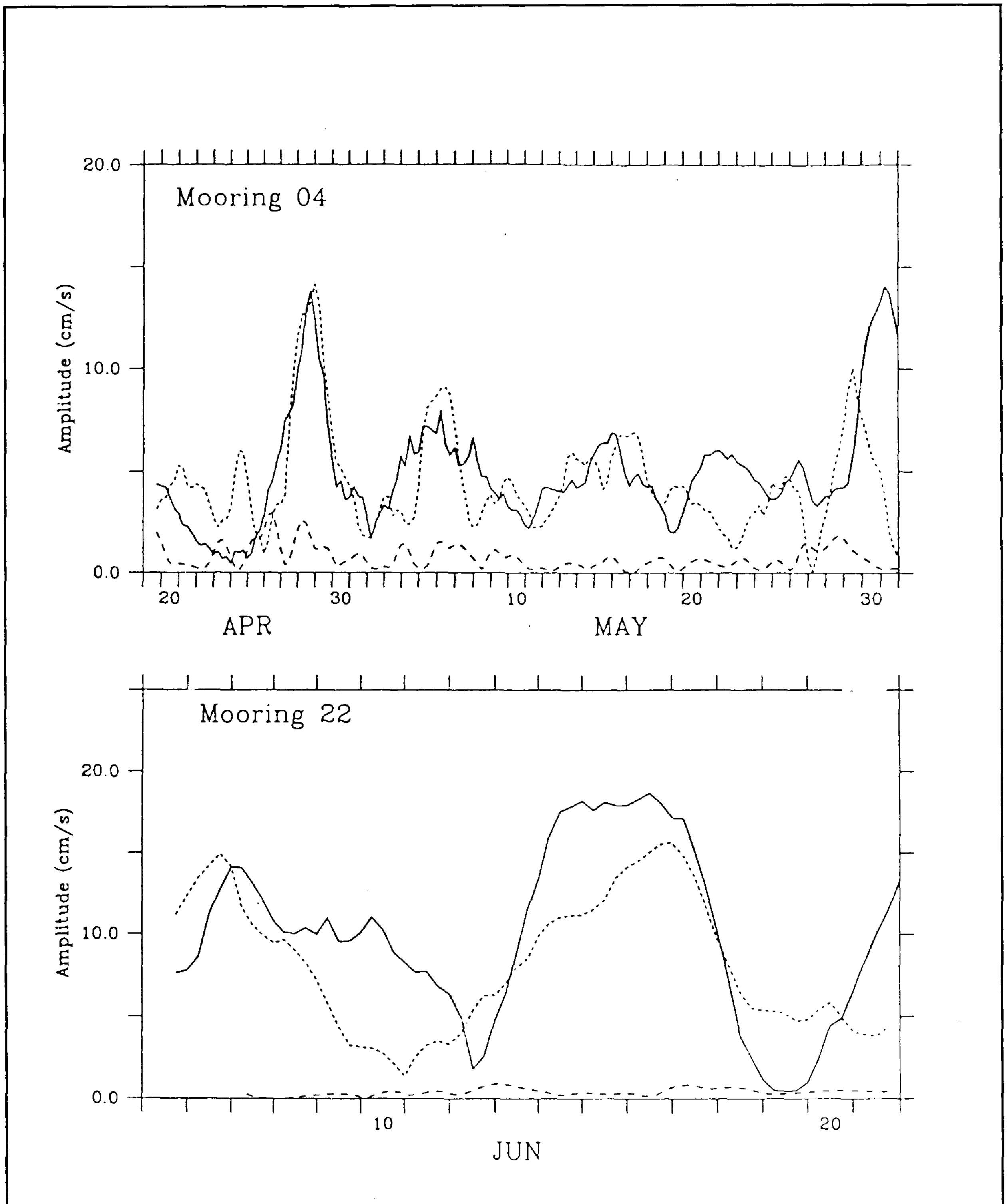

Figure 2D.13. Comparison of amplitudes between the observed (solid line) and predicted (short dash line) near-inertial currents at 10 m at mooring 04 during 19 April-31 May 1992 and 3 m at mooring 22 during 2-21 June 1992. The long dash line in each figure indicates the amplitude of the near-inertial currents predicted only by temporal variation of low frequency wind stress.

Robert Reid is a Distinguished Professor of Oceanography, Emeritus, of Texas A&M University. He has 42 years of service in teaching and research spanning the fields of physical oceanography, meteorology, and coastal engineering. His recent studies have focused on mesoscale ocean circulation modeling.

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ON THE REVERSAL OF THE MID-SHELF CIRCULATION IN THE LATEX REGION DURING JUNE 1993

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The Louisiana-Texas Shelf Physical Oceanography Program (LATEX Program) is producing an extensive coordinated data set suitable for use to confirm and refine the general circulation picture envisioned by Cochrane and Kelly (1986). With the LATEX Program field work approximately half completed it is perhaps too early to attempt the "grand synthesis," however, one aspect of the Cochrane and Kelly paradigm which can be investigated now is the mechanism, extent, and timing of the flow reversal which takes place off the Texas coast in June-July.

On 16 June 1993, two of our satellite-tracked drifters, 06937 and 06939, entered a narrow coastal jet off Galveston and were advected southward along the 20 to 30 m isobath at speeds exceeding 100 cm/s. After eight days, 06937 reached Port O'Connor and then abruptly reversed direction. Eleven days later it had returned to its original longitude off Galveston. Drifter 06939, (Figure 2D.14), followed a similar course, taking 12 days to reach Port Aransas, reversing course, returning to its original longitude 13 days later. Upcoast speeds during the transit were between 50 and 75 cm/s. Similar trajectories were observed in many of the 16 drifters deployed as part of the Surface Current and Lagrangian-drift Program (SCULP), (another Minerals Management Service (MMS) sponsored study). Some of the SCULP drifters entered the jet farther upcoast near Port Arthur and were carried as far south as Padre Island before reversing course. Cochrane and Kelly (1986) have discussed the reversal of a coastal jet off Freeport in June.

Cochrane and Kelly (1986) present a conceptual sketch of the circulation over the Texas-Louisiana shelf. This picture was pieced together from an assemblage of many different data sets collected in different years. The pattern they synthesized is one in which a cyclonic gyre spans the Texas-Louisiana shelf from the Mississippi Delta to some distance south of Port Aransas during much of the year. The nearshore current, from Galveston southward, is a strong narrow jet, the result of persistent easterly and downcoast alongshore winds. During July-August, the anticyclonic flow is replaced by a cyclonic gyre, again the result of alongshore winds, which in the spring, tend to blow toward the north. By late August, the prevailing winds become easterly again restoring the cyclonic flow. While Cochrane and Kelly had limited data sets and had to infer much of the circulation upcoast and downcoast of Freeport where there most extensive current records were collected, our drifters passed among 20 surrounding LATEX Program current meter moorings and five meteorological stations, (Figure 2D.15).

The drifters were manufactured by Clearwater Instrumentation Inc. and are similar to World Oceans Circulation Experiment (WOCE) specifications except that the holey-sock drogues are shorter, six m, with the bottom at nine m. The drifter consists of a surface float and instrument housing attached by a three m tether to a six m long canvas cylinder. The housing contains a radio transmitter, a thermistor, and battery supply sufficient for approximately one year of service. The transmitted signals are received by one of two orbiting NOAA satellites which relay the location and ancillary data to ground stations who in turn forward this information to the Data Office via e. mail. We get approximately eight locations per day from each drifter. The drifter velocities are computed

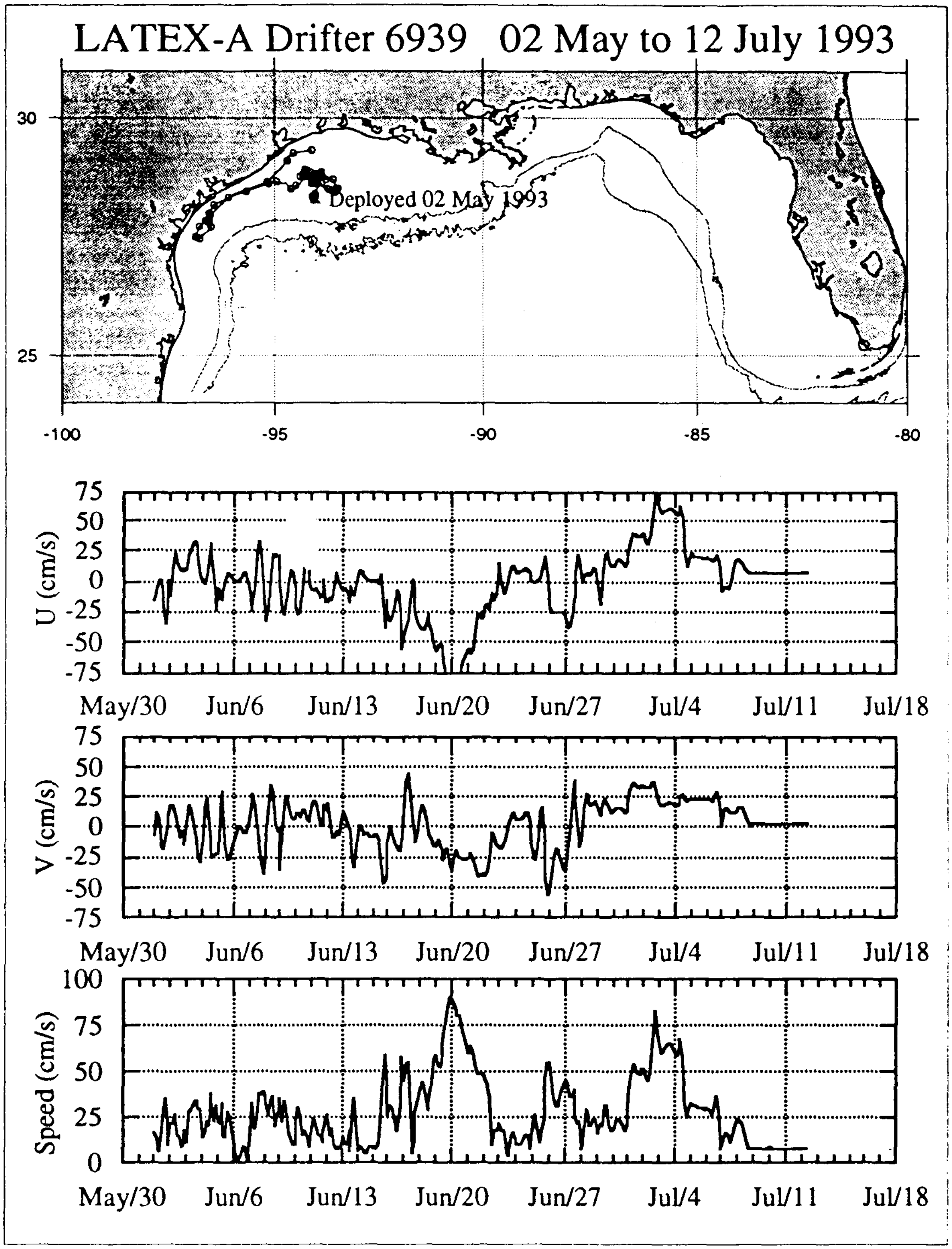
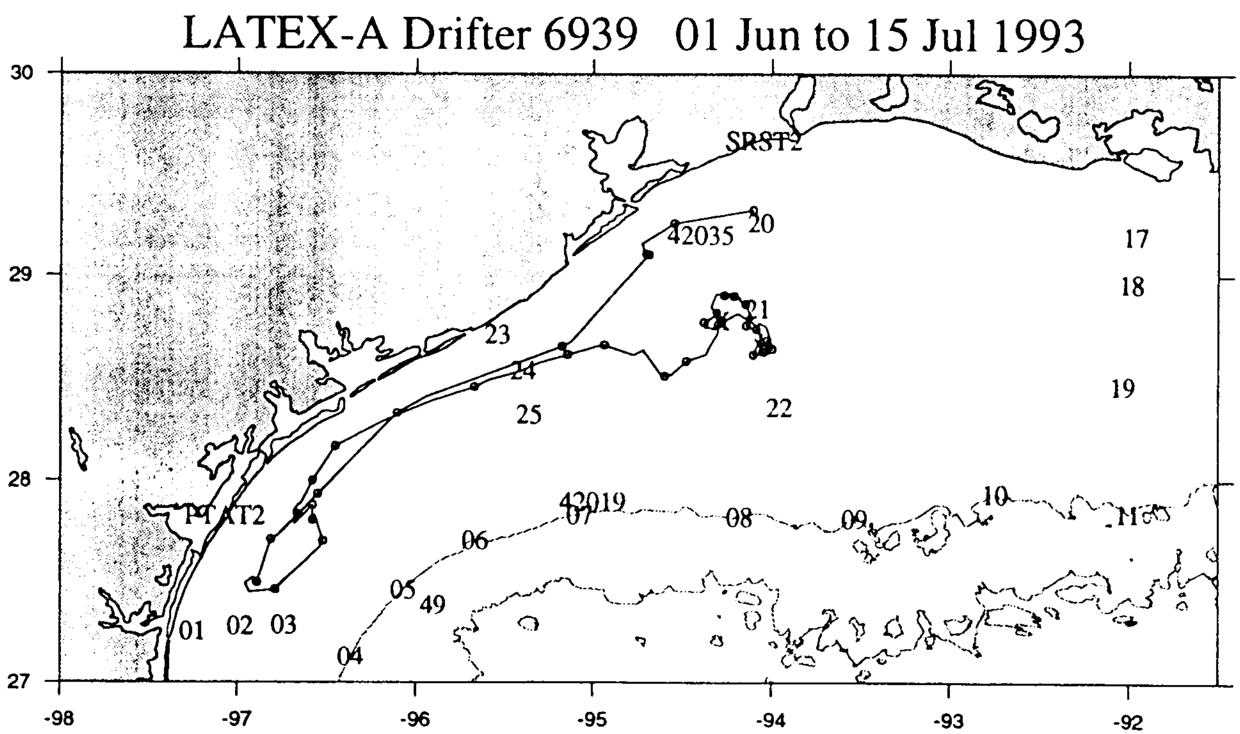


Figure 2D.14. Trajectory of LATEX drifter 6939 May to December 1993 with speed and velocity components U (East) and V (North) for June and July 1993. Circles on trajectory are daily markers.



X Marks the position on 01 June 1993.
o Circles indicate daily drifter position.
Numbers and letters mark location of current meter moorings and meteorological stations.

Figure 2D.15. LATEX-A drifter 6939 from 1 June to 15 July 1993 on a map overlay showing the current meter and meteorological stations. The 200 m and 2000 m isobath are shown.

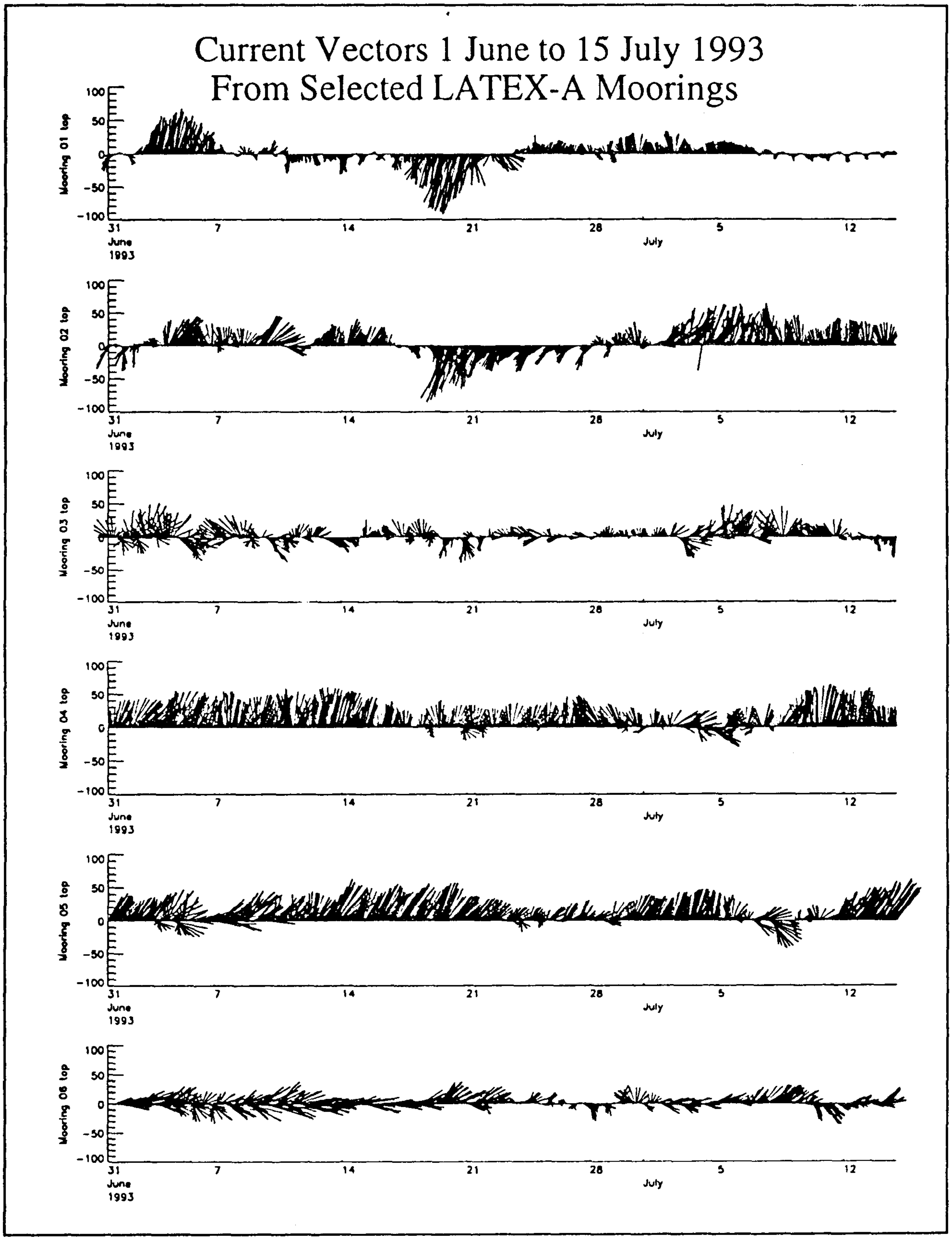


Figure 2D.16. Time series of current vectors at selected LATEX-A moorings in the western Gulf of Mexico from 01 June to 15 July 1993. The vertical scale is in cm/s and the vectors point in the direction the current is going.

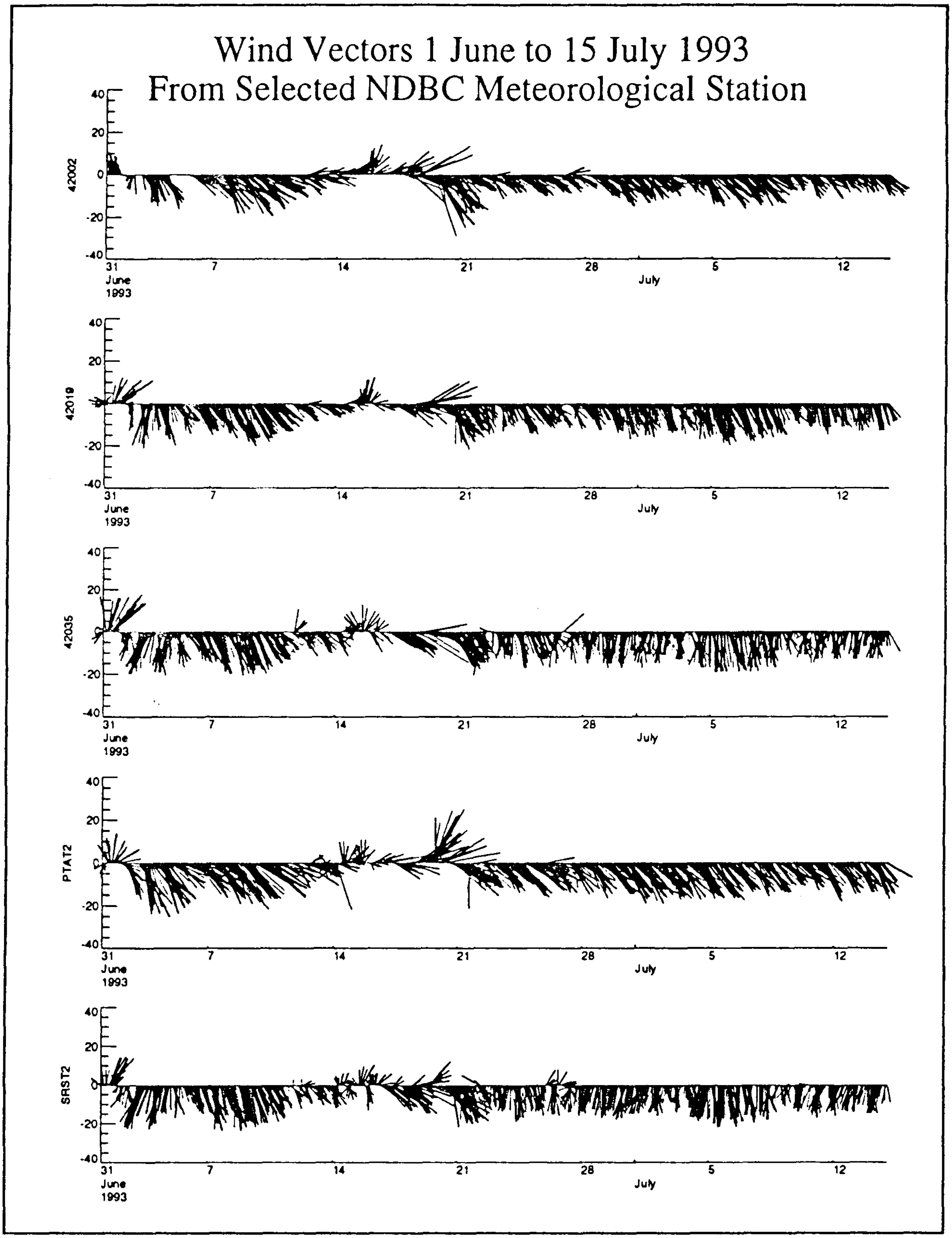


Figure 2D.17. Time series of wind vectors at selected meteorological stations in and around the western Gulf of Mexico from 01 June to 15 July 1993. The vertical scale is in knots and vectors point in the direction the wind is from.

from first differences of three hourly data produced by cubic splines.

Most LATEX moorings carry two or more current meters; however, in this preliminary look I have only present data from the surface meters. All of the current meters, except four, are tethered ENDECO 174SSMs sampling once each hour. The remaining four are InterOcean electromagnetic S4s sampling at 30 minute intervals. All current meters also record water temperature and conductivity.

Hourly meteorological data are available from stations maintained by the National Data Buoy Center and from meteorological buoys maintained by the LATEX Program. Daily Weather Maps were obtained from NOAA's Climate Analysis Center.

During the period 1 June through 15 July the surface weather over the LATEX Shelf is best described as calm and clear. During this period a weak high pressure cell, east of the LATEX study area, moved south generating easterly winds and later southerly winds as the cell moved south of the area. Winds during the entire period were 10 to 15 knots.

The time series of wind vectors and current vectors for selected stations are shown in Figures 2D.16 and 2D.17. The station locations are shown in Figure 2D.15. The wind vectors for Port Aransas, (and all the others), clearly show a transition on 14 June from south-southeasterly flow to more easterly flow. Easterly winds should produce a southward flowing jet perhaps as far south as the Mexican boarder. After 21 June, the winds become southerly, which for this segment of the coast is a pure alongshore wind stress and should give rise to a strong northward flowing jet. Mooring 01, 02, and 03 are closest to the Port Aransas meteorological station. An examination of the current vectors from these moorings show the coastal jet is seen at both mooring 01 and 02 but not at mooring 03 further offshore. The downcoast event is present in the records of both mooring 23 and 24 but not in the offshore mooring 25. However, the upcoast event is not strong in any of these moorings. An examination of the conductivity records for moorings 23, 24, and 25 show that mooring 23, the inshore mooring, is located in a low salinity frontal boundary indicating the jet may lie inshore of this mooring. Following the upcoast event, the conductivity at mooring 20 drops dramatically. The next offshore mooring, 22, shows a small drop in conductivity while mooring 22 show no fresh water intrusion at all.

The next step in this ongoing work is to decompose the current and wind records into their alongshore and cross-shelf components and perform the cross-spectral analysis pairs. We are in the process of obtaining sea level records from the Conrad Blucher Institute for the period May 1993 through the present. This data should provide useful information on the timing of the migration of convergence zone. Middle and bottom current meters will be examined. We would like to examine the dates and locations of the reversals of all the SCULP drifters.

This work has been performed as part of the Texas-Louisiana Shelf Circulation and Transport Process Study, a component of the Louisiana-Texas Shelf Physical Oceanography Program sponsored by the Minerals Management Service (MMS) under MMS contract number 14-35-0001-30509.

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Dr. Matthew Howard has worked at the Geochemical Environmental Research Group at Texas A&M University for the past two years as a assistant research scientist. His areas of research interest are coastal oceanography and numerical modeling of topographically controlled flows. Dr. Howard took his B.S. in physical oceanography at Humboldt State University, California and his Ph.D. in physical oceanography at Texas A&M University, Texas.

EFFECTS OF LATEX CYCLOGENESIS ON THE "BLIZZARD OF THE CENTURY" 12-15 MARCH 1993

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INTRODUCTION

Cyclogenesis is a very important phenomenon in certain coastal regions. Cyclogenesis is defined as any development or strengthening of cyclonic circulation in the atmosphere; the opposite is cyclolysis. The term is applied to the development of cyclonic circulation where previously it did not exist (commonly, the initial appearance of a low or trough, as well as the intensification of existing cyclonic flow).

Cyclogenesis is not unusual in certain coastal regions, for example, along the mid-Atlantic coast of the United States and in the northwestern Gulf of Mexico. Cyclones that form off the mid-Atlantic coast can be divided into two types. One of these develops well offshore along or east of the Gulf Stream and moves in a northeasterly direction. The other originates in the Gulf coastal region or near the southeast coast and rapidly intensifies as it moves up the East Coast. This type generally develops as a secondary disturbance to a primary cyclone moving through the Great Lakes region. These secondary disturbances can give rise to devastating weather. One example is the President's Day snowstorm on 18-19 February 1979 which deposited a record-breaking snowfall on the Middle Atlantic states. (For more detail, see Hsu 1988).

WINTER CYCLOGENESIS IN THE LATEX REGION IN 1993

In order to study the intensity of winter cyclogenesis over the Gulf of Mexico, a classification scheme based on the approximate balance between the centrifugal force and the pressure gradient of the storm has been devised by Hsu (1993) as shown in Figure 2D.18. On the basis of this classification, there were eight winter cyclogenesis cases between November 1992 and May 1993 (Table 2D.1). In general we have approximately 10 cyclogenesis per year (see Johnson *et al.* 1984). Note that among these eight cyclogenesis, the one which developed on 12 March 1993 (a Class 4 cyclone) over our southern LATEX region (Figure 2D.19) later evolved into the blizzard of 1993 which some refer to as the storm of the century (see the spring 1993 issue of the Mariners' Weather Log published by the U.S. NOAA).

CYCLOGENESIS OF 12 MARCH 1993

According to McCraw (1993), while the explosive cyclogenesis (extratropical low pressure system where pressure falls at least 24 millibars in 24 hours) is common over oceanic regions, the coastal winter storm of 12-15 March 1993 is easily categorized as one in a hundred year weather phenomena. As noted from the transposed microbarograph tracings from Naval Air Stations along the Gulf of Mexico and the eastern seaboard, the extremely low pressures that were experienced made this storm one to remember.

Beside the bitter cold and heavy snowfall, which shattered records along its path, extremely high winds were also common. For nearly 48 hours stationsexperienced sustained winds of 25 to 40 knots with gusts to 60 knots while hurricane force winds caught many offshore by surprise. The Eighth Coast Guard District, headquartered in New Orleans, which covers the Gulf Coast from Apalachicola Bay in Florida to the U.S.-Mexico border near Brownsville, reported 111 storm search and rescue cases. This involved 64 vessels and two aircraft in distress. During the period of March 12-15, the Coast Guard flew 99 aircraft sorties with 61 vessel sorties which saved 33 lives.

As shown in Figure 2D.19, in our southern LATEX region on 12 March 1993, the pressure dropped from 1,007 mb to 1,002 mb within six hours. This deepening in pressure along 26°N is considered to be a "meteorological bomb." In fact, according to Gilhousen (1993), two data buoys supported by the MMS (#42019 and #42020 shown in Figure 2D.21) recorded the wave steepness, which may be the "steepest waves" NDBC (National Data Buoy Center) has ever measured. They indicate phenomenal wave growth and confirm the presence of strong winds and a rapidly deepening storm. Their steepness also

Table 2D.1. Winter Cyclogenesis over the N.W. Gulf of Mexico from November 1992 through May 1993.

Year	Month	Date	Intensity*
1992	November	4	2
	November	24	3
	December	9	2
	December	15	3
1993	February	22	2
	March	12	4
	April	8	3
	May	12	1

*The intensity classification is based on Hsu (1993). The data source is from "Daily Weather Maps" published weekly by NOAA.

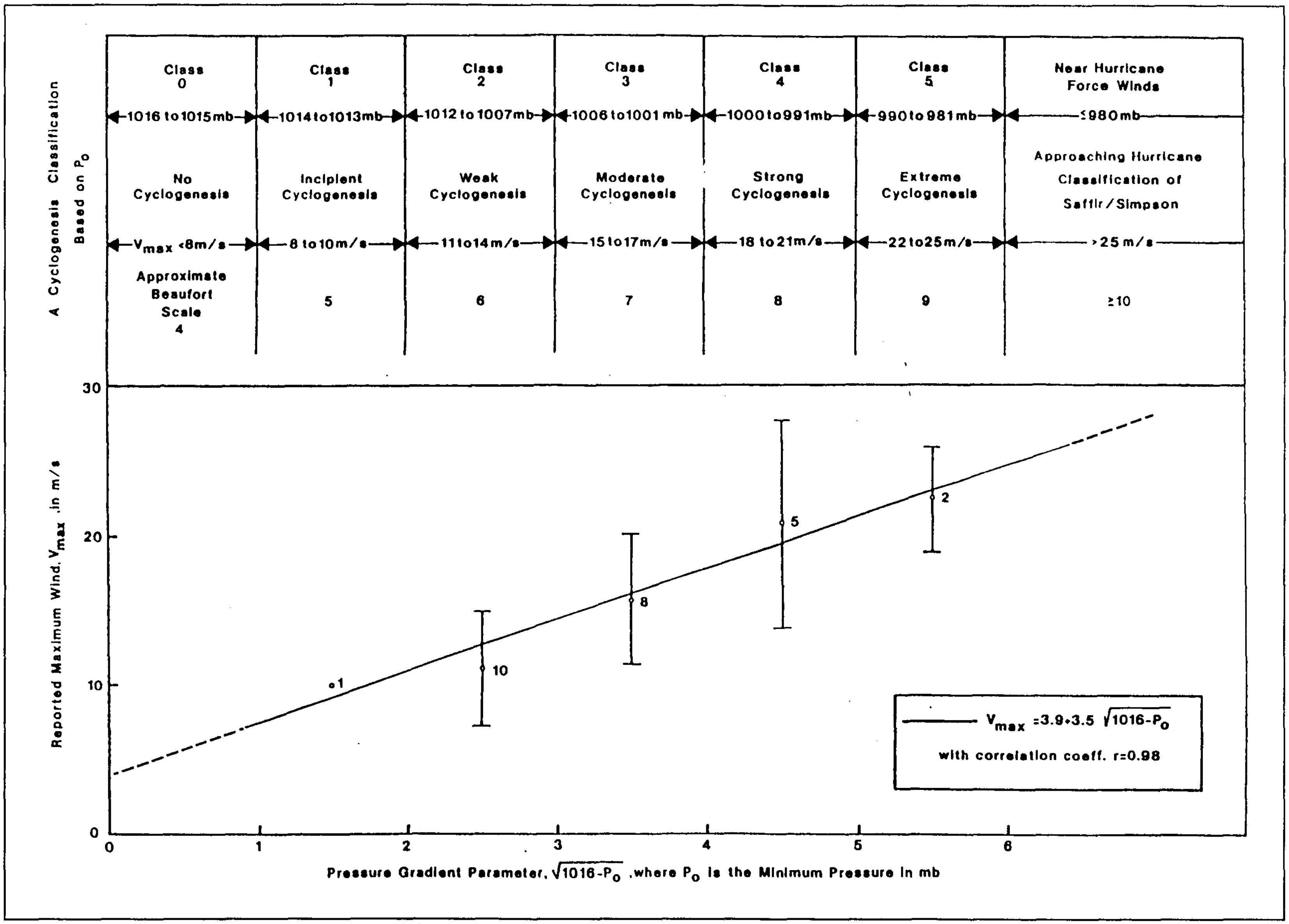

Figure 2D.18. This winter cyclogenesis classification is devised by Hsu (1993) and based on the minimum pressure of winter storms in the Gulf of Mexico.

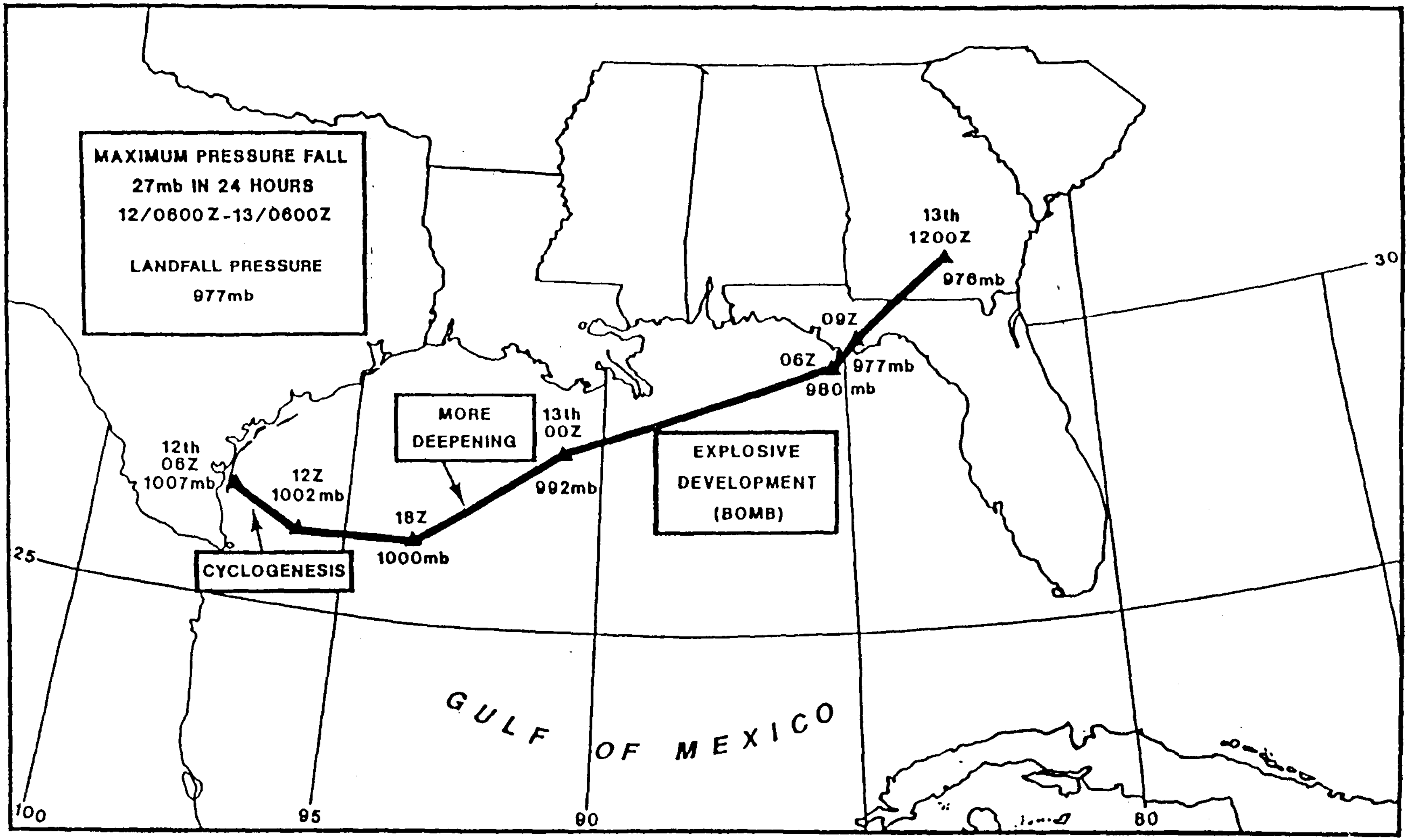

Figure 2D.19. Storm track of the cyclogenesis during 12 and 13 March 1993 over the southern LATEX region which later developed into the "Blizzard of the Century."

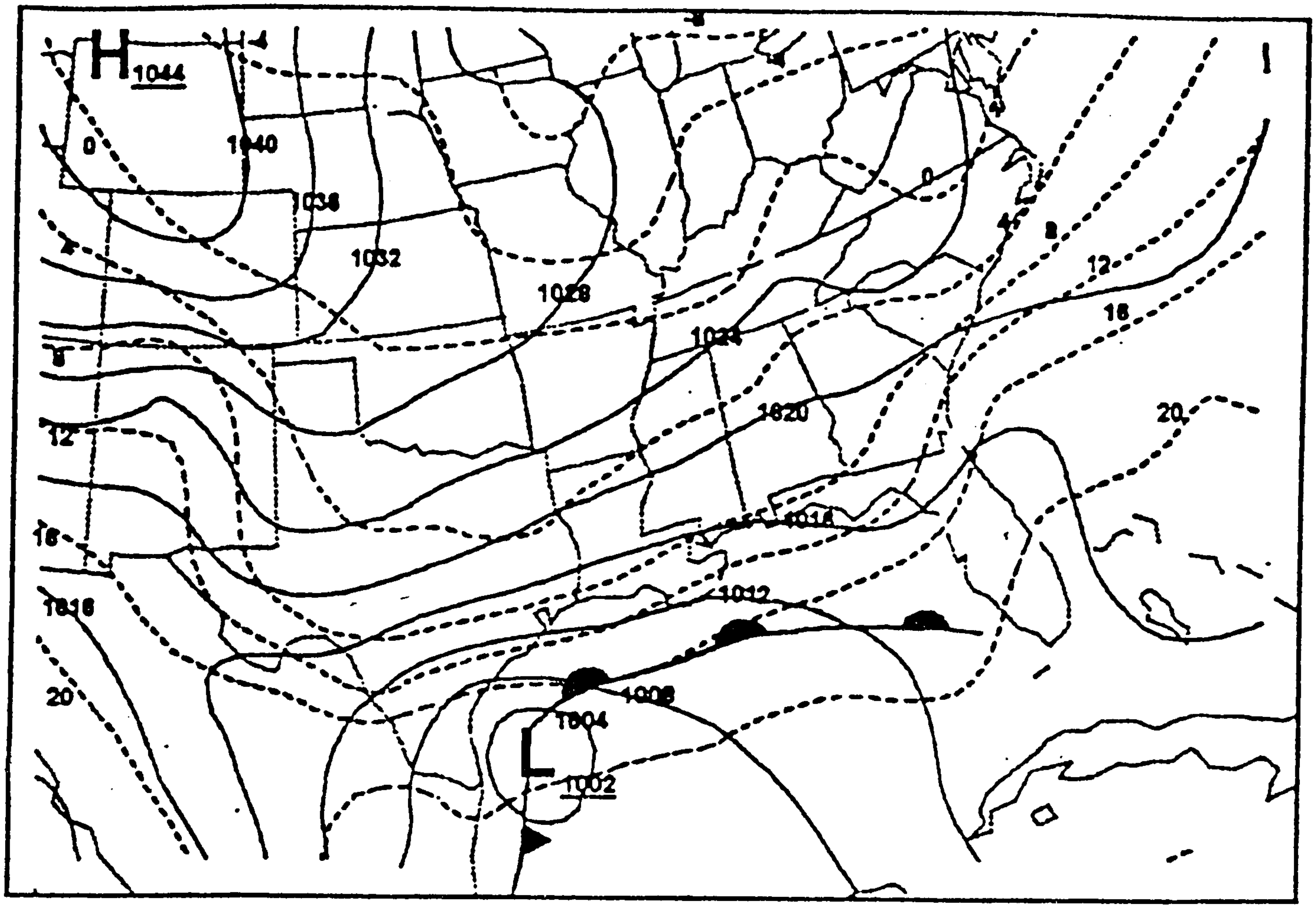

Figure 2D.20. Surface fronts (heavy solid) and isobars (solid, millibars) with 1000 mb temperatures (dashed, degrees C) for 12Z, 12 March 1993.

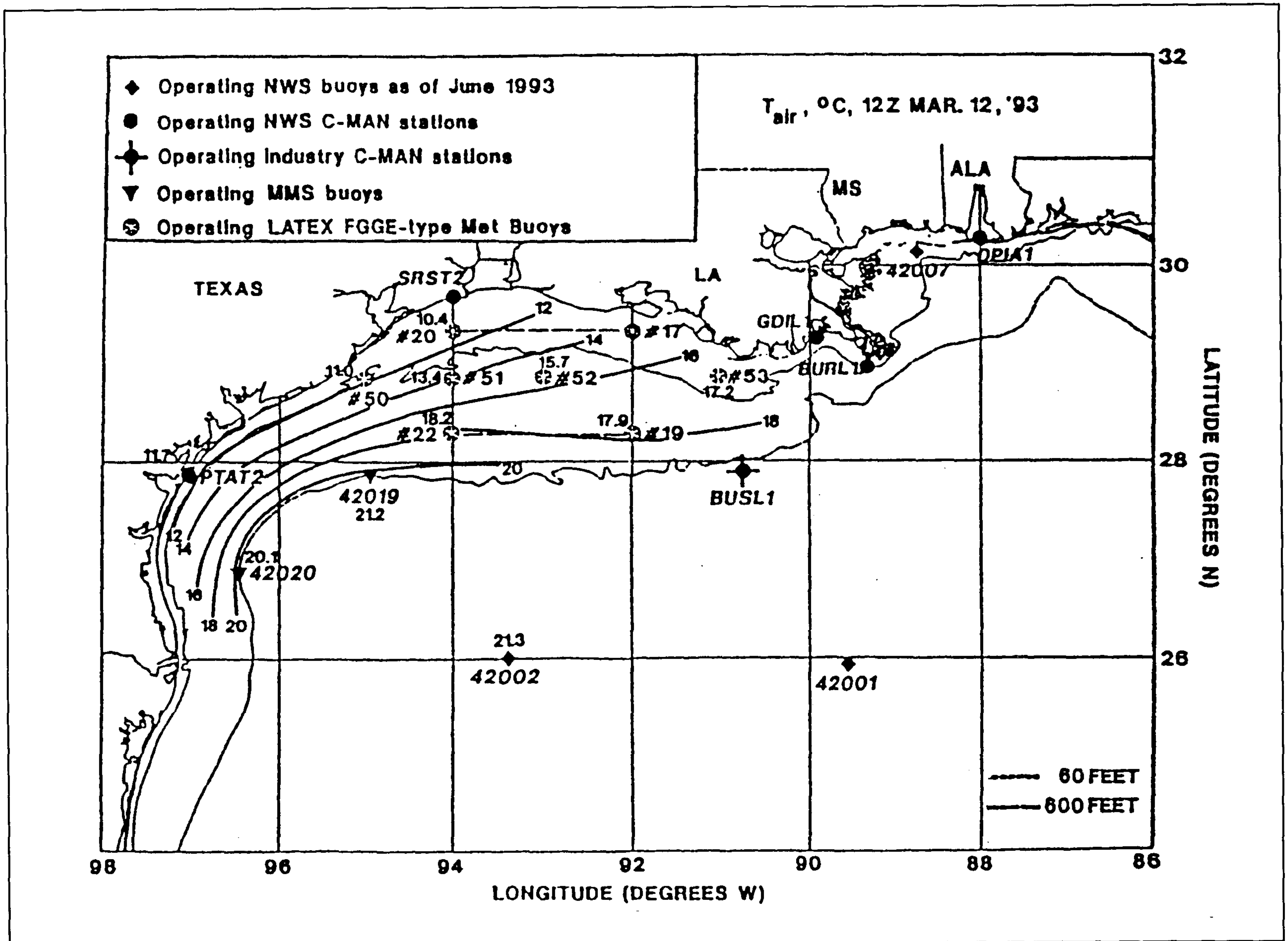

Figure 2D.21. The distribution of the air temperature at 12Z, 12 March 1993 during the initial stage of the "Blizzard of the Century."

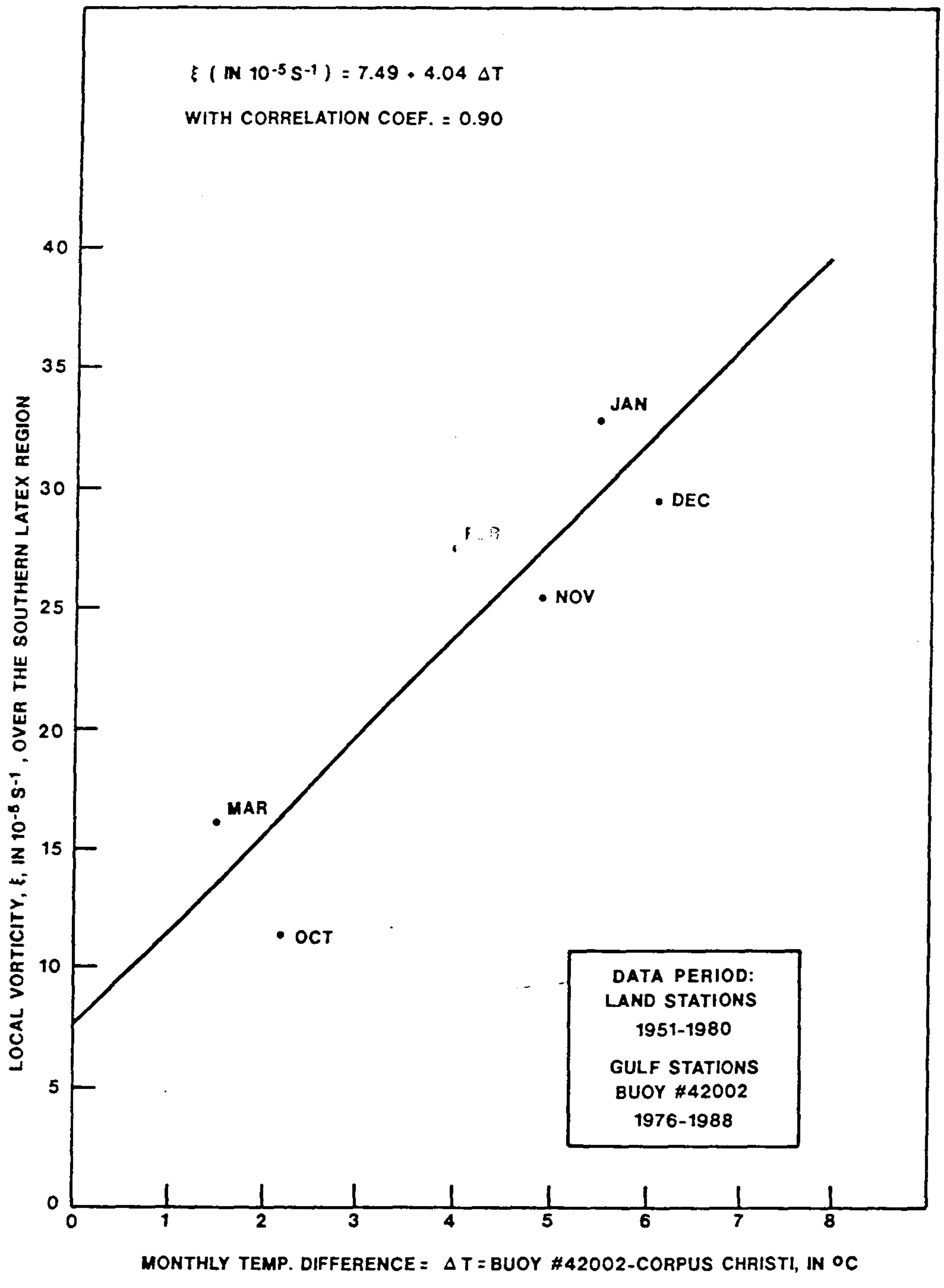

Figure 2D.22. Linear regression between the local geostrophic vorticity over the southern LATEX region centered over Corpus Christi and the monthly temperature difference between buoy station #42002 in the deep Gulf and Corpus Christi, Texas (for methodology, see Hsu, 1992).

portends the type of widespread maritime calamity that followed as discussed above by McCraw (1993).

SURFACE BAROCLINICITY OVER THE LATEX REGION

Based on the "official" model output for the surface conditions at 12Z 12 March 1993, as shown in Figure 2D.20, the isotherms over the southern LATEX region were approximately running east-west.However, detailed analysis of the temperature field by incorporating both NDBC buoys (including C-MAN stations) and our LATEX meteorological buoys as shown in Figure 2D.21, reveals that the isotherms were running approximately in the north-south direction along the isobaths. This means that if the isobars were running east-west we should have more baroclinic than barotropic fields. Therefore, the "official" forecasts underestimated the deepening potential as confirmed by many marine forecasters.

In addition, since the difference in air temperature between buoy #42002 and C-MAN station PTAT2 was 9.6°C, the vorticity according to Figure 2D.22 should be about 46 x 10^{-5} s^{-1}, which is nearly three times larger than the normal vorticity in March. Furthermore, because of the presence of a large warm eddy - Eddy Vasquez (see Walker 1993), the difference in air temperature between the deep-Gulf buoy #42002 and shelf buoys #42019 and #42020 was around 1°C. This indicates that the large vorticity value of 46 x 10^{-5} s^{-1} was located between the Texas coast and the shelf break, which enhances the cold-air advection in the region west of the shelf while warm-air advection occurs in the region east of the shelf. Thus, deepening is ensured.

SUMMARY AND CONCLUSIONS

Winter cyclogenesis over the northwest Gulf of Mexico from November 1992 through May 1993 was investigated. There were eight cyclogenesis cases during this period as compared to about 10 occurrences generally. However, the intensity of the storm which developed on 12 March 1993 was by far the most severe based on both maritime calamity viewpoints and the steepest waves measured. The 10°C difference in air temperature between the shelf break and the shoreline translated into over 45 x 10^{-5} s^{-1} in vorticity which is three times larger than the normal value in March.

On the basis of isotherm analysis, the air temperature field runs parallel to the isobaths. This information may be useful as an aid to the marine forecasters since the computer-generated forecast models tend to show the opposite case. It is recommended that in the future improvements to the model may be made from LATEX's baroclinic analysis.

ACKNOWLEDGEMENTS

S.A. Hsu was supported in part by the Louisiana/Texas Shelf Physical Oceanography Program funded by the U.S. Minerals Management Service (MMS) under Contract 14-35-0001-30509 for work to be performed by the Texas A&M University System and subcontractors. The contributions that Murray Brown of MMS has made towards the success of the program are appreciated. The contents of this paper do not necessarily reflect the view or policies of the MMS, nor does mention of trade names or commercial products constitute endorsement or recommendations for use.

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Dr. S. A. Hsu received his Ph.D. from the University of Texas at Austin. He has been a professor of marine meteorology in the Coastal Studies Institute at L.S.U. for the past 24 years. His research interest has been in coastal and marine meteorology and air-sea interaction. He is the author of a book entitled *Coastal Meteorology* published by Academic Press in 1988.

LATEX SHELF HYDROGRAPHY IN AUGUST 1992 AND AUGUST 1993—A COMPARISON

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INTRODUCTION

The hydrography component of the Louisiana-Texas Shelf Circulation and Transport Processes Study (LATEX A) has conducted seven quarterly surveys of Louisiana shelf waters during the last 20 months. The oceanographic data collected during these surveys is being used to characterize the seasonal water mass patterns, study water mass modification and dynamical processes of circulation, and begin to assess the inter-annual variability. The results of these surveys are now being used to refine our view (based on the scheme of Cochrane and Kelly 1986) of the spatial distribution and seasonal variability of temperature, salinity, dissolved oxygen, nutrients, particle scattering, downwelling irradiance, and phytoplankton pigments over the study area. The ultimate goal of the LATEX hydrography program is to provide a high-quality, comprehensive time series of oceanographic data that can be used to evaluate and predict the low frequency circulation on the Texas-Louisiana shelf.

Two advantages the LATEX hydrography program has over many other shelf oceanography studies arethe repetitiveness of the sampling plan and the duration of data collection. By sampling the same oceanographic stations every three months, hydrographic conditions on the Texas-Louisiana shelf are easily comparable between locations and years. This sampling requirement for defining the low-frequency circulation also allows comparison of shorter-term variations which occur due to changes in physical forcing processes on the shelf. The two major physical processes controlling shelf circulation are the wind and buoyancy forcing due to the presence of river water on the shelf. The wind stress forcing varies significantly with season, even changing direction during some seasons, but the long-term winds are relatively predictable. On the other hand, the flow of river water onto the Texas-Louisiana shelf (primarily from the Mississippi and Atchafalaya rivers) can and does vary significantly with season and from year to year. Since 1930 the annual discharge of the Mississippi River has varied from less than 250 km3 to greater than 650 km3, with the highest flow during that period in 1973. The yearly discharge pattern is complex. It is not uncommon for a year of low river discharge onto the Texas-Louisiana shelf to be followed by a year of extremely high river flow. The amount and distribution of fresh water on the Texas-Louisiana shelf is highly variable from year to year and from month to month. That variability is one reason why the LATEX program was planned as a multiple season, multiple year study.

Water mass distributions on the Texas-Louisiana shelf were studied on the first seven cruises of the LATEX hydrography program during 1992 and 1993. Freshwater discharges onto the LATEX shelf during 1992 were near the mean of 422 km3 for the Mississippi River and 171 km3 for the Atchafalaya River. While 1992 was a near-normal year, 1993 was different. The 1993 river flows were affected by excessive rain and flooding in the upper Mississippi River basin beginning in April 1993. The period from April to June 1993 was one of the wettest observed in the upper Mississippi River basin in the last 99 years. These rains produced much higher than average Mississippi and Atchafalaya river flows, especially during August 1993, when record river flows were recorded for most of the month. This record river runoff (for August) discharged almost twice the volume of fresh water into the northern Gulf of Mexico as was discharged during August 1992. The summer flooding, the fate of this water and its effect on the Texas-Louisiana shelf created tremendous public interest. Fortunately, LATEX hydrography cruises were surveying the shelf during both August 1993, and August 1992. The data from the 1993 stations will be compared with stations on the Louisiana shelf from the August 1992, cruise to determine the effect of this increased fresh water input on shelf hydrography.

METHODS AND RESULTS

The locations of the LATEX A hydrographic stations on the August 1993 cruise were arranged into eight cross-shelf transects extending from near shore to the shelf edge (about 500 meters depth). The cross-shelf transects are numbered from one to eight, beginning with the line at the eastern edge of the study area near the Mississippi River mouth. In addition, two along-shelf transects are occupied during each survey, one along the 50 m isobath and another along the 200 m isobath. During 1992, only the Louisiana shelf portion of the grid was surveyed. During both years, oceanographic data were collected at 114 identical LATEX hydrographic station locations over the Louisiana shelf. The identical station locations are on transect lines one, two, three, and four. At each station, measurements were made of conductivity, temperature and depth (CTD) using a Sea-Bird Electronics SBE-911plus CTD system. Simultaneous measurements were made of dissolved oxygen, particle scattering, light transmission and in situ chlorophyll fluorescence. The surface water salinity and temperature from 1992 and 1993 were compared to determine the extent the fresh water on the shelf. The effect of increased summer stream flow into the northern Gulf of Mexico in 1993 was evident in the data from the August 1993 survey. High temperature, low salinity surface water was observed over a large area of the Louisiana shelf. The 1993 cruise track covered an area southwest of the Mississippi River Delta from shallow, coastal water (10 m depth) due south to offshore water with depths greater than 500 m. The transect line closest to the Mississippi River was at 90o 30'W longitude, just south of Terrebonne Bay, Louisiana. This transect line is designated as Line one on all LATEX hydrography cruises.

Differences in salinity between 1992 and 1993 surveys were seen both in the surface water and at depth. Surface water salinities in 1993 ranged from nine to 26 along Line 1. These low salinities compared with a salinity range from 27 to 33 along the same track during August 1992. Near shore, the freshest water in 1993 was confined in a layer only 5 m thick. The depth of the low-salinity plume increased with distance from shore. On the middle shelf, surface water temperature in 1993 was also higher than in the comparable period in 1992. The differences in surface temperature between the two years was most apparent near shore, but the salinity differences were observed all along the transect.

The volume of fresh water in the surface layer (zero-five m) on the Louisiana shelf, west of the Mississippi River, was calculated for August of each year. For this calculation, the shelf surface water was divided into 32 boxes of 0.5o latitude by 0.5o longitude. The fresh water fraction of each of the five-m deep boxes was calculated using the equation described in Dinnel and Wiseman (1986). A salinity of 36.560 was used as the baseline value. In August 1992, the upper 5 m of the Louisiana shelf contained 4.0 x 1010 m3 of fresh water. In August 1993 following the record river flows that month, the shelf contained 6.1 x 1010 m3 of fresh water, a 50% increase.

SUMMARY

The record high flow of the Mississippi River during August 1993 had a significant effect on salinities all across the Louisiana shelf. In August 1992, the most obvious salinity feature in the surface water was a low-salinity plume from the Atchafalaya River which covered the shelf shallower than 40 meters. During August 1993, the fresher river water was observed at a level one and a half times higher than in 1992, was found further to the east (nearer the Mississippi River delta) and extended farther offshore, to the 200 m isobath. The increased water column stability, due to the fresher surface water, probably contributed significantly to the wide area of hypoxic conditions observed in the bottom waters on the Louisiana shelf. Texas shelf waters were less affected by the higher river flows. The eastward component of the wind stress over the Texas-Louisiana shelf during August causes an upcoast circulation pattern which forces the water flowing from the Mississippi and Atchafalaya rivers toward the east. Except near the coast, surface water salinities on the Texas shelf waters in August 1993 were no higher than in 1992.

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Dr. Denis A. Wiesenburg has worked at Texas A&M University for the last five years and was an Associate Research Scientist in the Geochemical and Environmental Research Group. He has been named the Director of the Center for Marine Science at the University of Southern Mississippi, beginning his new post in May 1994. He serves as the Principal Investigator of the LATEX A Standard Grid Hydrography Program. His areas of research interest are ocean frontal processes, interactions of physical and biological processes in the ocean, and anoxic systems. Dr. Wiesenburg received his A.B. in chemistry from Duke University, his M.S. in oceanography from Old Dominion University and his Ph.D. in oceanography from Texas A&M University.

WAVES AND CURRENTS DURING HURRICANE ANDREW AS SEEN BY THE LATEX A ARRAY

Dr. Steven F. DiMarco
Dr. Norman L. Guinasso, Jr.
Mr. F.J. Kelly
Mr. Linwood L. Lee, III
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Wave and current data at several sights on the Texas-Louisiana shelf were taken during the passage of Hurricane Andrew (Figure 2D.23). The directional wave spectra associated with Andrew at two sites (LATEX Sites 16 and 23) show the direction of short period waves, generated by local wind, and the longer period swell from distant storms. The spectra are computed using a modified method of Longuet-Higgins that utilizes the measured pressure and horizontal velocity. The directional spectrum is useful in showing that remote storm events can greatly influence the conditions several hundred kilometers away.

The effects of Andrew first become evident in the wave spectra with the arrival of waves of about 14 second period at a site 20 km south of Terrebonne Bay (Site 16); about five and a half hours later they arrive off Freeport, Texas (Site 23). Both arrival times correspond to a location for Andrew in the deep eastern gulf at 26.6N, 86.7W. Figure 2D.24 shows the directional spectrum at Site 16 with 12 second waves propagating to the west. The eye is five hours from its closest approach to this site. When the center of Andrew moved onto the shelf, the longer period waves at the coast decreased in magnitude and shifted to higher frequencies. Significant wave heights at the site near Terrebonne Bay reach eight m while those near Freeport approach 1.1 m. The observed horizontal velocities of the 14 second waves, superposed with the mean flow, are capable of resuspending bottom sediment in depths of 20 meters.

Figure 2D.25 shows current stick plot diagrams at four sites (12-15) in the path of Andrew. The current is strong and to the southwest when the eye is located to the southeast of the sites. As the eye passes, we see a complex wind driven response. This is followedby five days of inertial oscillations after the hurricane passes which is superposed on a mean westward flow.

The directional wave gauges experienced a number of unrelated problems that limited the wave data collection to two of the five sites (Kelly *et al.* 1993). Only 10 minutes of the 17 minute burst was usable to determine the directional wave spectrum due to a warm-up transient response in the pressure sensors. (This problem has since been corrected by replacing the pressure sensor with a new improved model.) At a bottom depth of 20 meters the resolution of the pressure sensor limited the minimum detectable wave period to four and a half seconds. (This problem can be remedied by moving the gauges to shallower water.) Calibrations performed by the Northwest Regional Calibration Center revealed a temperature dependence of the pressure sensors which was corrected using a least-squares fit that is linear in temperature and quadratic in pressure.

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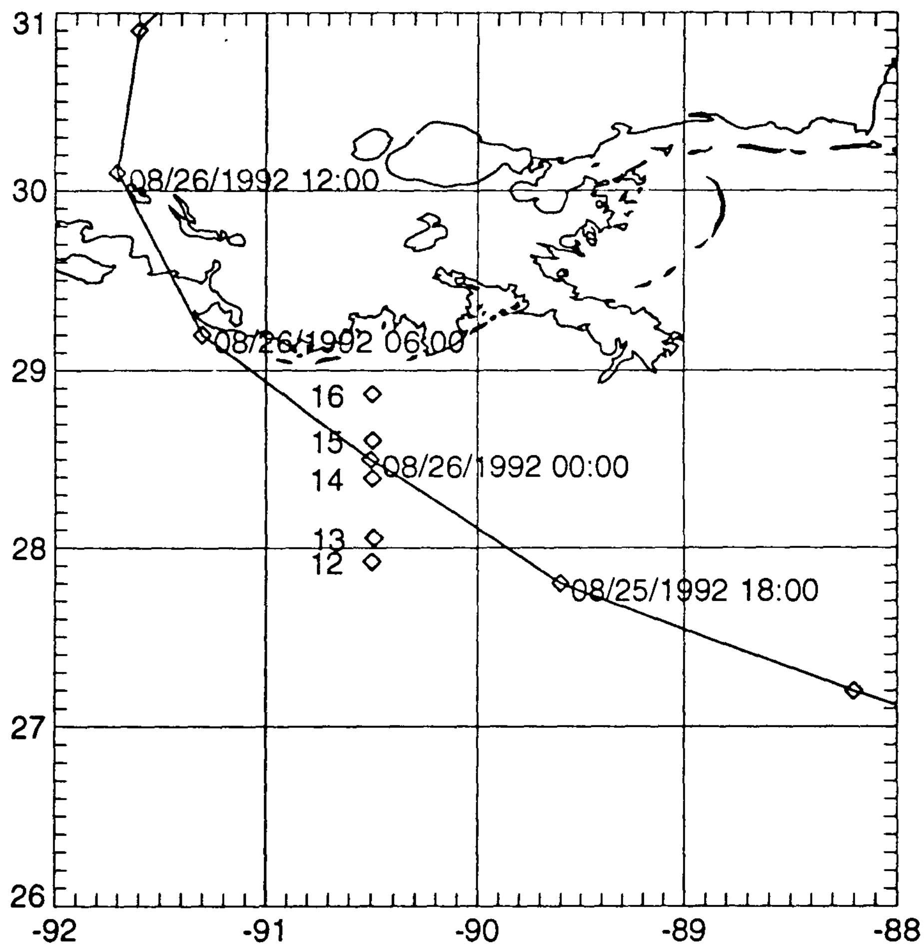

Figure 2D.23. LATEX current and directional wave gauge mooring locations during Hurricane Andrew, 8/25/92.

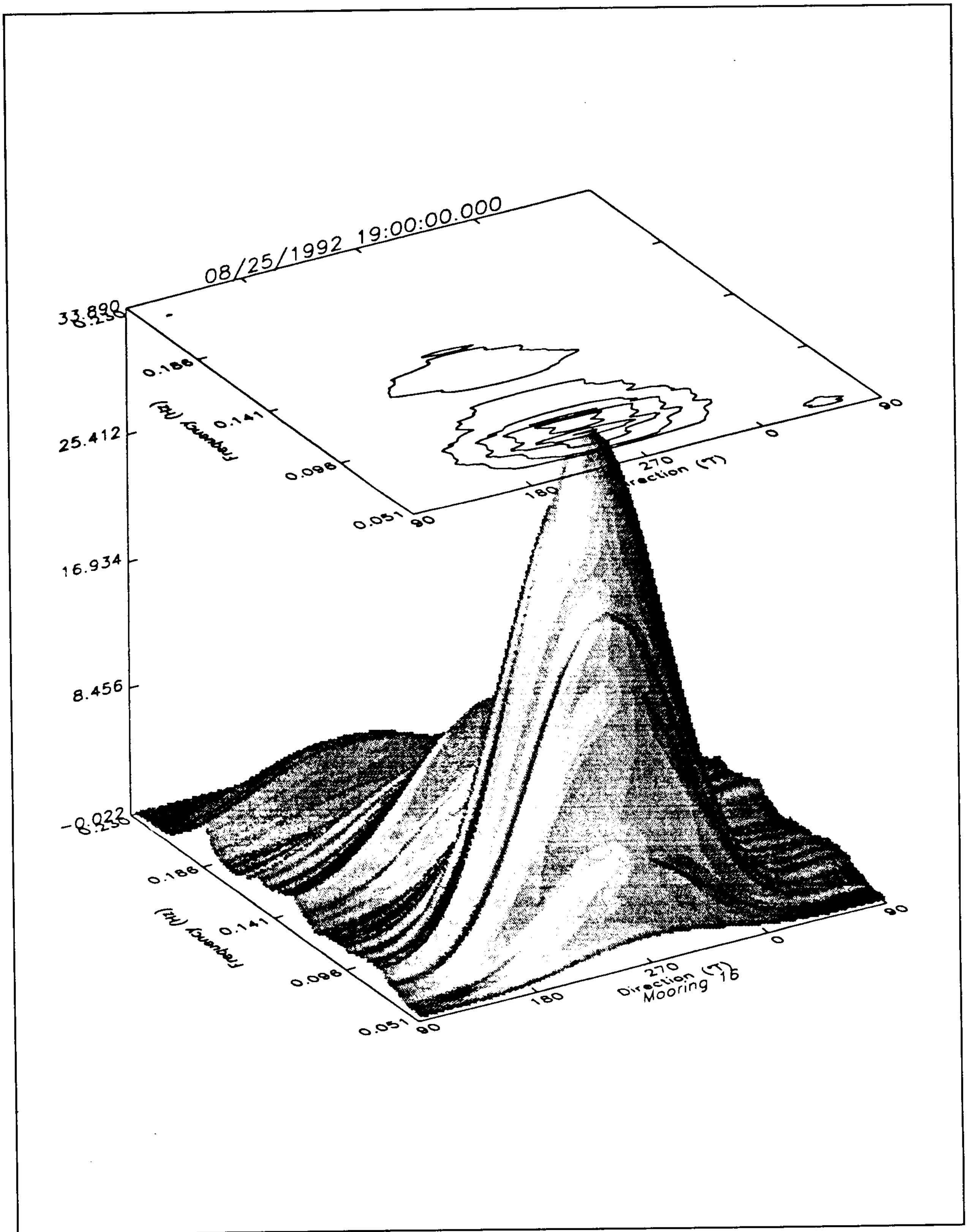

Figure 2D.24. Directional wave spectrum at LATEX Site 16 during Hurricane Andrew.

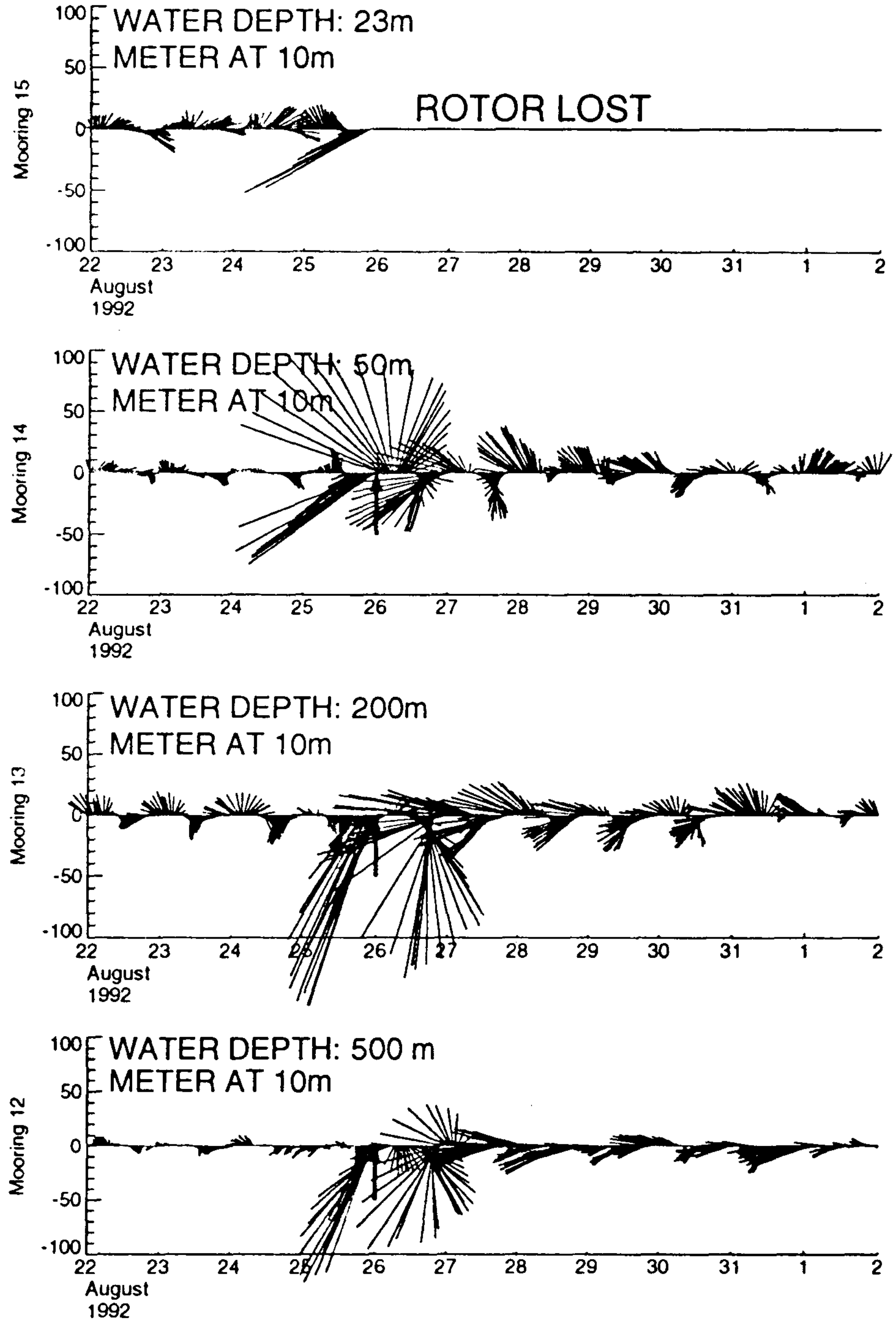

Figure 2D.25. Current stick plots at LATEX sites 12-15 showing current speed and direction during Hurricane Andrew. Arrow indicates beginning of passage of eye.

Dr. Steven F. DiMarco is a research associate in the Geochemical and Environmental Research Group in the College of Geosciences and Maritime Studies at Texas A&M University. Dr. DiMarco received his B.A. in physics from the University of Dallas and his M.S. and Ph.D. in physics from the University of Texas at Dallas. He has done postdoctoral research at the Max-Planck-Institut für Quantenoptik in Munich, Germany. His current research interests include wave dynamics in the Gulf of Mexico.

Dr. Norman L. Guinasso Jr. is an associate director of the Geochemical and Environmental Research Group in the College of Geosciences and Maritime Studies at Texas A&M University. He is the principle investigator for the Data Management and Public Information tasks of the LATEX A program. His research interests in the Gulf of Mexico include the study of its naturally occurring deep-water oil seeps and its physical oceanography. He has led numerous cruises in surface ships and submersibles.

Mr. F.J. Kelly is an assistant research scientist in the Geochemical and Environmental Research Group in the College of Geosciences and Maritime Studies at Texas A&M University. Mr. Kelly received his B.A. in physics from the University of California, Berkeley and M.S. in oceanography from Texas A&M University. He has been investigating the physical oceanography of the Gulf of Mexico for the past 15 years. He is co-author with Prof. J.D. Cochrane of the seminal paper describing the seasonal circulation on the Texas-Louisiana Shelf.

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SESSION 3A

OIL SPILL RESPONSE II

Session: OIL SPILL RESPONSE II

Co-Chairs: Mr. Gary Rutherford and Ms. Gail Rainey

Date: December 15, 1993

Presentation	Author/Affiliation
Introduction	Mr. Gary Rutherford Minerals Management Service Gulf of Mexico OCS Region
Document not submitted	Captain Jenson National Strike Force Coordination Center
Tidal Inlet Protection Strategies for Oil Spills	Dr. Miles O. Hayes Research Planning Institute Columbia, South Carolina

TIDAL INLET PROTECTION STRATEGIES FOR OIL SPILLS

Dr. Miles O. Hayes
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Columbia, South Carolina

INTRODUCTION

This paper summarizes a presentation on protection strategies devised for the inlets along the outer coast of California. The coastal inlets of California are the focal points for designing strategies to protect the vital resources of the state's estuaries and bays, because it is through these conduits that oil spilled on open ocean waters could reach the resources. Therefore, a project was commissioned jointly by the Marine Spill Response Corporation (MSRC) and the Office of Oil Spill Prevention and Response (OSPR) of the California Department of Fish and Game to provide a synopsis of the relevant characteristics of the coastal inlets in the state, as well as a discussion of potential protection strategies for each inlet. Protection strategies were designed for 170 coastal inlets. Every inlet in the state was covered, with the possible exception of a few minor stream mouths that could be closed easily with sediment dikes in the event of an oil spill. Entrances to all of the major harbors and marinas were included, although many of them are not natural tidal inlets in a strict geomorphological sense.

TIDAL INLETS—GENERAL

ORIGIN

In the classic sense, *tidal inlets* are channels that divide barrier islands into segments. They are subject to reversing tidal currents and are conduits for the volume of water that flows in and out of the estuarine system landward of the inlet during a tidal cycle, called the *tidal prism*. Tidal inlets on the sandy coastal plain of the eastern United States are usually formed by either of two mechanisms: 1. storm-generated scour channels (resulting inlets are usually shallow and prone to rapid migration); or 2. closure of estuarine entrances by growth of sand spits (resulting inlets usually deep and fixed in place).

MORPHOLOGY

As shown in Figure 3A.1, a typical tidal inlet in a barrier island setting consists of a deep channel between the adjacent sand spits, called the *inlet throat*, and lobate-shaped sand bodies on either side

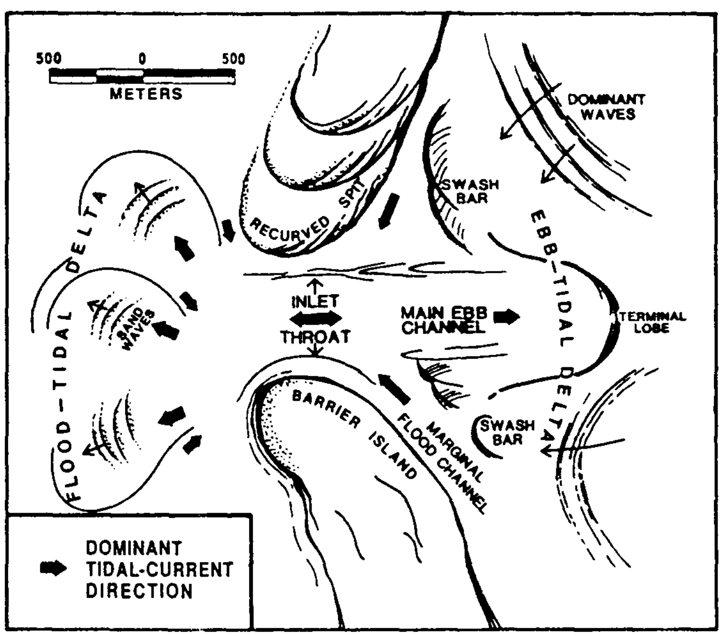

Figure 3A.1. General model showing the morphological components of a typical tidal inlet.

of the inlet, called *tidal deltas*. The sand deposit on the landward side of the inlet, the *flood-tidal delta*, is typically composed of sheet-like lobes of sand with seaward-sloping ramps on their seaward sides covered by landward migrating waves of sand. The sand deposit on the seaward side of the inlet, the *ebb-tidal delta*, is built seaward by ebb-tidal currents, but waves mould the outer margins into an arcuate shape and build landward migrating intertidal bars (*swash bars*) on the delta surface. The tidal flow on the ebb-tidal delta is horizontally segregated, with the *main ebb channel*, which usually projects perpendicular to shore off the inlet throat, being dominated by ebb-tidal currents. Shallower, flood-dominant channels (*marginal flood channels*) flank both sides of the ebb-tidal delta (see Figure 3A.1). The marginal flood channels are important in oil-spill response because the first waters to enter the inlet during the rising tide flow down these channels, even as residual ebb-tidal currents are flowing out the main ebb channel. This allows for a period of time (one hour or so) when any oil heading landward would be moving only down the marginal flood channels, during which time it could possibly be diverted to the adjacent sand beach, rather than allowing it to enter the inlet and the highly sensitive estuary behind it.

TIDAL INLETS—CALIFORNIA

Tidal inlets in California are highly variable. There are a number of inlets in barrier-island systems that fit the morphological pattern described in Figure 3A.1, which is based on the typical tidal inlets found on the East and Gulf Coast shorelines of the USA. Examples include Drake's Estero Inlet in Marin County, Tijuana Estuary Inlet in San Diego County, and Eel River Inlet in Humboldt County. However, California's coast is dominated by bedrock shores, not barrier islands, primarily because it is located on the leading edge of the North American plate, a zone of collision with the Pacific plate, and, hence, mountain building. This fact accounts for the occurrence of a wide variety of inlet types in California, including a. entrances to flooded major alluvial valleys; b. stream-mouth/bar systems; c. "half-inlets" (one-half of inlet is bedrock and the other half has the typical inlet configuration shown in Figure 3A.1); d. fault-zone inlets; and e. crenulate bayhead inlets.

INLET PROTECTION STRATEGIES USED

Protecting the inlets of California in the event of major oil spills will be a complex and difficult task. The primary goal of the project discussed in this presentation was to do a basic scientific inventory of the inlets present. Once this was completed, potential protection strategies were proposed based on the following assumptions:

- The most important consideration is keeping the oil on the seaward side of the inlet because of the abundant natural and human resources usually found landward of the inlet, as well as the high environmental sensitivity of the habitats commonly present there.
- If at all possible, a sediment dike should be used to prevent oil from passing to the landward side of the inlet.
- When oil is on the water, the first priority is *containment* and the second is *recovery*.
- Following guidelines established by the U.S. Coast Guard Strike Team, we concluded that *deflection booms* were the best means of controlling oil in the vicinity of tidal inlets because of the common occurrence of tidal currents greater than 0.7 knots, the threshold velocity for entrainment of oil past a boom set at 90° to the current.
- Collection of oil from the water surface with skimmers is the preferred method of *recovery*. However, if this is not possible, the oil should be diverted to a *catchment area* along shore where the oil can be cleaned up. The preferred catchment area is a fine- to medium-grained sand beach, which is easily cleaned and where penetration of oil into the sediment is minimal. Coarse-grained gravel beaches, rip rap, tidal flats, and marshes should not be used as catchment areas except as a last resort. Trapping oil against vertical rock scarps or concrete seawalls is also acceptable.
- Many of the breakwaters and groins in the harbors in California constructed of rip rap are permeable, and oil would be able to pass through them. In many situations, the landward side of

the rip rap could be *lined with sorbent boom* to protect the inner harbor. This is a highly recommended technique and should be used whenever feasible.

- Entrainment of the deflection booms will occur, regardless of the angle of deployment, if the current velocity exceeds about 3.5 knots. Large waves also may cause both entrainment and washover, depending upon the physical configuration of the boom.

- The protection strategies depicted in our report on this project related only to spills located seaward of the inlet; the strategy recommended applies only to flood-tide conditions.

Therefore, most of the potential inlet protection strategies suggested in the report used a sediment dike if there was any chance of closing the inlet. If not, deflection booms were used to divert oil to skimmers or to sand catchment areas. Where feasible, deflection booms were used to divert oil approaching the inlet along shore to outer sand beaches. However, in many instances, waves will be too large to allow booms to function just offshore of the outer beaches.

The proposed response strategies for some of the more difficult inlets were intended to be phased, and not necessarily all be put in place at the same time. The sequence for establishing the different protection equipment could be either landward to seaward or seaward to landward, depending upon local conditions and priorities. This is a decision that will have to be made at the time of the spill.

An example of how these suggestions are presented graphically is given in Figure 3A.2. In that example,

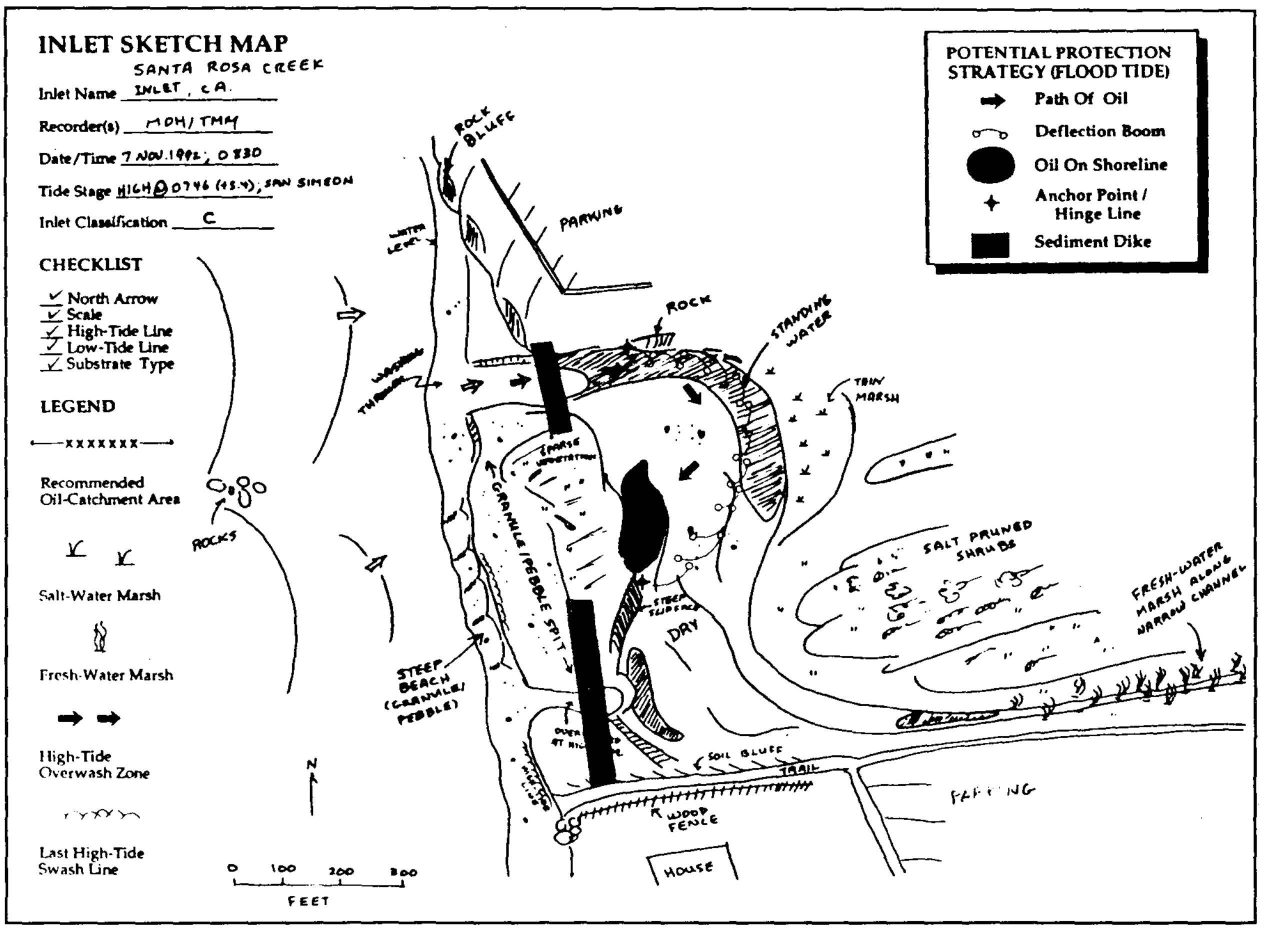

Figure 3A.2. Potential ranking strategy (flood tide) suggested for Santa Rosa Creek Inlet, San Luis Obispo County, California.

Table 3A.1. Proposed ranking scale for California coastal inlets, based on estimated degree of difficulty for containment and recovery.

A.	Extremely difficult because of large size and extreme physical conditions. Large expense because of magnitude of resources to protect.
B.	Difficult because it is permanently open; subject to strong currents and/or large waves.
C.	Inlets that can be closed with a sediment dike under mild conditions but that are reopened under normal adverse conditions (i.e., normal storms, 10-year floods, spring tides).
D.	Can be closed with sediment dike under normal adverse conditions.

the first recommendation was to close off the inlet with a sediment dike. If the dike were to fail, then it is recommended that deflection booms be used to divert the oil to a sandy catchment area on the landward side of the spit. Problems associated with waves may preclude this and cause protection efforts to be shifted further inside the inlet.

INLET CLASSIFICATION

INTRODUCTION

After much deliberation and discussion, a decision was made to classify the coastal inlets of California on the basis of the degree of difficulty for containment and recovery of spilled oil once it reaches the inlet. This ranking, which is summarized in Table 3A.1, is on a scale that ranges from A to D, with the inlets classed as A's being the most difficult, and, consequently, the most expensive ones to deal with.

DISCUSSION

- Of the fifteen class A inlets, five occur within the less than 50 miles between the Golden Gate and Bodega Head—San Francisco Bay Entrance, Bolinas Lagoon Inlet, Drake's Estero Inlet, Tomales Bay Inlet, and Bodega Bay Inlet. All of these inlets require special strategies, and the tidal-current systems need study.

- The seven most difficult inlets in the state are: 1. San Francisco Bay Entrance (easily the most difficult); 2. Tomales Bay Inlet; 3. Drake's Estero Inlet; 4. Humboldt Bay Inlet; 5. Noyo Harbor Inlet; 6. Moss Landing Inlet; and 7. Eel River Inlet. All of these inlets need more research on their current patterns to improve significantly the suggested protection strategies.

ACKNOWLEDGMENTS

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SESSION 3B

UNIVERSITY RESEARCH INITIATIVE PROGRESS REPORTS II

Session: UNIVERSITY RESEARCH INITIATIVE PROGRESS REPORTS II

Co-Chairs: Dr. Robert Rogers and Dr. Paul Sammarco

Date: December 15, 1993

Presentation	Author/Affiliation
The Use of Remotely Sensed Data in Monitoring Oil Spill Impacts in Wetlands	Dr. Irving Mendelssohn Mr. Mark W. Hester Louisiana State University Dr. John Hill Houston Advanced Research Center
Restoring Louisiana Coastal Habitats by Sensing Existing Pipeline Canals	Dr. Denise J. Reed Louisiana Universities Marine Consortium Dr. Lawrence P. Rozas National Marine Fisheries Service

THE USE OF REMOTELY SENSED DATA IN MONITORING OIL SPILL IMPACTS IN WETLANDS

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Mr. Mark W. Hester
Louisiana State University

Dr. John M. Hill
Houston Advanced Research Center

Oil spills can have a significant short-term impact on coastal marshes, but the long-term effects and perhaps eventual recovery are not well documented. The overall goal of this investigation is to document the long-term recovery rate of a Louisiana brackish marsh impacted by an oil spill on 23 April 1985, to separate the effect of the oil spill on marsh deterioration from ambient rates of marsh degradation, and to test means by which recovery can be accelerated and the damage mitigated. These goals have been accomplished through both remote sensing and ground truth assessments, ground based vegetation stress measurements, and manipulative field experiments. This abstract specifically reports on the use of remotely sensed data to monitor oil spill impacts and to differentiate between oil spill-induced wetland loss and wetland loss caused by other factors.

Historical photography was acquired and photomosaics constructed to visually assess regional land loss rates. The historical imagery was used to generate detailed maps of the original study site (impacted and control marshes). Approximately eight-10 year time intervals were mapped prior to the spill. Low altitude color infra-red imagery was acquired of the study site every other year after the spill and used to determine post-spill recovery rates. The mosaics were photointerpreted and land cover categories assigned and digitized. Acreage estimates were acquired for both pre- and post-spill conditions and rates of wetland loss calculated for each time period before and after the spill event.

Marsh loss at the study site between 1950 and 1960 was primarily caused by shoreline erosion, canal dredging and spoil deposition on the marsh; the latter two factors were dominant in the oiled marsh and the north control marsh. Between 1960 and 1970, land loss was relatively small (< 500 m2 y-1) as a result of the absence of new canal dredging and the paucity of interior marsh loss. The primary cause of the marsh loss was shoreline retreat during this period.

The period from 1970 to 1978 exhibited a general increase in marsh loss rate, especially for the oiled marsh and the north control marsh. The majority of this marsh loss was due to interior marsh degradation. Shoreline retreat contributed to marsh loss as in previous years. Shoreline erosion at the site was rather constant from 1950 to the present (1990), averaging approximately 15 m during the forty-year project period. The actual amount varies from area to area. Although the period from 1978 to 1982 exhibited relatively minor additional marsh loss in the oiled marsh and the north control marsh, the south control marsh experienced massive interior deterioration resulting in the highest annualized land loss rate of the study. The absence of measurable shoreline retreat during this period may have been an artifact of the aerial photography used for mapping since this was the only period that appeared to have no shoreline erosion.

Between 1982 and 1990, a period which brackets the date of the oil spill (1985), land loss rates were similar to other periods in the past. Although the spill caused significant short-term mortality of the vegetation, the marsh vegetation showed near complete recovery by 1990 and marsh loss rates were not accelerated over previous time intervals. Background interior marsh loss (except for that caused by canal dredging) and shoreline erosion appeared to have slowed considerably since 1982.

Rates of land loss at the study site fall into the range of land loss rates determined by the U. S. Army Corps of Engineers (Dunbar *et al.* 1992) between 1932 and 1990 for the Empire 7.5 o quadrangle, in which the study site is located, with one notable exception. The south control marsh exhibited an exceptionally high marsh loss rate of 3.95 % y-1 during the 1978-82 period. This rate exceeds that determined for the Empire quadrangle (1.92 - 2.01% y-1) by almost 2 % y-1 for the same general time period (Dunbar *et al.* 1992). The high rate of land loss in the south control marsh was due to interior marsh degradation. The reason for such an extreme rate of marsh loss during this four-year period at the south control marsh, but not at the oiled or north control marshes, is not immediately apparent.

However, it is likely that these spatial differences in marsh loss are characteristic of the highly site-specific nature of the land loss process. Even at larger spatial scales, these site-specific differences in marsh loss rate are evident. For example, annualized rates of land loss during the past 20 years for the Empire quadrangle (1.55 - 2.01% y-1) are approximately 5 times higher than that for the entire Mississippi River Deltaic Plain (0.36 - 0.42 % y-1, Dunbar *et al.* 1992).

In summary, this particular spill event, although having a dramatic negative short-term impact on the wetland vegetation, did not accelerate the longer term rate of wetland loss for the oil-affected marsh.

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RESTORING LOUISIANA COASTAL HABITATS BY INFILLING EXISTING PIPELINE CANALS

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INTRODUCTION

The impact of canals and their dredged-material levees on Louisiana coastal marshes has been assessed in a number of studies. In addition to the direct loss of marsh habitat caused by the canals, the indirect effect of dredge material placement in levees on natural marsh hydrology can be dramatic (Swenson and Turner 1987) and has been associated with marsh deterioration. Dredging activities convert marsh and shallow subtidal habitat to a combination of uplands, on the dredged-material levees which are above the elevation of normal marsh flooding and deep-water habitat. Canals are usually straight, deep, and steep-sided; their average depth (1.8-3.6 m) is substantially greater than nearby natural tidal channels or ponds (Tabberer *et al.* 1985, Abernethy and Gosselink 1988, Wicker *et al.* 1989, Rozas 1992). Most of the subtidal area in canals is too deep for submerged aquatic vegetation (SAV) development, even where turbidity and salinity are favorable for its establishment. Deep canals may provide a refuge for large predators that would otherwise be constrained by the shallow water in natural marsh systems. These deep corridors may allow predators easy access to what little shallow subtidal habitat there is along canal shorelines. Consequently, the presence of large predators in canals may reduce densities of early life stages of nekton (fishes and decapod crustaceans), either by increasing mortalities or because potential prey avoid canals with high predator densities.

Studies have shown that canal infilling was generally successful in reducing canal depth and restoring marsh vegetation in the area covered by the levee. However, such infilling does not restore emergent marsh vegetation in the canal because of the lack of remaining dredged material in the levees. Rather, shallow water bodies are produced, typically 0.5 - 1.5 m deep (Abernethy and Gosselink 1988, Neill and Turner 1987). The degree to which the canal can be infilled depends upon the amount of dredged material available and the bathymetry of the canal at the time of backfilling. Infilling may enhance the nursery value of pipeline canals by expanding the area of shallow subtidal habitat and reducing the density of large predators (McIvor and Odum 1988, Baltz *et al.* 1993).

This study aims to evaluate the potential change in habitat availability which might result from infilling and to establish simple techniques which can be used by managers to examine the potential result of infilling specific canals and the type of habitat which may result.

STUDY AREA

The study was conducted in brackish and saline marshes in coastal Louisiana between the Atchafalaya River and Bayou Lafourche. Our study was restricted to pipeline canals which support OCS (Outer Continental Shelf) oil and gas activities.

METHODS

For field sampling purposes we randomly selected study sites in each of four types of canal: saline-plugged, saline-unplugged, brackish-plugged and brackish-unplugged. The field survey to evaluate the potential for infilling consisted of four components:

1. Three cross sections were chosen in the segment of the canal determined by the site selection procedure, usually located at each end of the canal segment and in the middle.

2. Rod and level techniques were used to survey the ground elevations across the dredged-material levees on both sides of the canal at each cross section.

3. A recording fathometer was used to obtain a bathymetric profile of the canal at each cross section. In areas too shallow for use of the fathometer, depth profiles were determined by poling.

4. Soil samples were taken from the edge of each canal (either marsh or dredged material depending on levee proximity to canal), the middle of the dredged-material levee and the marsh behind the levee. These samples were analyzed for soil dry bulk density and organic matter content.

Field studies for the evaluation of fisheries habitat were conducted on a sub-sample of canals. Samples were collected using a 2 m2 throw trap and a 2.4-m otter trawl. We used the throw trap only in subtidal habitats <2 m deep, which represented on average >80 percent of total canal area.

RESULTS

Potential for Canal Infilling

Fathometer records and topographic survey data for the selected canals were combined to estimate the amount of material available in the levees and the amount of material required to fill in the canal. The results were combined into an Infilling Index (the mean ratio of levee cross section to canal cross section for the three sections measured in each canal segment). Statistical analyses indicate no significant differences between the index values for plugged and unplugged canals for either saline or brackish marshes. The index values were used with the canal area and width information to estimate the depth of water which would remain after canal infilling. The results of this analysis are shown in Table 3B.1.

Table 3B.1. Mean depths after infilling estimated from index values, canal area and width data.

Canal Type	Estimated Depth After Infilling (m)
Brackish Plugged	1.23
Brackish Unplugged	0.62
Saline Plugged	1.57
Saline Unplugged	0.87

The table shows that for both brackish and saline canals, those that are left unplugged have shallower depths after infilling. However, neither of these comparisons is statistically significant. Only seven of the 18 canal segments for which the depth calculation can be made will have depths of greater than 1 m after infilling. Three of these are on the Trunkline pipeline canal which was originally dredged to a depth of approximately 4 m according to the information provided by the pipeline company, much deeper than the other canals included in the field survey. In addition, although the canal was first constructed in 1958, a second pipeline was placed in the canal in 1980, resulting in very recent dredging activity. Tennessee #3 also shows greater depths after infilling than many other canals, and this also has been used for the laying of two pipelines. The original canal was constructed in 1968, but in 1977 the pipeline company laid another line in the same canal which required a second episode of dredging activity.

These two cases indicate the possible role of canal age in controlling the depth after infilling. Figure 3B.1 shows the relationship between age of the canal, or time since most recent dredging activity, and the estimated depth after infilling for brackish canal segments. There is a strong negative relationship showing that infilling older canals is more likely to result in the creation of shallow water habitat than infilling younger canals. A similar, but less strong, relationship for saline canal segments is shown in Figure 3B.2. Of the two main factors influencing the amount of material available and necessary for efficient canal infilling, decomposition and compaction of dredged material and natural canal infilling, it might be considered that both would change over time. One might expect that as the canal gets older less material is available in the levee for infilling, but also less material is required because the canal has had an opportunity to naturally infill. These data indicate that these two factors do not both progress at the same rate and that the amount of material available and the amount required converge with time. The data also indicate differences in these relationships between brackish and saline areas.

Evaluation of Fisheries Habitat

Nekton assemblages using pipeline canals in our study area included 43 species of fishes and six species of decapod crustaceans. We collected a total of 25,670

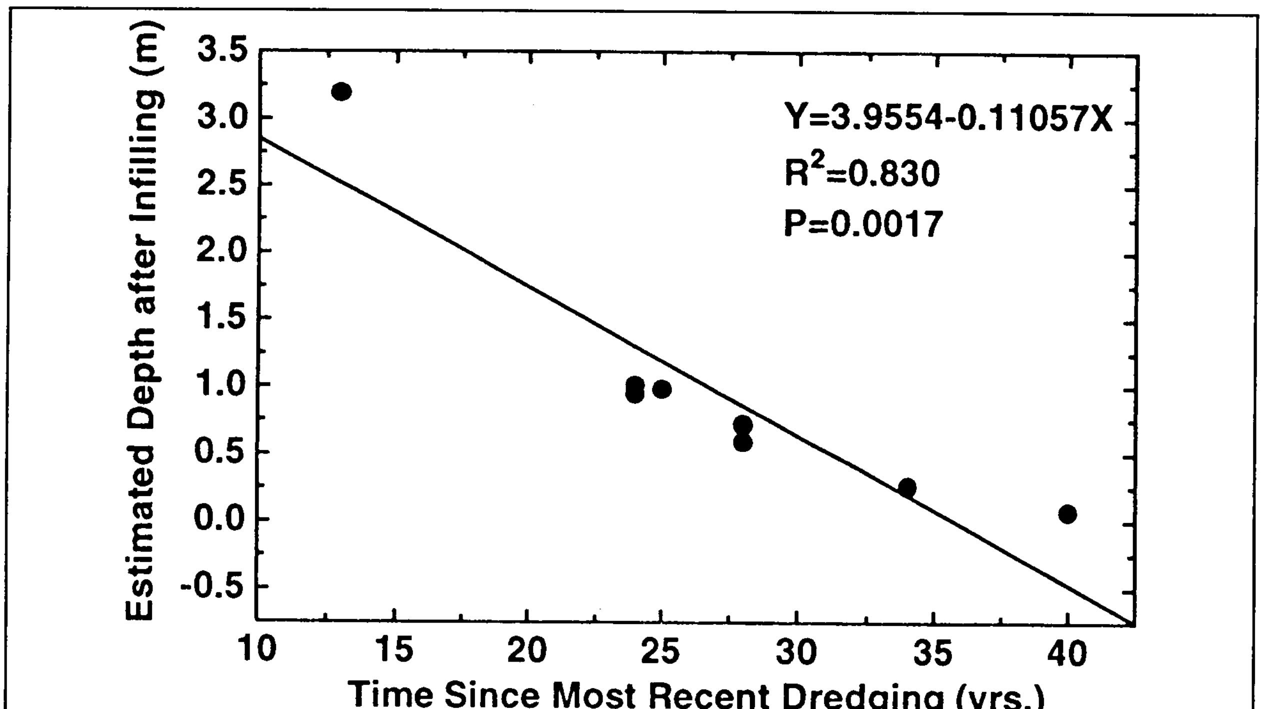

Figure 3B.1. Relationship between canal age and estimated depth after infilling for brackish canals sampled in this study.

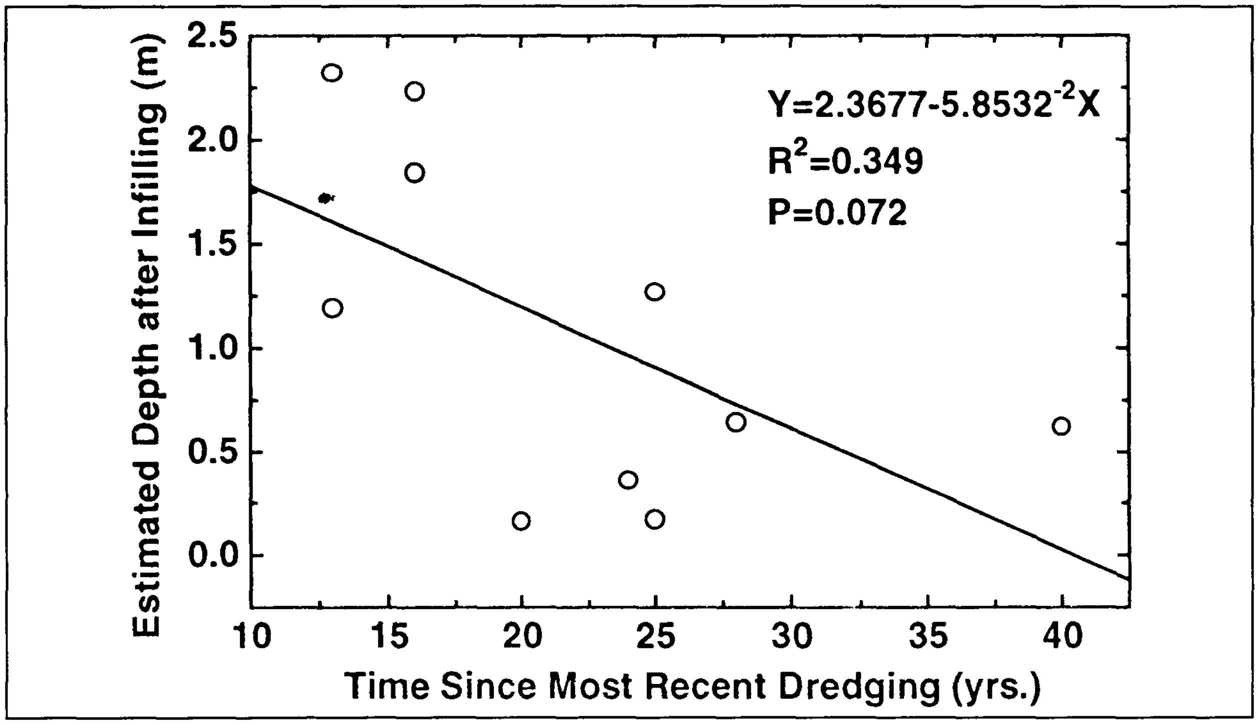

Figure 3B.2. Relationship between canal age and estimated depth after infilling for saline canals sampled in this study.

organisms having a wet weight of approximately 10.94 kg. Species richness was greater in brackish than saline canals (43 vs. 37 species). Daggerblade grass shrimp *Palaemontes pugio* was the most abundant estuarine resident species in both brackish and saline canals. Other numerically dominant residents occupying brackish canals were naked goby *Gobiosoma bosc*, rainwater killifish *Lucania parva*, and gulf pipefish *Syngnathus scovelli*. Two additional resident species, clown goby *Microgobius gulosus* and sailfin molly *Poecilia latipinna*, were only seasonally abundant in brackish canals. Bay anchovy *Anchoa mitchilli*, blue crab *Callinectes sapidus*, brown shrimp *Penaeus aztecus*, and gulf menhaden *Brevoortia patronus* were numerically dominant transient species in both saline and brackish canals. White shrimp *Penaeus setiferus* and Atlantic croaker *Micropogonias undulatus* were dominant transient species in saline canals only.

Variation in the abundance of numerically dominant species could not be related to maximum canal depth. Within the same canal, however, the distribution of some species seemed to be influenced by habitat depth. The strength of the relationship between habitat depth and animal density varied not only among species, but also by marsh type and with time of year. The degree of habitat segregation with depth was most pronounced in brackish canals during late spring and summer when submerged aquatic vegetation(SAV) was very abundant in shallow areas. Densities of both total fishes and total decapod crustaceans were significantly greater in shallow water in May and June. Numerically dominant species that were significantly more abundant in shallow water at this time included naked goby, rainwater killifish, gulf pipefish, blue crab, and daggerblade grass shrimp (Figure 3B.4). Bay anchovy was the only numerically dominant species that exhibited the opposite relationship. In June bay anchovy were concentrated in deep water (Figure 3B.4). In saline canals, blue crabs selected shallow habitats (Figure 3B.3). Bay anchovy was the only fish for which a relationship between water depth and density could be shown, and the relationship was identical to that found for brackish canals, one of greater abundance in deep water in June (Figure 3B.3).

A comparison of the patterns of habitat selection in brackish canals before and after the passage of

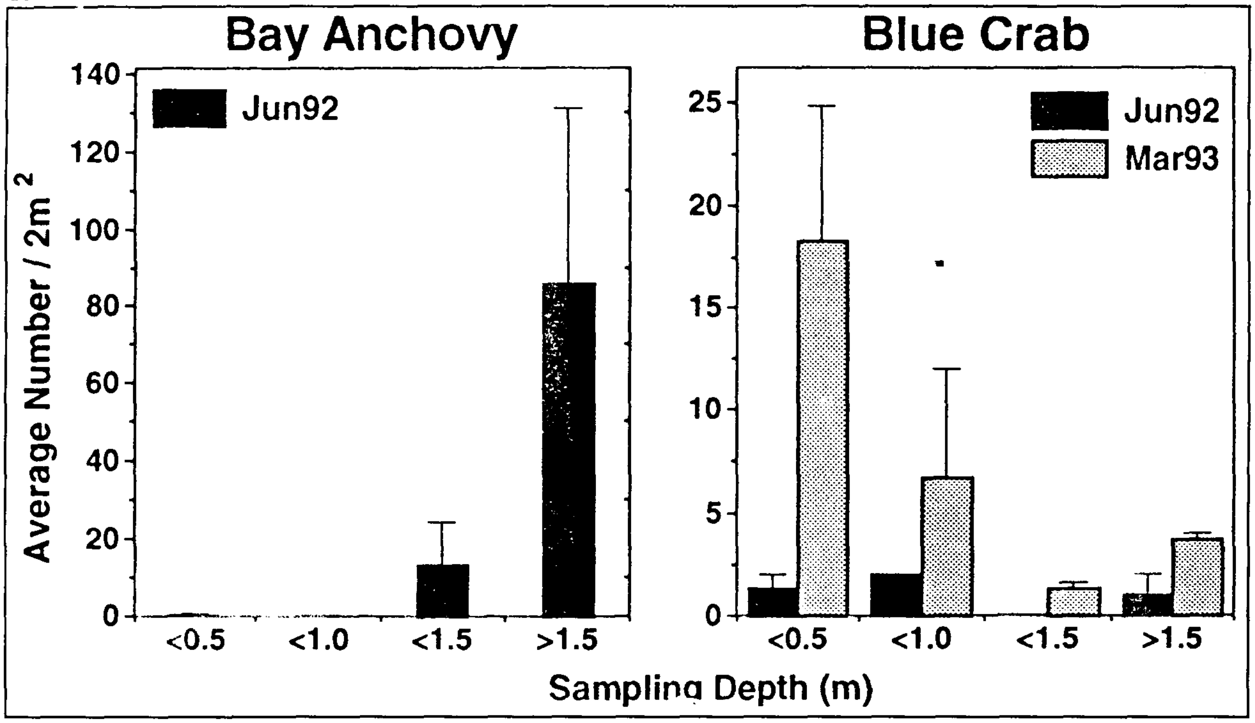

Figure 3B.3. Abundance-depth relationships determined from throw trap samples for two dominant species in saline canals.

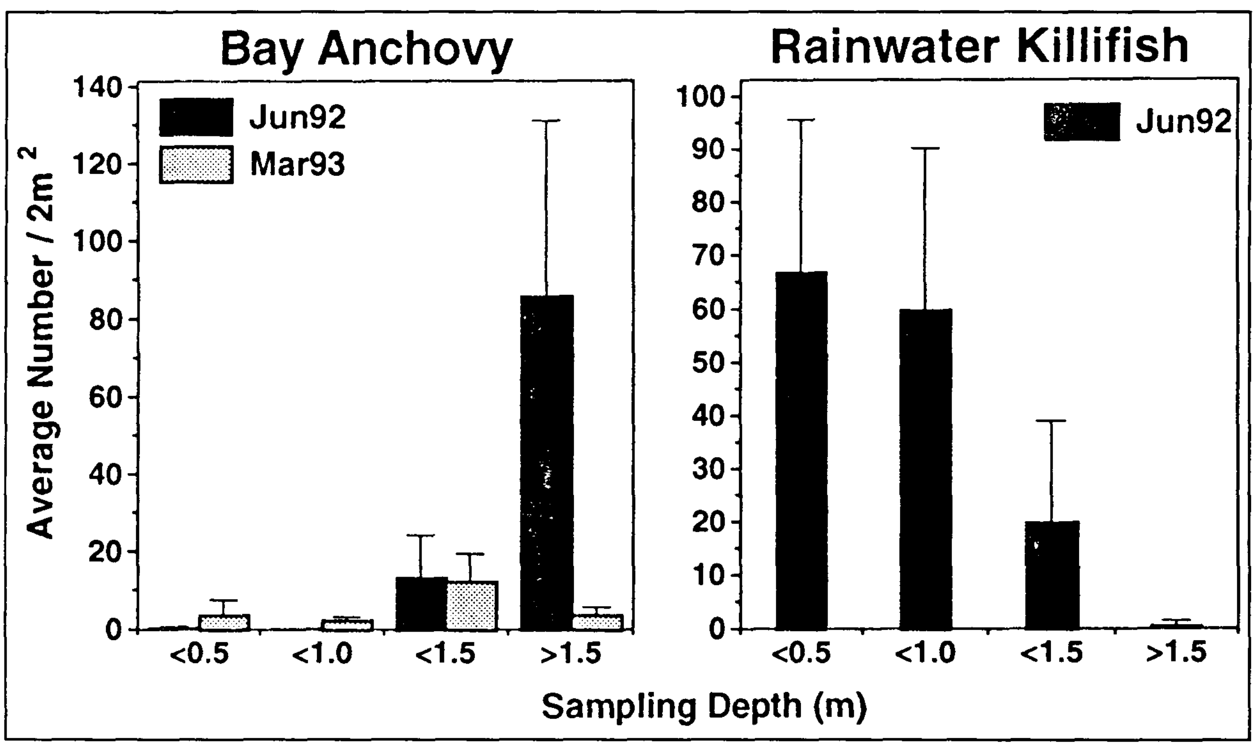

Figure 3B.4. Abundance-depth relationships determined from throw trap samples for two dominant species in brackish canals

Hurricane Andrew provides support for an enhancing effect of SAV in subtidal areas. In brackish canals prior to hurricane passage in August 1992, the average densities of total fishes, total decapods, and most dominant species were significantly greater in shallow water (<1 m) where SAV was abundant. However, after most SAV was removed by the hurricane, only one species (naked goby) showed a preference for the shallow habitat.

CONCLUSIONS

Our geomorphic evaluation of pipeline canals has shown that infilling the canals with dredged material from adjacent levees will rarely result in the restoration of vegetated marsh habitat except in the area where the levee is removed. However, there is frequently sufficient material available in levees to produce shallow-water habitat less than 1 m deep in the canal. Our study has shown that the efficiency of infilling increases with time after dredging for canals in both brackish and saline marsh areas. No significant difference in infilling potential was found between canals which had been plugged and those which had been left open, and for canals which could be infilled to depths of less than 1 m, this was the case for both brackish and saline canal segments.

Our results suggest that increasing shallow subtidal habitat in canals at the expense of deep areas would enhance the value of nursery habitat for some species, especially in brackish canals where backfilling would expand the subtidal area capable of supporting SAV. Increasing the abundance of SAV in backfilled canals would also enhance habitat quality for waterfowl, which use submerged vegetation as food. The only species that might be negatively affected by a reduction in deep habitats is the bay anchovy which preferred deep water during some times of the year. Backfilling would also benefit organisms that exploit marsh-surface habitats. Species dominating the assemblages in our study canals and known to use the adjacent marsh surface when it is flooded include daggerblade grass shrimp, naked goby, blue crab, brown shrimp, and white shrimp. Backfilling would benefit these species by restoring marsh-surface habitat which is presently buried beneath dredged material. Both the frequency and duration of flooding, and therefore availability of habitat, would be dramatically increased in the area presently covered by the levee.

Our analysis has demonstrated that simple survey techniques can be used to indicate the potential efficiency of canal infilling. We recommend that such surveys be used to evaluate both pipeline and disused location canals across the Louisiana coastal zone to determine the potential for increasing shallow-water habitat. Where canal infilling is found to be inefficient at present, we recommend that the canal be reevaluated at five-year intervals, as natural processes can greatly enhance the possibility of producing shallow-water habitat by infilling with the remaining levee material.

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SESSION 3C

ENVIRONMENTAL STUDIES PROGRESS REPORTS

Session: ENVIRONMENTAL STUDIES PROGRESS REPORTS

Co-Chairs: Dr. James Kendall and Dr. Ann Scarborough Bull

Date: December 15, 1993

Presentation	Author/Affiliation
Minerals Management Service Environmental Studies Progress Reports: Introduction	Dr. James J. Kendall Dr. Ann Scarborough Bull Minerals Management Service Gulf of Mexico OCS Region
Long-Term Assessment of the Oil Spill at Bahia Las Minas, Panama: The Final Results of the Five-Year Effort	Dr. Brian D. Keller Dr. Jeremy B. C. Jackson Smithsonian Tropical Research Institute
Impact of Exploratory Drilling Offshore Florida	Dr. Eugene A. Shinn Ms. Barbara H. Lidz Mr. Christopher D. Reich U. S. Geological Survey Center of Coastal Geology
Estimation of Fisheries Impacts Due to Underwater Explosions Used to Sever and Salvage Petroleum Platforms	Mr. Gregg Gitschlag Galveston Laboratory Southeast Fisheries Center
The Effects of Oil and Dispersed Oil on the Early Life Stages of Select Marine Vertebrates and Invertebrates from the Gulf of Mexico	Mr. Ken Fucik Ms. Kelly Carr The SeaCrest Group Broomfield, Colorado Mr. Brian Balcom Continental Shelf Associates, Inc. Ventura, California
Progress to Date on the Gulf of Mexico Air Quality Study (GMAQS)	Dr. Mark A. Yocke Systems Applications International Mr. Paul Roberts Sonoma Technology, Inc. Mr. William Steorts Minerals Management Service Gulf of Mexico OCS Region
Sea Turtle Behavior Relative to Offshore Structures in the Western and Central Gulf of Mexico	Dr. Warren E. Stuntz National Marine Fisheries Service Pascagoula, Mississippi
Environmental and Economic Assessment of Discharges from Gulf of Mexico Region Oil and Gas Operations	Dr. David A. Gettleson Dr. Alan D. Hart Mr. Bruce D. Graham Continental Shelf Associates, Inc. Jupiter, Florida

MINERALS MANAGEMENT SERVICE ENVIRONMENTAL STUDIES PROGRESS REPORTS: INTRODUCTION

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

INTRODUCTION

This session on Minerals Management Service (MMS) Environmental Studies was organized to give MMS contractors an opportunity to present progress reports from their respective studies.

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 these issues are prioritized, studies are designed and procured to address the information need.

Since the inception of the Bureau of Land Management (BLM)/MMS Environmental Studies Program in 1974, approximately $120 million has been spent in the Gulf of Mexico to fulfill identified information needs.

Presentations described MMS's efforts to fulfill information needs involving the long-term impacts of oil spills and operational discharges, threatened and endangered species, issues dealing with post-lease activities such as structure removal and site clearance, and efforts to examine the impact of OCS activities in air quality.

Dr. James J. Kendall is the Chief of the Environmental Studies Section, MMS, Gulf of Mexico Regional Office. His research interests include the effects of contaminants on the physiology of corals, the behavior of reef animals, and procedures for aquatic toxicity testing. Dr. Kendall has conducted research and monitoring programs in the Gulf of Mexico, Galveston Bay, the Florida Keys, and the Gulf of Eilat, Red Sea. Dr. Kendall received his B.S. in biology from Old Dominion University and his Ph.D. in oceanography from Texas A&M University.

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LONG-TERM ASSESSMENT OF THE OIL SPILL AT BAHIA LAS MINAS, PANAMA: THE FINAL RESULTS OF THE FIVE-YEAR EFFORT

Dr. Brian D. Keller
Dr. Jeremy B. C. Jackson
Smithsonian Tropical Research Institute

INTRODUCTION

This paper provides an overview of a major oil spill based on a five-year study at Bahía Las Minas, Panama (Keller and Jackson 1993). The spill was the largest yet reported in coastal habitats of the tropical Americas and caused extensive mortalities of both subtidal and intertidal organisms (Cubit *et al.* 1987; Jackson *et al.* 1989). Biogenic habitats formed by long-lived organisms such as mangrove trees, seagrasses, and corals dominate warm-water regions. Their die-offs can lead to permanent or prolonged habitat loss with concomitant affects on associated populations and communities.

In addition to initial lethal and sublethal effects of major oil spills, long-term retention and release of oil may lead to chronic biological effects (Berthou *et al.* 1987; Teal *et al.* 1992; Burns *et al.* 1993; Guzmán and Holst 1993; Keller and Jackson 1993). Recovery of tropical coastal ecosystems from major oil spills apparently requires from decades to more than a century because of these chronic effects and the long life cycles of habitat-structuring organisms such as mangroves and reef corals (Jackson and Keller 1993).

THE BAHIA LAS MINAS ECOSYSTEM

Bahía Las Minas, Panama (Figure 3C.1), is a topographically complex, shallow-water, tropical embayment whose margins are dominated by extensive mangrove forests, seagrass beds, and coral reefs (Cubit *et al.* 1985). These relatively large, long-lived, photosynthetic organisms together buffer the coastal zone from freshwater runoff and erosion from the land and wave energy from the open sea.

Much of the Bahía Las Minas study area has a long history of exposure to various kinds and degrees of human disturbance and pollution (Keller *et al.* 1993). These include construction of the Panama Canal and the city of Colón, followed by decades of excavation, dredging, land filling, swamp drainage, mosquito spraying, and erosion. On the mainland there has been extensive deforestation, resulting in increased erosion and siltation and deposition of sediments on coral reefs (Guzmán *et al.* 1993). Recent industrialization and development at Bahía Las Minas include a petroleum refinery that started operating in 1961, an electricity generating station, and a now-closed cement plant (Figure 3C.1). The 1968 breakup of the tanker *Witwater* caused a spill of approximately 20,000-30,000 bbl of diesel oil and Bunker C (Rützler and Sterrer 1970; Birkeland *et al.* 1976). Since the 1986 refinery spill, described below, a few small oil spills occurred in the study area. These included a diesel spill in May 1988 west of the Panama Canal entrance (Garrity and Levings 1990), and fuel-oil spills in December 1988 and June 1990 at the electricity generating station.

FATE OF THE SPILLED OIL

The oil spill occurred in April 1986 at a petroleum refinery at Bahía Las Minas, Panama (Cubit *et al.* 1987; Jackson *et al.* 1989; Keller *et al.* 1993; Figure 3C.1). Approximately 240,000 bbl of medium-weight crude oil drained from a ruptured storage tank. Much of this oil flooded through a containment dike, separators, and a retaining lagoon. It was reported that 60,000 bbl of oil were recovered from the sea, and we estimate as much as at least 100,000 bbl of crude oil spilled into the sea, considering shoreline and benthic deposition, evaporation, dispersion, photo-oxidation, bacterial degradation, and other possible fates. This spill was larger than any other reported near coral reefs and mangroves in the tropical Americas (Loya and Rinkevich 1980; Lewis 1983).

There were three phases: (1) spillage and initial entrapment in Bahía Cativá (Figure 3C.1), (2) escape and spread into the larger Bahía Las Minas ecosystem and beyond, and (3) residual storage, degradation, release, and redispersal thereafter (see Cubit *et al.* 1987; Jackson *et al.* 1989; Keller *et al.* 1993; Cubit and Levings 1993; Cubit and Connor 1993*a*). Eventual deposition and storage of oil were greatest in low-energy environments, especially mangrove channels and streams, and seagrass sediments. Chemical dispersant was applied in some areas and may have contributed to localized toxic effects. The restricted use of dispersant could not, however, have caused the widespread subtidal reduction in living corals observed (Burns and Knap 1989; Guzmán *et al.* 1991, 1993) and other widespread biological damage.

The initial assessment of where oil went, and in what quantities, was based on visual assessment from land, sea, and air. Subsequent chemical analyses of amounts and types of hydrocarbons in samples of sediments, water, and organisms generally confirmed the visual rankings. Moreover, there was excellent agreement between results of different chemical analytical methods (ultraviolet fluorescence and gas chromatography; Burns 1993*a*, *b*).

Characterization of an unspilled sample of the oil allowed detailed study of subsequent chemical alteration in different environments and uptake by organisms (Burns 1993*a*). Oil persisted in greatest quantities in sediments, and both the amount of oil and its persistence were inversely correlated with prevailing energy conditions and sediment grain size in the environment. Oil in reef and seagrass sediments was greatly weathered and degraded in the first samples collected only 5 months after the spill but could still be clearly identified as coming from the refinery. In contrast, mangrove sediments from a heavily oiled stream contained a fairly fresh oil residue with a full suite of *n*-alkanes preserved 5 years postspill (Burns *et al.* 1993, in press; Burns 1993*a*). Bivalves attached to mangrove roots had oil in their tissues until at least 5 years after the spill (Burns 1993*a*; Burns and Yelle-Simmons in press).

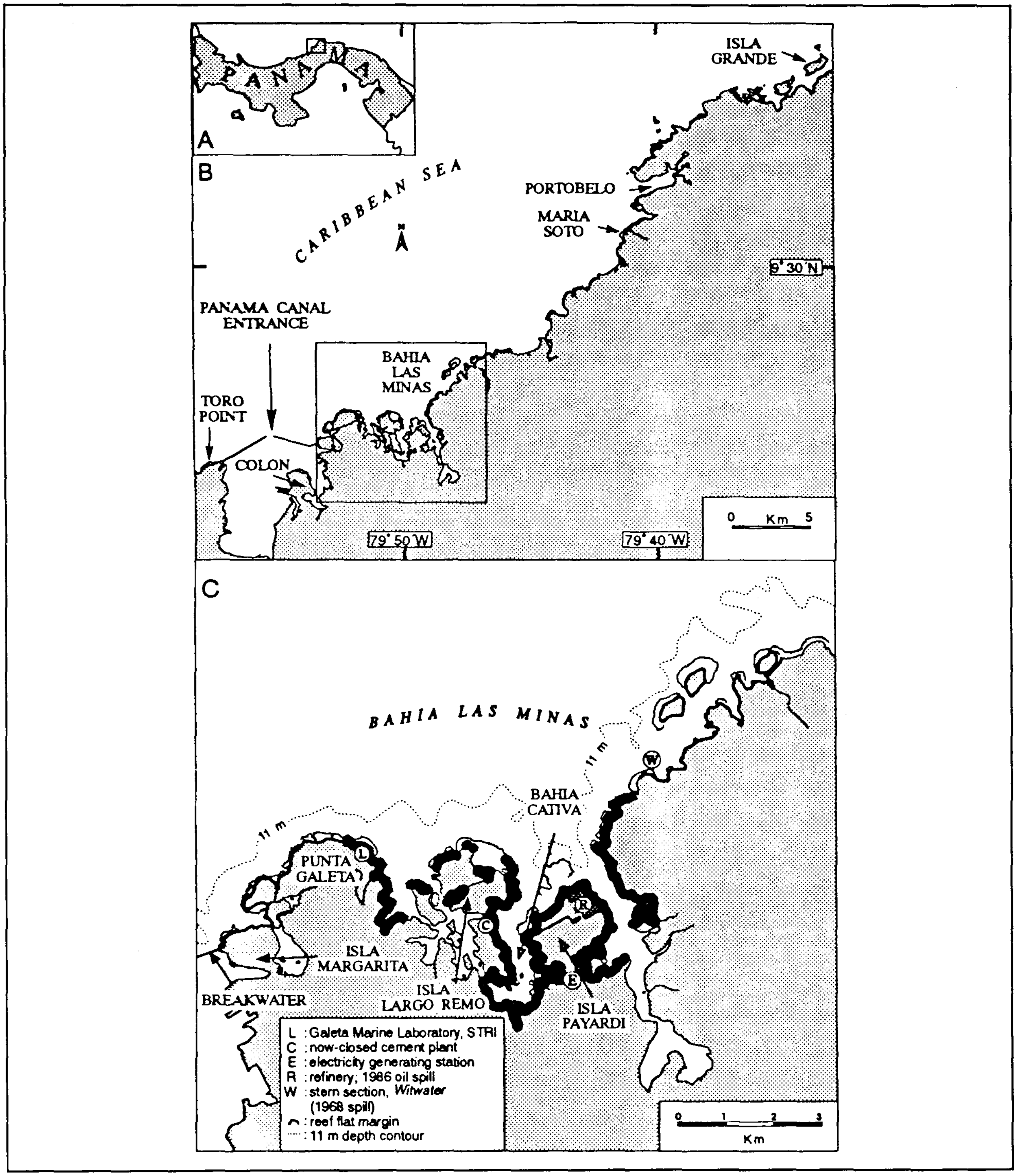

Figure 3C.1. Region of Panama affected by the 1986 oil spill. *A*. Republic of Panama, showing the study region on the Caribbean coast. *B*. Study region, showing the area of the most heavily oiled coastal habitats in and near Bahía Las Minas. Some unoiled sites were near Portobelo and Isla Grande. *C*. Map of Bahía Las Minas depicting the approximate distribution of heaviest oiling (*heavy line*) and moderate oiling (*medium line*). Oiling was not observed in the embayments east of Isla Margarita, south of Isla Largo Remo, and southeast of Isla Payardí.

MAJOR BIOLOGICAL EFFECTS AND THEIR PERSISTENCE

The oil spill had major biological effects in all environments examined including the principle habitat-structuring organisms of coral reefs, reef flats, mangroves, and seagrass beds (Jackson *et al.* 1989; Keller and Jackson 1993). There were widespread lethal and sublethal effects on both infaunal and epifaunal populations. All trophic levels were affected, including primary producers, herbivores, carnivores, and detritivores. Highly mobile animals, such as large fishes, may have escaped direct effects of the spill, but were not studied.

Initial effects of the oil spill in Bahía Las Minas set off a chain reaction of events that continued to affect organisms in all habitats, even though they may not have continued to be exposed to oil (Figure 3C.2). Analysis of aerial photographs showed that 64 hectares of mangroves (7 percent) were killed (Duke and Pinzón 1993). Extensive areas of seagrass beds were also killed (Cubit and Connor 1993*a*; Marshall *et al.* 1993). This resulted in physical destruction of habitats and sediments eroded at rates of up to several centimeters per year (Steger and Caldwell 1993). The eroded sediments and unknown amounts of varyingly degraded oil were deposited in large amounts in neighboring environments, as measured by a more than doubling of resuspended sediments settling onto heavily oiled coral reefs between 1988 and 1991 (Guzmán *et al.* 1993).

The secondary biological effects of erosion and redeposition of oily sediments included greatly increased levels of injuries and decreased growth and sexual reproduction for surviving subtidal reef corals in Bahía Las Minas compared to reefs outside the bay

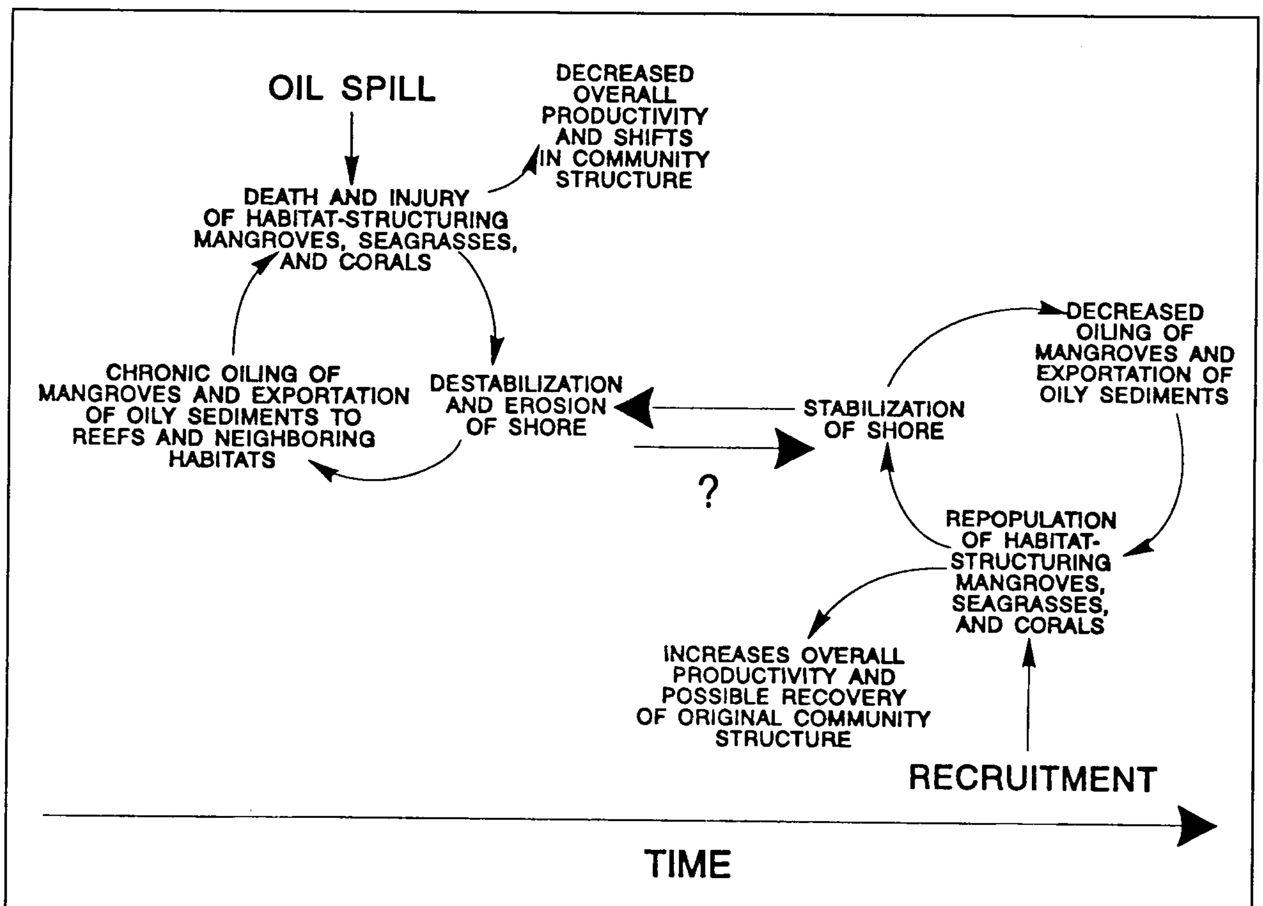

Figure 3C.2. Model of the chain reaction of habitat and biological damage due to the oil spill, and the presumed cycle of repopulation of habitat-structuring organisms and diminishing release of oil, showing the likely link at the process of shoreline stabilization.

(Guzmán *et al.* 1991, 1993; Guzmán and Holst 1993; Guzmán *et al.* 1993). The consequence of such events is that the entire Bahía Las Minas ecosystem is more vulnerable to natural or human disturbances. Hints of this appear in the patterns of macroalgal mortality on reef flats due to extremely low tides in 1988 (Cubit and Connor 1993*a*).

Reef Flats

Macroalgae, crustose coralline algae, and sessile invertebrates at and near the seaward edge of the Punta Galeta reef flat were directly exposed to oil and suffered heavy mortality, resulting in the lowest cover of these organisms in nearly 20 years (Cubit and Connor 1993*a*, *b*). Elevation of the reef flat varies by only a few centimeters over wide areas, so the spatial pattern of damage was dependent on sea level and weather at the time of the spill (Cubit and Levings 1993). Apparent recovery of many species was complete within a year, except for sessile invertebrates at the seaward edge which declined everywhere after the lowest sea levels ever recorded at Punta Galeta in 1988.

Effects on mobile animals were more variable. Sea urchins suffered an immediate decline that could be distinguished statistically from normal variation despite the episodic fluctuations of populations characteristic of this environment (Cubit and Connor 1993*a*). Recovery was rapid at all but a single reef flat adjacent to the refinery. Stomatopod crustaceans were virtually eliminated from one site where the seagrass bed disappeared; these had not recovered after five years (Steger and Caldwell 1993). Their abundance and size decreased at the other oiled site as well, compared to two unoiled or slightly oiled sites. The consequence was more rapid growth, and decrease in aggression and competition for living cavities among survivors which actually enjoyed greater habitat quality and less injury than those on unoiled reef flats.

The small infauna in algal turf suffered considerable mortality immediately after the spill, but populations were very similar among oiled and unoiled reef flats within one year detailed comparative investigations began (Cubit and Connor 1993*a*).

Snails died in heavily oiled zones of a reef flat near Punta Galeta, but not at a control site until it was affected by a small diesel spill 2 years after the refinery spill (Garrity and Levings 1990).

Reef Corals

The cover, size, and diversity of live corals decreased greatly on two oiled reefs compared to values before the spill while values initially increased on unoiled reefs (Guzmán *et al.* 1991). These differences persisted, although diminished, even after a precipitous, unexplained coral mortality at unoiled reefs between 1986 and 1988. In contrast, numbers of corals increased on oiled reefs as formerly large colonies were reduced to larger numbers of small, surviving fragments of live tissue (Guzmán *et al.* 1993). Likewise, the frequency of injuries to corals was much higher on heavily oiled reefs. These patterns were correlated with both the amount of oil in reef sediments and subsequently increased amounts of resuspended sediments at heavily oiled reefs. Sublethal consequences for corals included decreased growth, reproduction, and recruitment, which resulted in little prospect for rapid recovery.

Mangrove Forests

The area, condition, and maturity (successional state) of mangrove forests in Bahía Las Minas were determined using a combination of aerial photographic surveys over the past 25 years, and ground surveys to calibrate the photographs and make additional observations (Duke and Pinzón 1993). Deforestation after the 1986 oil spill amounted to 64 hectares, mostly in an approximately 50-m wide coastal strip and as wedges penetrating entrances of smaller streams. This was about 7 percent of the total area of mangroves in the bay. By comparison, the 1968 oil spill following the wreck of the tanker *Witwater* resulted in the death of 46 hectares, or roughly 72 percent of the 1986 value.

Measurements were made of the status of the canopy of surviving trees adjacent to deforested areas as an assay of forest condition. Factoring out salinity as a confounding variable and comparing wave-exposed and sheltered environments (Duke and Pinzón 1993), the number of leaves per shoot, leaf longevity, and leaf biomass per hectare all decreased significantly at sublethally oiled sites compared to unoiled controls. Thus, the oil spill affected far more than the area of forest that actually died.

Mangrove Fringe and the Epibiota of Mangrove Roots

The oil spill had immediate effects on the epibionts of mangrove prop roots on the open coast, in channels and lagoons, and in streams (Garrity and Levings 1993*a*, *b*; Garrity *et al.* 1993). Within three to nine months most of the common taxa were greatly reduced or eliminated. This was evident by piles of recently dead mollusc shells at oiled sites (except open coast), as well as by statistical comparisons of community composition at a smaller number of sites before and after the spill. Community composition on roots had not recovered completely in any of the three environments after 5 years (Levings *et al.* in press).

Open-coast roots in Bahía Las Minas were dominated by foliose macroalgae before the spill, and the same was true at unoiled sites afterward. These populations had nearly recovered at the end of the study. Channel and lagoonal root community composition varied considerably. Nevertheless, there was a catastrophic decrease in abundance of oysters and other bivalves at oiled sites after the spill compared to unoiled mangroves, with little or no recovery after 5 years. The same was true in streams where roots had been dominated by false mussels. None of these has recovered.

In addition to these effects on epibiota, there was substantial loss of mangrove roots as substrata (Burns *et al.* 1993; Garrity and Levings 1993*a*; Garrity *et al.* in press). The area of mangrove fringe lost 5 years after the spill totaled 33 percent, 38 percent , and 74 percent on the open coast, in channels, and in drainage streams, respectively. This habitat loss probably affected associated mobile fauna, as well as the sessile epibiota.

Seagrass Beds

Reef-flat seagrass beds died and disappeared at four sites (Steger and Caldwell 1993; Cubit and Connor 1993*a*), and the area of shallow subtidal beds decreased (Marshall *et al.* 1993) after the oil spill. Biomass of surviving seagrasses declined considerably, but thinning occurred at unoiled beds as well. Numbers of infauna were lower in oiled beds after the spill, and these differences persisted for more than two years. Amphipods, ophiuroids, sipunculids, and tanaids were the groups affected most, whereas hermit crabs increased, perhaps due to increased availability of shells. Epifauna showed generally similar patterns. The most lasting difference was in the total number of echinoderms (ophiuroids, echinoids, and holothurians) that were moderately abundant at unoiled sites but still virtually absent from oiled seagrass beds after two-and-a-half years. This pattern still held after six years for large echinoids and holothurians.

PROCESSES OF REPOPULATION (RECOVERY)

The re-establishment of populations to levels similar to those before an oil spill depends on at least six factors: (1) severity of initial damage, (2) extent of habitat destruction, (3) frequency and severity of previous damage, (4) life-history characteristics, (5) multiple stable states, and (6) restoration. We expect that habitat-structuring organisms will recruit and repopulate areas damaged by the spill, and that this will eventually lead to stabilization of the shore and decreased release of oil (Figure 3C.2). Mangrove trees have started the long process of recruitment and growth in many areas, but require at least 50 years to reach full adult size (Duke and Pinzón 1993). An extensive planting effort had an overall detrimental effect on recovery. Reef-building corals are not yet recruiting on oiled reefs in sufficient numbers to replace lost cover, and seagrass plants have not spread or recruited shoreward to replace beds eliminated after the oil spill. Massive corals such as the dominant forms in Panama may require a century or more to reach the size of many of the colonies killed by the spill.

RECOMMENDATIONS FOR FUTURE STUDIES

Based on the findings of this study, we offer the following recommendations for studies of oil spills: (1) a regional perspective is essential for understanding biological consequences of large, catastrophic events such as oil spills, and this scale should be incorporated in study designs; (2) time-series aerial photographs coupled with ground-truth observations may be the best way to document changes in the areal extent of habitats such as mangroves (Duke and Pinzón 1993) and seagrass beds; (3) observations immediately before, during, and after an oil spill should consist of simple, easily repeatable observations to determine its scale and pattern and immediate biological consequences; (4) initial biological surveys should emphasize abundant species or those known to play an important ecological role in their community (habitat structure, keystone predators); (5) basic biological knowledge of the taxa involved is required to understand the consequences of an oil spill, and predicting effects is impossible without data on life histories, natural enemies, behavior, and reproductive characteristics; (6) habitat restoration should be carefully conceived if employed at all to avoid doing more harm than good; and (7) retrospective analyses may be powerful tools, as shown by the reconstruction of effects of the 1968 *Witwater* oil spill on mangrove forest structure (Duke and Pinzón 1993); patterns of leaf nodes on mangrove seedlings and sclerochronological studies of coral growth, injury, and regeneration are other ways to identify biological effects long after an event has passed (Dodge and Vaisnys 1980; Knowlton *et al.* 1992; Duke and Pinzón 1992).

Every oil spill is different in the kind and amount of oil spilled, weather and sea conditions, and special characteristics of the areas affected. Nevertheless, it is important to identify which of these differences are fundamental to the consequences of an oil spill, and which are not. In principle, the chain reaction of habitat and biological damage triggered by tropical oil spills should eventually be countered by cycles of habitat recovery and shoreline stabilization (Figure 3C.2). Slow-growing, long-lived organisms require considerable time to recover fully from extensive die-offs, almost regardless of their causes. In all these respects our results should be of general significance to other tropical coastal sites with abundant mangroves, seagrass beds, and coral reefs, despite inevitably great differences in local environmental conditions.

RESPONSES TO OIL SPILLS

It cannot be overemphasized that all reasonable efforts must be taken to keep oil out of mangroves, seagrass beds, and equivalent habitats elsewhere, such as salt marshes. Oil trapped in these environments can persist and remain toxic for decades, and is virtually certain to set off the kind of chain reaction illustrated in Figure 3C.2. No oil processing or shipment facility near such habitats should operate without adequate booms and other equipment ready for immediate deployment because the average time for repopulation to original levels after inadequate protection is probably on the order of 50 years.

All the serious consequences of the Bahía Las Minas oil spill existed because of the long-lived, biogenic nature of the affected habitats. They may be exacerbated because of interactions among coastal habitats (Ogden and Gladfelter 1983), which may result in chronic contamination of reefs as erosion releases oily sediments from mangroves (Guzmán and Holst 1993). We do not know how long this cycle of environmental and biological damage will last.

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IMPACT OF EXPLORATORY DRILLING OFFSHORE FLORIDA

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While more than 30 offshore exploratory wells have been drilled in the eastern Gulf of Mexico during the 1970s, 1980s, and early 1990s, little is known of the aerial extent of any impacts to the environment resulting from these activities. As a result of concern about possible impacts, a moratorium was placed on all OCS areas south of parallel 26° N. A National Academy of Sciences panel review report in 1989 highlighted the lack of knowledge, as did a 1989 State of Florida Governor's Report. A drilling moratorium for the northeastern Gulf of Mexico is being sought by a coalition of many interested parties. This study presents the finding of the examination of six abandoned exploratory well sites in various environments ranging in depths from 21 to 149 m.

The objectives of this study were to locate and systematically sample, video, and photograph six different drill sites in the eastern Gulf of Mexico (the age of these sites ranged from 15 months to 17 years since drilling took place); to conduct grain-size, mineralogical and elemental analyses to map aerial extent of any benthic impact; and (3) to determine whether drill sites recovered to predrilling conditions over time.

Six drill site locations provided by the Minerals Management Service (MMS) Gulf of Mexico Region were located using the global positioning system (GPS) and examined using a two-person research submersible. Using the submersible's collecting arm, samples were taken in radial transects extending outward from the borehole. Samples were sieved into 16 separate grain sizes, and the percent of grains larger than 2 mm was used to circumscribe a halo of impact surrounding the borehole. The mud fraction was analyzed for barium, the weighting component of drill mud, and tract metals Cr, Fe, V, and Zn, using Induction Coupled Neutron Activation Analysis (INAA). X-Ray diffraction (XRD) was used to detect barite. A continuous video record was made at each site along with selected still photographs.

Sites ranging in depth from 21 to 149 m consisted of Pensacola Block 996 No. 1, drilled in 1988; Destin Dome Block 56 No. 1, drilled in 1989; Gainesville Block 707 No. 1, drilled in 1985; Main Pass Block 255 No. 1, drilled in 1990; Florida Middle Ground 455 No. 1, drilled in 1986; and Florida Middle Ground Block 252 No. 1, drilled in 1974 (see Figure 3C.3 and Table 3C.1). Bottom habitats included medium quartz sand, carbonate mud, coarse biogenic carbonate sand, hard limestone with corals and gorgonians (tropical organisms), and relict reefs (pinnacle reef trend with deep-water gorgonian fauna).

Areas impacted by cuttings and drilling debris (especially used welding rods) ranged from as little as a few meters to over 13,000 m^2 (over 3 acres). Barium at levels above background (200 ppm is considered natural background) extended beyond the range of our sampling pattern but clearly show a bullseye distribution of decreasing values away from the borehole. High levels near boreholes were on the order of 50,000 to 150,000 ppm. At the shallow Gainesville Block 707 site, which had been affected by two post-drilling hurricanes, barium was at background level except in one sample taken at the borehole where the level was eight times backgroundlevel. Tropical fish were abundant, and 11 groupers were counted in and around the borehole.

At the oldest site (Middle Ground Block 252 No. 1 drilled 17 years ago), only background barium levels were detected. Cuttings mixed with biogenic sand were rippled and little debris was detected; no fish life was observed.

Main Pass Block 255, in 104 m of water, had been drilled adjacent to a pinnacle reef, and a reentry device with provisions for four wells was attached on the bottom. The site is within the nepheloid layer. The bottom was dusted with fine rust-colored mud, and water visibility was very poor. The greatest impact at this site was a series of zigzag trenches apparently made by the legs of a jack-up rig during either mobilization or demobilization. Large fish had been attracted to the reentry structure.

The well head at Destin Dome Block 56 No. 1 was covered with a steel pyramid-shaped protection device. This was the most heavily impacted site observed. The well was a very deep test and produced more cuttings than the other wells. Fish were abundant.

Only one dive was made at Middle Grounds Block 455 No. 1, which was the deepest site examined (149 m). The bottom consisted of burrowed lime mud with no plant life. Very large groupers hovered around the borehole, which was in the center of a hexagon-shaped steel template half buried in the mud. In general, sites with structures, open boreholes and/or debris served as artificial reefs and harbored the most diverse fish fauna. Our observations indicate that sites in shallow water return more quickly to predrilling conditions than do sites in more than 50 m of water. Storm waves and currents can more easily remove drilling debris and barium, and the organisms that live in shallow water grow much faster than those in deep cold waters.

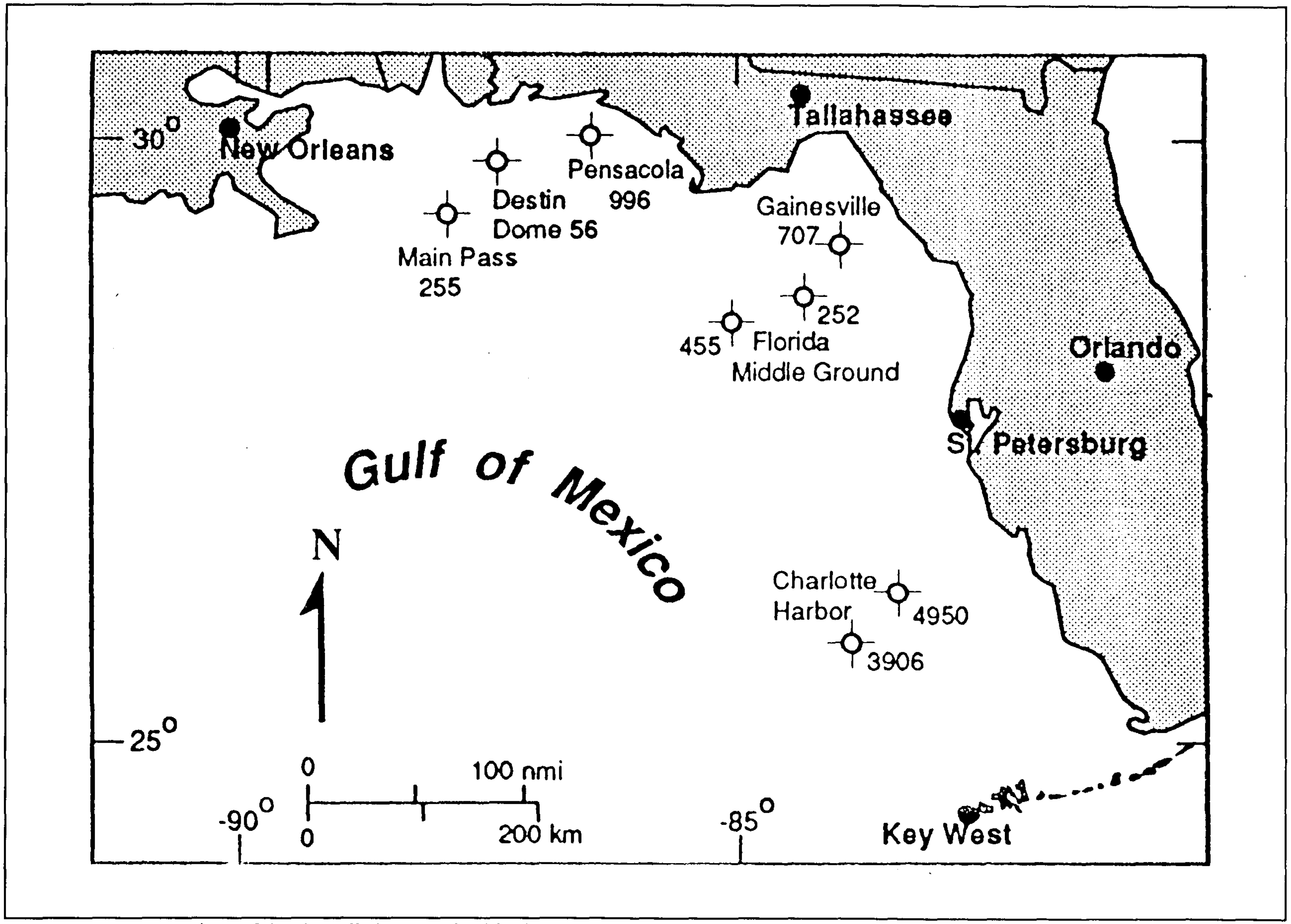

Figure 3C.3. Locations of the six well sites examined in this study. The two Charlotte Harbor wells were described in previous studies (Shinn et al., 1989; Dustan et al., 1991).

Table 3C.1. Essential data for sites examined in this study (* proprietary data not available at this time).

Well Name	GPS Lat. and Long.	Water Depth	Year Drilled	Well Drilled	Company	Rig Type	Bottom Type
Pensacola Block 996 No. 1	86°23.750 30°01.167	48.8 m	1988	5,430 m	Texaco	Jack-up	Sandy with macroalgae
Destin Dome Block 56 No. 1	87°12.758 29°53.579	57.3 m	1989	*	Conoco	Jack-up	Sandy with macroalgae
Main Pass Block 255 No. 1	87°48.752 29°19.221	103.6 m	1990	*	Elf Aquitaine	Jack-up	Rock pinnicles w/thin mud over rock
Gainesville Block 707 No. 1	83°57.107 29°14.805	21.3 m	1985	4,860 m	SOHIO/BP Exploration	Jack-up	Limestone w/thin patchy sediment
Florida Middle Ground 252 No. 1	84°19.859 28°41.739	37.2m	1974	4,644 m	Texaco	Jack-up	Rippled lime sand
Florida Middle Ground 455 No. 1	85°09.276 28°30.690	149.4m	1986	3,790 m	Chevron	Semisub-mersible	Mud with burrow mounds

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ESTIMATION OF FISHERIES IMPACTS DUE TO UNDERWATER EXPLOSIONS USED TO SEVER AND SALVAGE PETROLEUM PLATFORMS

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INTRODUCTION

Federal regulations require removal of offshore oil and gas structures within one year after lease termination. The most popular and cost-efficient method of platform removal utilizes high velocity explosives to sever conductors and supporting legs. These explosions can injure or kill nearby fishes, endangered or threatened sea turtles and protected marine mammals. The National Research Council (1985) estimated more than 1,000 structures will be removed during 1990-2000. It is, therefore, essential to quantify fish mortalities in order to document the effects of explosive removal of platforms, especially on managed fish stocks. Once the potential impacts are determined, mitigative actions can be identified, if necessary.

Nine platform removals are planned for the study. This report describes initial results from the assessment of fisheries impacts at the removal of one platform located approximately 25 nm offshore at Ship Shoal Block 158 in 55 ft of water.

OBJECTIVES

The goal of this project is to provide information for effective management of fish stocks through quantification of potential impacts caused by the use of explosives in the removal of offshore petroleum and gas platforms. Specific research objectives to address this goal are as follows:

1. Estimate the number of fish at risk at study platforms

2. Estimate the mortality of fish at study platforms

3. Estimate the total at-risk population in the Gulf of Mexico

4. Estimate the effects on the productivity of at-risk populations (especially red snapper)

5. Compare these effects with those from other sources of mortality

6. Evaluate mitigation strategies for impacts on reproduction

7. Assess need for additional sampling to improve the precision of the determinations of the impacts

METHODS

Prior to detonation of explosives, fish capture, tag, and release operations were conducted. SCUBA divers conducted twelve pre-detonation fish surveys beneath the platform using a method described by Bohnsack and Bannerot (1986).

After detonation, samples of dead fish were collected from which estimates of total mortality were calculated. Moribund fish floating on the surface were gathered from inflatable boats using dip nets. Dead fish that sank to the bottom were sampled using line transect methods and frame nets. Eight 100 m transect lines radiating from the platform were deployed (Figure 3C.4). Eight nets measuring 9.3 square meters were placed beneath the platform (Figure 3C.5). Forty-four nets measuring 13.4 squaremeters were haphazardly deployed within a radius of approximately 100 m of the platform except on the side occupied by the salvage barge (Figure 3C.6).

RESULTS

A total of 228 man hours of fishing effort yielded 74 fish captures including primarily gray triggerfish and Atlantic spadefish. Sixty-nine fish were tagged and released. Blue runner, sheepshead, and spadefish were the most abundant species observed by divers during pre-detonation visual surveys. Surface fish kill totaled 109. One Atlantic spadefish, the dominant species observed, was recovered with a tag.

The contents of eight under platform nets sampled by SCUBA divers included 162 fish, primarily blue runner and Atlantic spadefish. These nets covered approximately 30 percent of the "footprint" area of the sea floor beneath the platform.

Forty-four nets deployed in open water within about 100 m of the platform were retrieved aboard ship. Sixteen of these nets collected a total of 111 fish, mainly Atlantic spadefish and blue runner. Two of the spadefish were tagged. The remaining nets were empty.

Although five of eight 100 m transect lines were surveyed, not all samples were collected due to equipment loss (Figure 1). Lost samples included the first 40 m of Transect #1, the first 30 m of Transect #2, and the first 15 m of Transect #8. Forty-four fish were recovered from transect lines. Spadefish and blue runner were the dominant species. One gray triggerfish recovered from Transect #5 had been tagged.

A total of 426 fish were collected from all sampling equipment combined. Fish collections included 59 percent Atlantic spadefish, 23 percent blue runner, 8 percent sheepshead, 6 percent red snapper, and 4 percent other species. Red snapper measured from 25-75 cm in total length. All fish collected in bottom samples were taken within approximately 55 m of the platform.

Estimates of fish mortality were calculated for each type of sampling gear. The number of fish killed under the platform was estimated at 540. The fish kill outside of the platform footprint was estimated in two ways. Lift net samples provided an estimate of approximately 4,200 within 55 m of the platform while transect samples yielded 1,700 within 30 m. Both values were probably low. The open water nets could not be deployed on the downcurrent side of the platform due to the presence of the salvage barge. Divers found many fish along the downcurrent transect line, but these samples were lost during gear retrieval. Combining the estimate of open water mortality with that for the platform footprint and surface fish kill gives a total mortality estimate of about 4,900 fish. This should be considered a minimal estimate.

SUMMARY

Atlantic spadefish, blue runner, sheepshead, and red snapper were the four most abundant species collected. No fish were collected more than 55 m from the platform in bottom sampling gear. Fish mortality was underestimated at approximately 4900 due to the lack of downcurrent samples.

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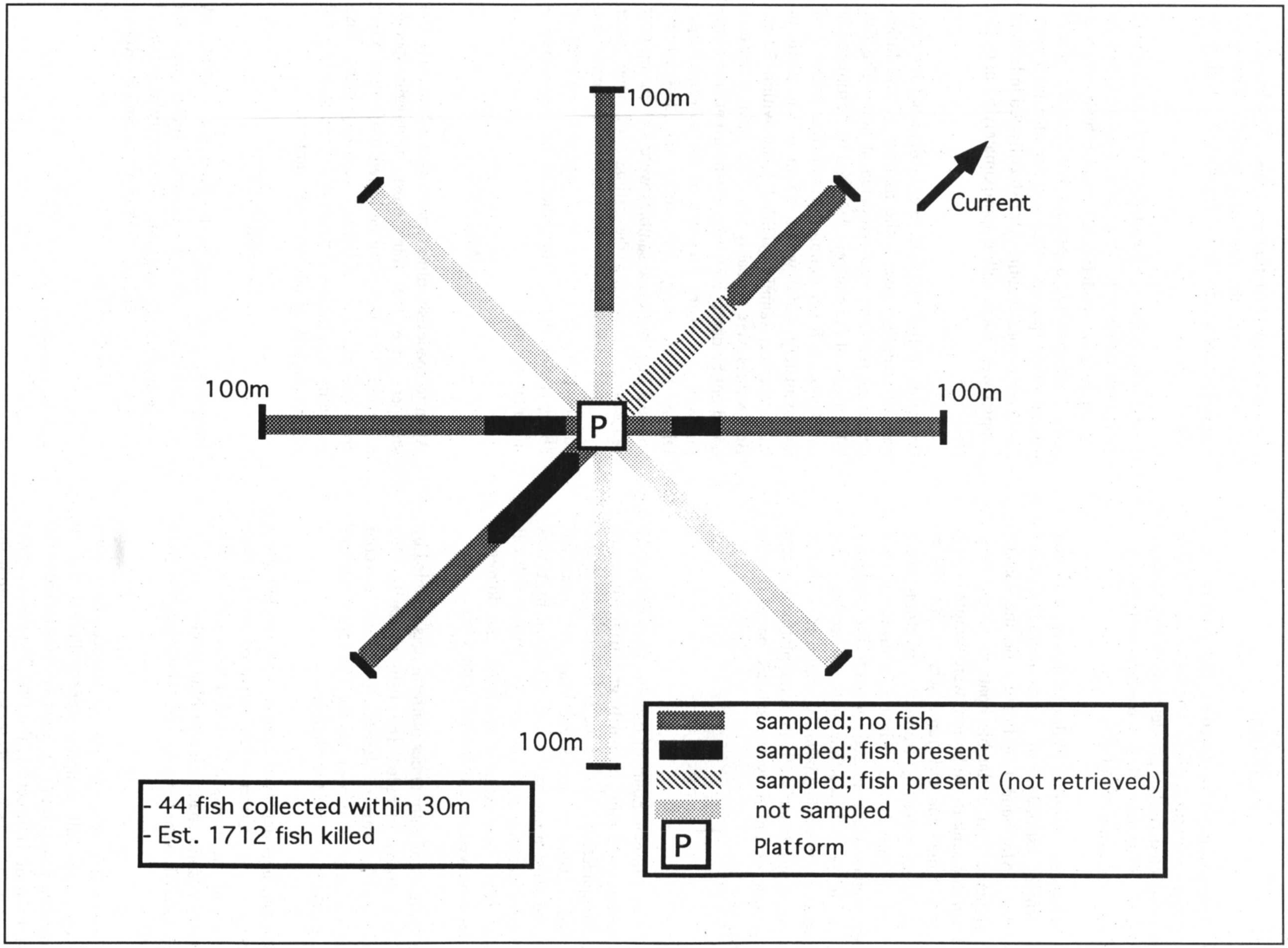

Figure 3C.4. Transect results.

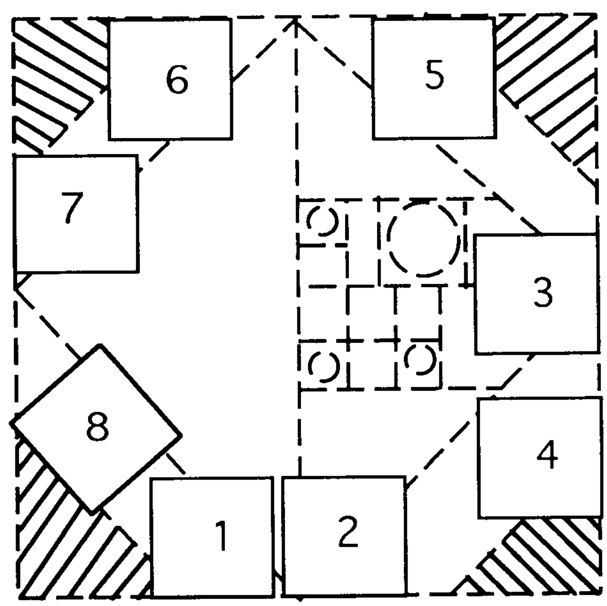

Figure 3C.5. Under the platform lift net placement.

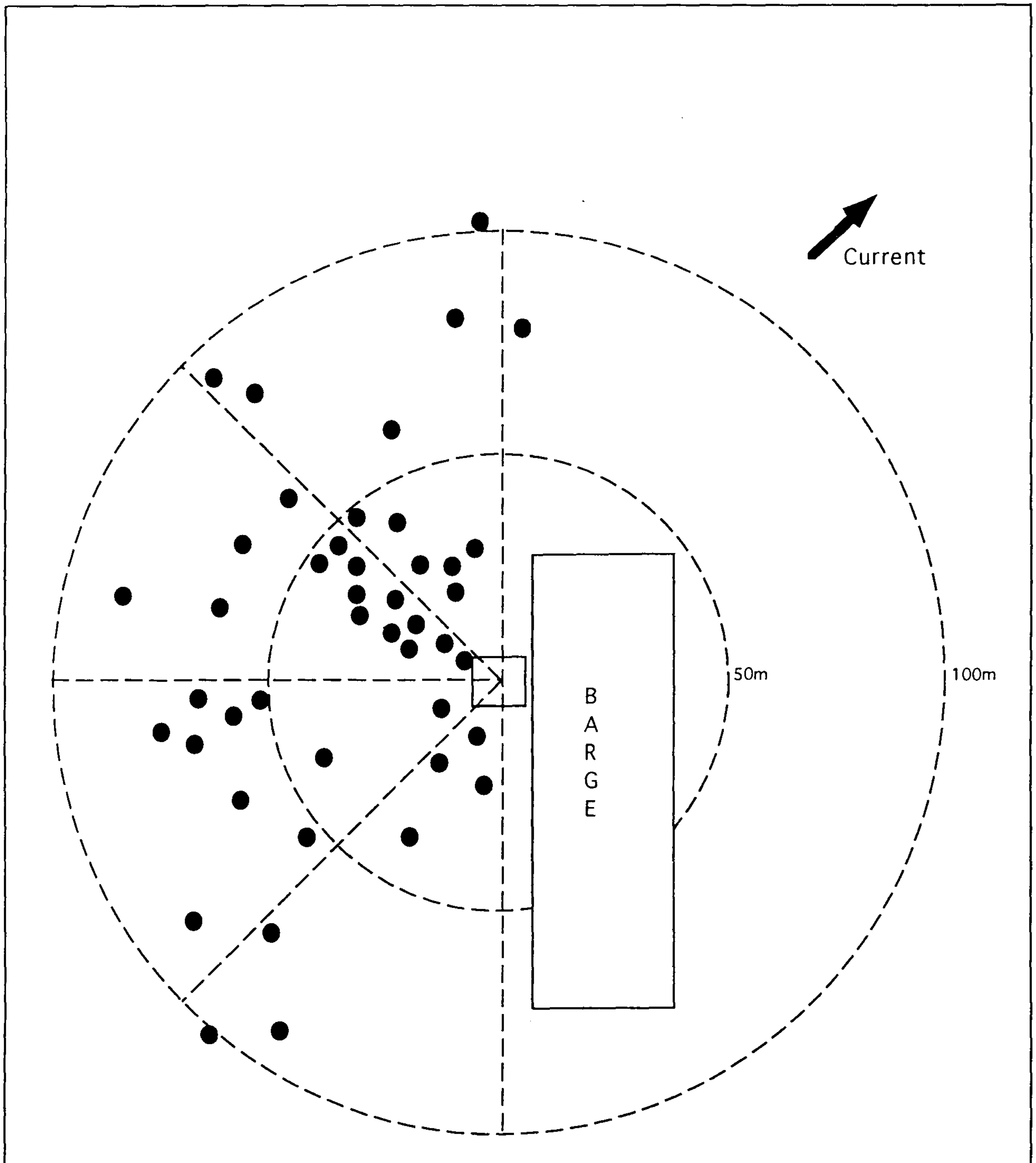

Figure 3C.6. Open water lift net placement.

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THE EFFECTS OF OIL AND DISPERSED OIL ON THE EARLY LIFE STAGES OF SELECT MARINE VERTEBRATES AND INVERTEBRATES FROM THE GULF OF MEXICO

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INTRODUCTION

Dispersants provide a means to treat oil spilled on the ocean. Early dispersants were in themselves toxic and caused effects on sea life as bad as the oil itself. Since their early uses in the 1960s, however, dispersant formulations have gone through several generations that have greatly reduced their toxicity.

Oil affects marine life either by coating and smothering biota or through its toxic components. Most effects from oil spills occur along sensitive shorelines where a spill grounds. Similarly, birds, marine mammals, and turtles are particularly affected when they are coated by contact with a spill. When such sensitive environments or species are at risk, the use of dispersants can potentially mitigate such effects. However, dispersants have the effect of increasing the amount of hydrocarbons entering the water column. This can potentially increase the risk to pelagic marine vertebrate and invertebrate species.

Toxicity testing has generally demonstrated that the early life stages of marine fish and invertebrates are the most sensitive to oil exposure. This is of particular concern in the Gulf of Mexico which supports commercially valuable species of shrimp, crabs, oysters, and fish, among others. However, a paucity of data exists about the effects of dispersed oil on the eggs and embryos of these species. The present study was designed to investigate the comparative effects of oil, a commercially available oil spill dispersant, and dispersed oil on the early life stages of several commercially available fish and invertebrate species from the Gulf of Mexico.

MATERIALS AND METHODS

Two representative oils from the western and central Gulf of Mexico oil producing regions were obtained for testing. Similarly, Corexit 9527, the dispersant of choice, was selected for individual toxicity testing and for application to each oil creating an oil-plus-dispersant mixture. Test species included redfish *(Sciaenops ocellatus)* embryos and larvae; menhaden (*Brevoortia sp.*) larvae; spot (*Leiostomus xanthurus*) larvae; the inland silverside (*Menidia beryllina*) embryos and larvae; oyster (*Crassostrea virginica*) larvae; white shrimp (*Penaeus setiferus*) postlarvae; brown shrimp (*P. aztecus*) postlarvae; and blue crab (*Callinectes sapidus*) megalopae. The animals were received from various sources including commercial aquaculture operations (redfish, shrimp, inland silversides, and oysters); the Virginia Institute of Marine Science (blue crabs); and the National Marine Fisheries Service - Beaufort, North Carolina (spot and menhaden).

Exposures were conducted using a water soluble fraction (WSF) of the oils. The WSF was prepared by mixing a 1:10 ratio of the oil to artificial seawater. Hawaiian Marine mix was used to prepare the artificial seawater mixture. The oil and water was mixed for 24 hours.

A 1:10 ratio of Corexit 9527 and the oil were mixed to prepare an initial dispersant concentration of 100 ppm. This mixture was then added to the artificial seawater. Corexit 9527 was tested by itself in the artificial seawater at an initial concentration of 100 ppm. A 50% dilution series was used in all exposures.

Tests were conducted in both flowthrough and static tests generally over 96 hours. The flowthrough system incorporated an original design that allowed fresh seawater to be gravity-fed into exposure vessels. Flowrates allowed a 50% renewal of test solution over a 24 hour period. Both static and flowthrough tests were run under a 16 hour light:8 hour dark cycle. LC50s were calculated for each set of tests after 48 hours and/or 96 hours.
Chemistry samples were collected with all tests. Analyses were conducted to measure volatile organics (benzene, toluene, ethylbenzene, and xylene); total petroleum hydrocarbons; and purgeable aromatics. EPA protocols were generally followed except for the purgeable aromatics where Gas Chromatography/Single Ion Monitoring (GC/SIM) was used. The GC/SIM technique allowed detection of naphthalenes, phenanthrenes, chrysenes, fluorenes, and dibenzothiophenes at levels in the parts per trillion range.

RESULTS

Table 3C.2 summarizes average hydrocarbon concentrations measured during the course of the testing. For the most part, the two oils produced relatively similar concentrations. This is consistent with the distribution of semivolatile hydrocarbons in the two oils which showed only minor differences (Figure 3C.7). Concentrations tended to be higher in static as opposed to flowthrough tests. The dispersed oil produced higher concentrations than did the water soluble fraction. An exception was noted with the BTEX concentrations where higher levels were measured in the WSF than with the dispersed oil. However, when viewed over time, hydrocarbon concentrations at the end of the 96 hour exposure were similar in the WSF and dispersed oil mixtures. This may indicate that volatility had a more significant role in the fate of dispersed oil as opposed to the WSF.

Table 3C.3 shows the results of testing with the various fish species while Table 3C..4 summarizes toxicity data for the invertebrate test species. Table 3C.5 compares toxicity of the WSF versus the dispersed oil mixtures. The range of sensitivities was generally similar for the two oils for both the fish and invertebrates. Fish embryos were less sensitive to the WSF, dispersant, or dispersed oil mixtures than the larval stages. Overall, the fish seemed to be more sensitive to the WSF than the dispersed oil, particularly in the Central Gulf oil. The invertebrates seemed to be more sensitive to the dispersed oil mixtures.

Table 3C.2. Comparison of average hydrocarbon concentrations in various exposure treatments. Concentrations are reported in ppm-hrs which were calculated by integrating total exposure concentrations over 96 hours.

TREATMENT	WESTERN WSF	WESTERN O&D	CENTRAL WSF	CENTRAL O&D
TOTAL NAPHTHALENES (ppm-hrs)				
S/FT	984±422	2651±866	726±359	2189±1081
TOTAL PETROLEUM HYDROCARBONS (ppm-hrs)				
STATIC	544	2570	572	2288
FLOWTHROUGH	486	422	34	1062
TOTAL BTEX (ppm-hrs)				
STATIC	690462±136480	25399±9719	644480±198991	29495±1270
FLOWTHROUGH	44223±2263	2717±39	47173±10814	4914±208

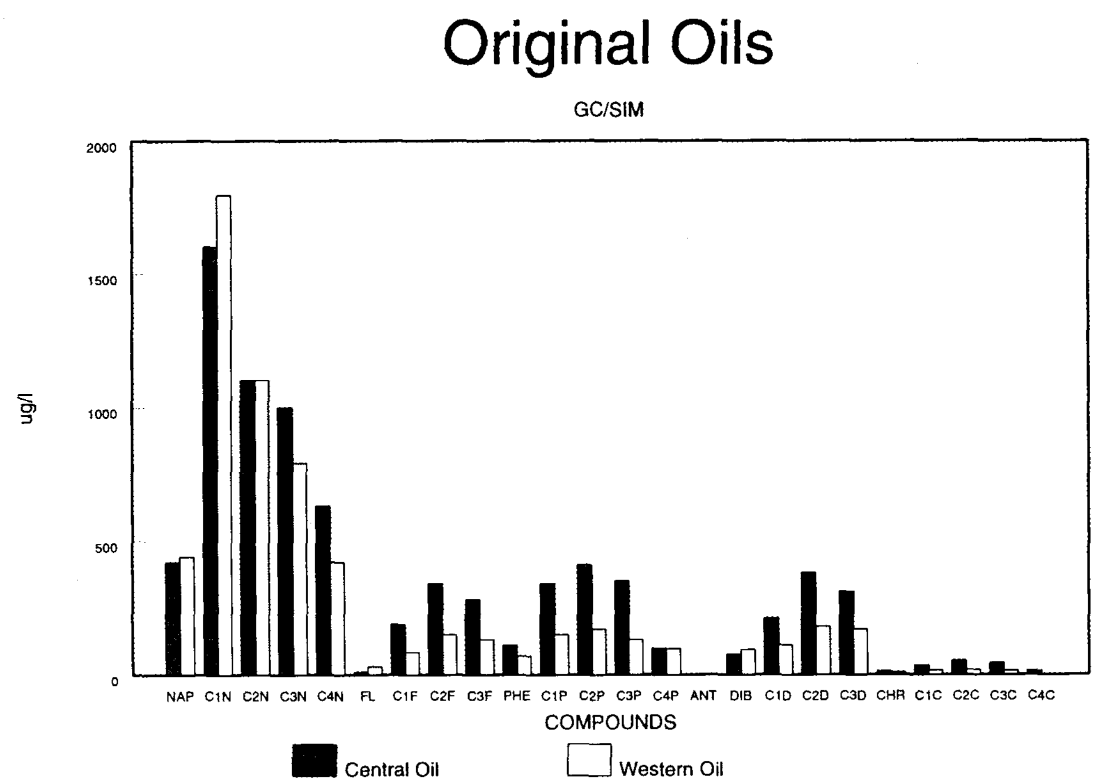

Figure 3C.7. Original oils.

Table 3C.3. LC50s (IC50s) for vertebrate species exposed to the WSF, Corexit 9527, and dispersed oil.

SPECIES	WSF (%)	DISPERSANT (mg/l)	OIL & DISPERSANT (mg/l dispersant)
WESTERN GULF OIL			
Menidia beryllina Larvae	60 72.8	56.7 28.3	52.8 66.0
Embryos	>100	>100	>100
Menhaden (48 hr)	19.6	42.4	30.6
Redfish (48 hr)	>100	52.6	>100
Spot (48 hr)	>100	27.4	68.2
CENTRAL GULF OIL			
Menidia beryllina Larvae	59.1	46.7	>100
Embryos	>100	>100	>100
Menhaden (48 hr)	33.9	42.4	21.6
Redfish (48 hr)	74.0	>100	>100
Spot (48 hr)	34.1	27.4	20.0

Table 3C.4. LC50s (IC50s) for invertebrate species exposed to the WSF, Corexit 9527, and dispersed oil.

SPECIES	WSF (%)	DISPERSANT (mg/l)	OIL & DISPERSANT (mg/l dispersant)
WESTERN GULF OIL			
Callinectes sapidus	>100*	81.2	90.8
Penaeus setiferus	>100	11.9	18.6
P. aztecus	59.9	-	52.7
CENTRAL GULF OIL			
Callinectes sapidus	70.7	77.9	19.8
Penaeus setiferus	30.2	11.9	13.8

Table 3C.5. Comparative toxicity of WSF and dispersed oil fractions to the various test species. The named fraction is the one having the higher relative toxicity.

SPECIES	WESTERN			CENTRAL		
	Total Naph.	TPH	BTEX	Total Naph.	TPH	BTEX
Callinectes sapidus	O&D	O&D	O&D	O&D	O&D	O&D
P. setiferus	O&D	O&D	O&D	WSF	WSF	O&D
P. aztecus	WSF		O&D			
Menidia						
larvae	WSF WSF	O&D O&D	O&D O&D	WSF	WSF	WSF
embryos	NT	NT	NT	NT	NT	NT
Menhaden	WSF	WSF	O&D	WSF	WSF	O&D
Redfish	NT	NT	NT	WSF	WSF	WSF
Spot	O&D	O&D	O&D	WSF	WSF	O&D

CONCLUSIONS

The two oils were similar in hydrocarbon composition and produced relatively similar levels of toxicity in all of the test species. The testing was complicated by several factors including the availability of animals which minimized the number of replicate tests which could be conducted. This was a particular problem with regards to the invertebrate species. All of the fish species were particularly delicate and control survival was a major problem. For most of the fish species, it was difficult to get survival beyond 48 hours at a level which was adequate to get meaningful data. The availability of test animals and the extreme sensitivity to handling of the fish larvae compounded efforts to replicate test results.Hydrocarbon concentrations were similar in the various tests making it possible to extrapolate chemistry data to each test. Overall, the dispersed oil mixtures did not appear to be significantly more toxic to the test organisms than the WSF. This may be due to the fact that the rate of decline in hydrocarbons during exposures seemed to be greater in the dispersed oil mixtures than in the WSF.

Mr. Ken Fucik is Chief Executive Officer of The SeaCrest Group. He has extensive project and managerial experience in the areas of aquatic toxicology and the fate and effects of oil and other contaminants in marine and freshwater systems. This experience dates back to 1972. He has a Bachelor of Science in Zoology from Texas Tech University and a Master of Science in Biological Oceanography from Texas A&M University.

Ms. Kelly Carr is laboratory manager for SeaCrest's Colorado laboratory. She directs an aquatic toxicology lab testing both marine and freshwater species. She has a Bachelor of Science in Marine Biology from the University of West Florida which was received in 1986.

Mr. Brian Balcom is a Senior Scientist with Continental Shelf Associates, Inc. (CSA), with duties encompassing program management, data collection and analysis, and technical writing and editing. Employed with CSA since 1981, Mr. Balcom also serves as Regional Manager of CSA's Ventura, California. Areas of interest include soft- and hard-bottom marine benthic community structure and the fate and effects of oil and drilling-related discharges on marine and coastal ecosystems. Mr. Balcom received his Bachelor of Science degree in biological sciences from the University of Southern California (USC) in 1975 and his Master of Science degree from USC in 1980

PROGRESS TO DATE ON THE GULF OF MEXICO AIR QUALITY STUDY (GMAQS)

Dr. Mark A. Yocke
Systems Applications International

Mr. Paul Roberts
Sonoma Technology, Inc.

Mr. William Steorts
Minerals Management Service
Gulf of Mexico OCS Region

The purpose of the Minerals Management Service (MMS) Gulf of Mexico Air Quality Study (GMAQS) is to evaluate the effects on air quality of the development of Outer Continental Shelf (OCS) petroleum resources. This study resulted from concern regarding the cumulative impacts of OCS emissions on ozone concentrations in nonattainment areas, particularly in Texas and Louisiana. The Clean Air Act Amendments of 1990 specifically require that a research study be conducted to assess potential onshore impacts and determine the need for further action.

The study has six specific objectives. These objectives address both near-term and longer-term needs. In the near-term, the study will provide analyses of historical data, supplemented by new meteorological measurements, that describe the conditions and likelihood of OCS emissions reaching coastal areas under conditions conducive to ozone formation. Quantitative (but preliminary) estimates of OCS contributions to on-shore ozone will also be developed. In the long term, it is anticipated that extensions and refinements of modeling techniques and applications will be needed to address the air quality planning needs of both the MMS and onshore jurisdictions. Therefore, the study will also critically evaluate the sources of uncertainty in its conclusions and make recommendations regarding future monitoring and modeling efforts that can address these uncertainties.

The overall objective of this study is quantitatively to determine through modeling (emissions, meteorological, and photochemical) the effects of current and future OCS development in the Gulf of Mexico on nonattainment areas for ozone in Texas and Louisiana. These areas include the area from Baton Rouge to the Gulf of Mexico; two parishes around Lake Charles in Louisiana; the Houston–Galveston–Beaumont–Port Arthur area; and Victoria County, Texas. The models we will apply are Systems Applications International's (SAI) Urban Airshed Model Version V (UAM-V), the SAI Meteorological Model (SAIMM), and SAI Emissions Preprocessor System (EPS2.0). The tasks include (1) the identification of representative ozone episodes; (2) development of appropriate emissions inventories for the episodes (including OCS and onshore emissions, and growth/control in calendar years of interest); (3) development and/or collection of appropriate meteorological and concentration data bases; (4) photochemical model application to assess the effects of alternative OCS development in the Gulf Coast area on the on-shore ozone nonattainment areas; (5) characterization of the uncertainty in the model estimations; and (6) evaluation of the needs for future research or data collection efforts to improve understanding of the OCS effects on ambient ozone on shore.

A team of highly qualified experts was assembled to carry out the stated tasks. The project team members and their areas of particular responsibility include

- Systems Applications International (SAI): Overall project management; meteorological, emissions, and photochemical modeling; data archiving, quality assurance, and existing data analyses.

- Sonoma Technology (STI): Field program design, field program data analyses.
- Alpine Geophysics (AG): Assistance in photochemical modeling.
- AeroVironment (AV): Auditing and quality assurance of field monitoring program.
- Sigma Research (Sigma): Meteorological and air quality data analyses, over-water dispersion analysis.
- Environmental Science and Engineering (ES&E): Evaluation of design for future ambient monitoring system.
- Tracer Technology: Assistance in development of possible inert tracer release and tracking experiments for future studies.
- Phil Roth, ENVAIR: Participation in developing recommendations on future work, especially how such future work may lead to reduced uncertainty in emissions change effects in future years.
- A.T. Kearney: Compilation and preparation of 1992 emissions estimates for each of the principal offshore emissions sources not related to OCS petroleum development, for inclusion in the overall emissions inventory prepared by SAI.
- Radian Corporation: Manufacture, installation, and maintenance of Radar profilers for continuous upper level wind and temperature measurements.
- Evans–Hamilton, Inc.: Offshore logistical support.

FIELD STUDY (APRIL - OCTOBER 1993)

Since the project initiation, a number of milestones have been achieved regarding the field study components of the study. A number of documents were prepared including a monitoring plan/protocol, an ozone episode forecasting protocol (based on analyses of historical data), aircraft sampling plans, and a data archival protocol. In addition, extensive site reviews were conducted both offshore in the OCS and onshore to identify and characterize potential measurement locations. Three offshore platforms and five onshore sites were selected for the study. The sites and a few other existing meteorological measurement sites are shown in Figure 3C.8.. The equipment was installed and began operating by mid-April 1993. These sites include the following:

- Texaco High Island 199A -- offshore, continuous upper air and surface meteorological measurements employing Radar Profiler/RASS and surface meteorological instruments for six months.
- ARCO Ship Shoal 178 -- offshore, continuous upper air and surface meteorological measurements employing Radar Profiler/RASS and surface meteorological instruments for six months.
- Chevron Garden Banks 236 -- offshore upper air soundings, two or three times per day during the six-week summer intensive period.
- Gilcrest, Texas -- onshore continuous surface air quality (NO, NO_2, ozone) and meteorological measurements for a six-month period and grab samples for volatile organic compound (VOC) and carbonyl analyses during intensives.
- LUMCON (Cocodrie, LA) -- onshore continuous surface air quality (NO, NO_2, ozone) and meteorological measurements for a six-month period and grab samples for VOC and carbonyl analyses during intensives. Onshore, continuous upper air and surface meteorological measurements employing Radar Profiler/RASS and surface meteorological instruments for six months.
- South East Houston (Hobby Airport) -- Onshore, continuous upper air and surface meteorological measurements employing Radar Profiler/RASS and surface meteorological instruments for six months.

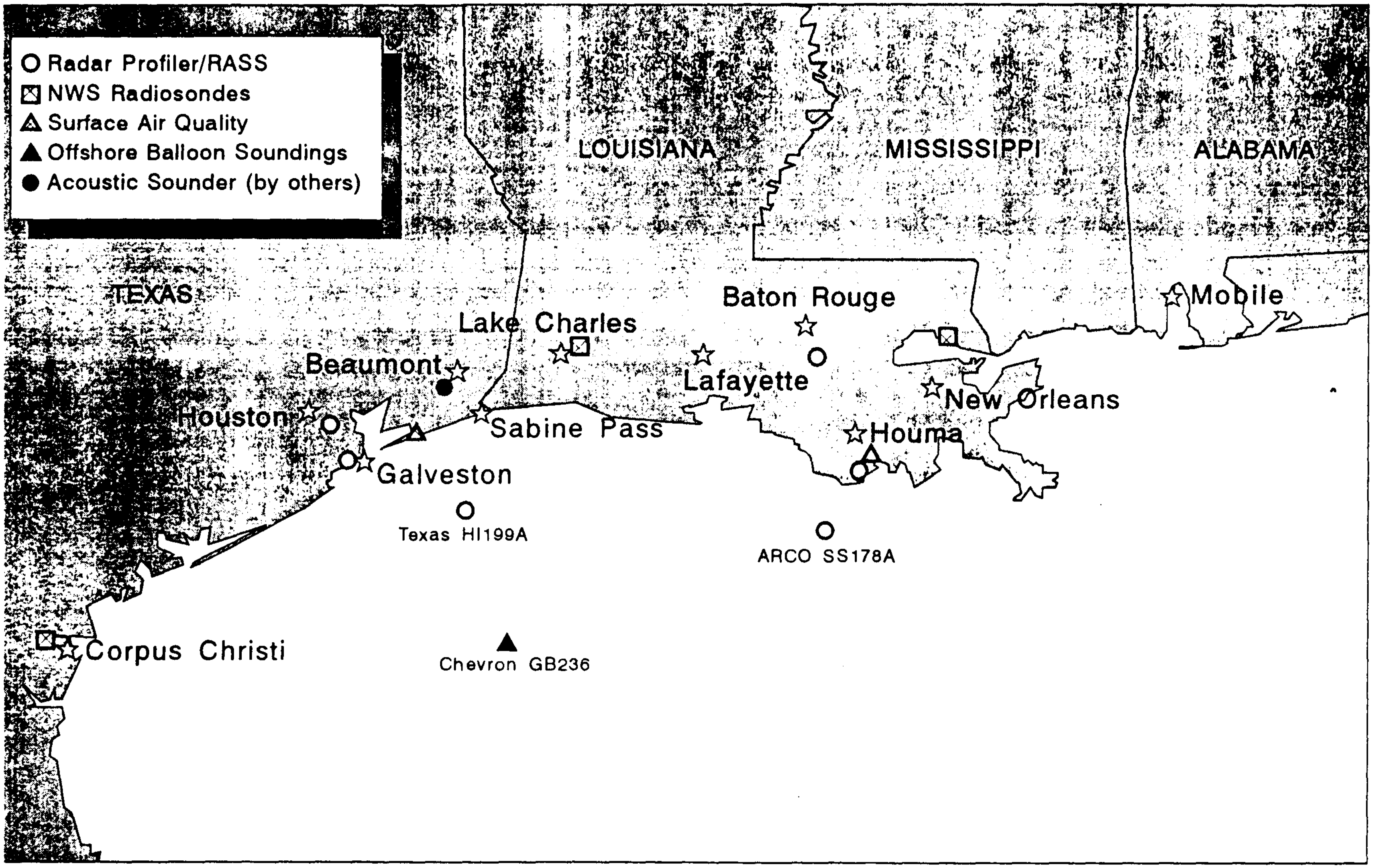

Figure 3C.8. MMS Gulf of Mexico air quality study region.

- Galveston, Texas -- Onshore, continuous upper air and surface meteorological measurements employing RadarProfiler/RASS and surface meteorological instruments for six months.

- Louisiana State University (near Baton Rouge, LA) -- Onshore, continuous upper air and surface meteorological measurements employing Radar Profiler/RASS and surface meteorological instruments for six months.

The intensive measurement portion of the field study ran from 18 July - 28 August 1993. During this time, two highly instrumented twin engine aircraft were on alert in Beaumont to fly when conditions were favorable for ozone exceedances. In addition, the National Weather Service (NWS) provided one additional upper air meteorological measurement daily as needed from Slidell and Lake Charles, Louisiana. During this intensive period, a daily conference callwas held at 3:00 p.m. EDT to decide a go/no-go for ozone exceedances for the next 24 and 48 hour periods. Data were transmitted daily to key personnel allowing a decision to be reached by each member and discussed during the conference call. If a go decision was reached, aircraft were deployed at 6:00 a.m. the following day on predetermined flight paths; the NWS launched an additional upper air sounding; an additional upper air sounding was taken at the Garden Banks platform; and field personnel gathered VOC and carbonyl samples from the Gulf Coast area. Additional conference calls were held on each flight day to discuss the afternoon flights.

FIELD PROGRAM/INTENSIVE MEASUREMENT PERIOD SUMMARY

Three major ozone episodes occurred in the Houston area: 28-31 July 1993; 9-13 and 18-21 August 1993. In addition, three other exceedance days were documented: 16 July, 3 August, and 25 August.

There was one exceedance day in Beaumont-Port Arthur: 19 August.

There were four exceedance days in Lake Charles: 31 July; 1, 18, 20 August.

All Beaumont-Port Arthur and Lake Charles episodes mentioned above appear linked to Houston and/or Baton Rouge ozone exceedances, probably more to Houston, implying that transport is involved.

There were two exceedance periods in the Baton Rouge area: 9-13 and 17-21 August.

Data analyses, archival, and modeling runs for these episodes will be completed by June 1994.

Quality assurance audits have been completed for all offshore and onshore sites, aircraft, and VOC/carbonyl laboratories.

DATA ANALYSIS

Data analysis tasks completed include selection of historical episodes for modeling; acquisition, processing, and analysis of the historical meteorological and air quality data; and the development of an episode forecasting methodology.

In selecting historical ozone episodes for modeling, air quality and meteorological data for the period 1987-1991 were examined. Ozone exceedance days within the three regions (Houston-Beaumont-Port Arthur, Lake Charles, and Baton Rouge) were identified and the potential for onshore transport of OCS emissions assessed. The determination of onshore transport included examination of daily surface weather maps (and pressure gradients), hourly surface winds at selected locations, and upper-air winds at nearby NWS radiosonde sites as well as the calculation of surface-layer particle paths. Based on this analysis, six modeling episodes were selected, including four primary episodes and two alternates. A technical memorandum summarizing the results of the episode selection process was prepared.

A major focus of this task was the preparation of a comprehensive meteorological and air quality data base for the historical modeling episodes. This was a time-consuming task due to the numerous data sources, types, and formats. The data were used in the preparation of gridded wind and temperature fields for the calculation of biogenic emissions using the Biogenic Emission Inventory System (BEIS), the preparation of air quality inputs for UAM-V, and the meteorological modeling.

Additional analysis of the historical meteorological and air quality data was performed to provide information for the development/refinement of the forecasting plan. This analysis included application of the Classification and Regression Tree (CART) software using air quality and meteorological data collected during July and August 1988-1991. The objective was to identify those measured and predicted variables that will be most useful in forecasting ozone events in both the Houston and Baton Rouge areas. Preliminary results have been summarized in a memorandum.

EMISSIONS INVENTORY DEVELOPMENT

Comprehensive gridded, hourly emissions inventories were prepared for the entire study area. These cover an area of nearly one million square kilometers, encompassing the OCS and onshore ozone nonattainment areas (Houston, Beaumont, Lake Charles, and Baton Rouge). Pollutants inventoried include NO, NO2, speciated VOC, and CO. These inventories were converted to formats suitable for input to the photochemical model using EPS2.0.

The emission inventories prepared in this study include both onshore and offshore emissions and OCS related emissions. All relevant emissions from anthropogenic and natural (i.e., biogenic and geogenic) sources were considered, with special attention focused on offshore anthropogenic sources. The latter included OCS oil and gas production facilities, crew and supply boats and helicopters serving OCS facilities, recreational and commercial shipping in the study area, and other sources located in the adjacent state waters.

Development of a comprehensive emissions database for the Gulf Coast study region requires that both onshore and offshore sources of emissions be considered. In particular, the following sources have been addressed in this effort:

Offshore anthropogenic sources:

- OCS oil and gas production facilities
- Crew and supply boats/helicopters serving OCS facilities
- Recreational and commercial shipping
- Pipeline vessels
- Military vessels
- Intercoastal barges
- Exploratory vessels
- The Louisiana Offshore Oil Port (LOOP)

Onshore anthropogenic sources [EPA's 1990 Interim State Implementation Plan (SIP) Data, Louisiana Department of Environmental Quality (LADEQ) & Texas Air Control Board (TACB) data]:

- Point sources
- Area sources
- Mobile sources

Natural sources:

- Biogenic sources
- Geogenic sources

In conjunction with MMS, three survey forms were designed to solicit the information needed to estimate emissions from OCS production platforms, crew/supply boats and crew/supply helicopters. The survey responses for crew and supply boats and helicopters were entered by MMS into Paradox database files (V3.5) and later translated to spreadsheets to calculate emissions. The survey responses for oil and gas production platforms were OPIS was designed for this study to estimate platform emissions by accessing the MMS database, assigning quality assurance tracking codes, making quality control checks and data corrections, calculating emissions, and preparing the emissions data files in the format required by EPS 2.0. The emission calculations performed by the OPIS reflect recent updates to the methodology given in EPA's Compilation of Air Pollutant Emission Factors (AP-42, Supplement E).

Fugitive emissions were estimated outside of OPIS using a FORTRAN program. These estimates were based on a recent MMS Pacific OCS Study (MMS 92-0043,44) and not API data as was originally intended. Based on the MMS Pacific Study, a methodology for estimating platform fugitive emissions was developed.

Additionally, emission methodologies were developed for several other OCS sources including pipeline and military vessels, and helicopters. The helicopter data used for emissions estimations was obtained from the survey, the military vessel from the Navy, and the pipeline vessel data from MMS.

In order to process the data through EPS, four subregions were defined and gridded. The entire region was gridded into four kilometer grids with nested grids in non-attainment areas. The 1990 base year EPA Interim Inventory was used for the onshore domain and was interfaced with the LADEQ biogenic inventory and the TACB 1988 point source inventory.

Estimates for motor vehicles were generated using the EPA 1990 Vehicle Miles Traveled (VMT) data.

Special surrogates for OCS region were setup for pseudo counties by lease block area, platform weighted area by lease block, and state waters.

Quality assurance guidelines and procedures were developed and documented to assure traceable emissions processing.

METEOROLOGICAL MODELING

Work performed to date on the meteorological modeling task has included set up and testing of SAIMM, development of a "nesting" procedure, refinement of the procedure for reformatting SAIMM fields for input into the UAM-V, and generation of meteorological fields for the 28-29 July 1988 episode.

Following preparation of the geographical and meteorological input data files required by the SAIMM, several test applications of the model were performed to establish the most appropriate set of input parameters and modeling procedures. For the coarse grid simulation, the SAIMM was exercised for the 29 July 1988 episode day using episode-specific temperature and moisture profiles and Four Dimensional Data Assimilation (FDDA) and variable surface characteristics.

A procedure for extracting information from the coarse-grid SAIMM simulations to provide time- and space-varying boundary conditions for the fine-grid simulations was developed and tested for the Houston domain using the 29 July 1988 coarse-grid simulation results. The SAIMM was exercised for the fine-grid domain using domain-wide initial temperature and moisture profiles, FDDA, and variable surface characteristics. Information from the coarse-grid simulation was transferred to the fine-grid simulation using the FDDA procedure; the FDDA analyses were prepared by incorporating observations into a coarse-grid-simulation-derived first-guess field. Several fine-grid simulations were run to determine how to best achieve the one-way nesting (i.e., which of the prognostic variables to nudge and the optimum strength of the nudging coefficients) in the fine-grid simulations.

The one-way nesting procedure was applied to the generation of meteorological fields for the 28-29 July 1988 episode. The coarse-grid wind fields show predominantly southerly flow during the two-day period. The wind fields for the small Houston domain also show primarily southerly flow; the influence of the sea breeze is apparent.

PHOTOCHEMICAL MODELING

An advanced photochemical air quality model, Urban Airshed Model (UAM-V), was set up and tested for one historical ozone episode. The gridded model inputs were developed under the emissions inventory development and meteorological modeling tasks. A nested grid was employed with the finest grid spacing over the urban ozone areas. The episode was selected on the basis of extensive historical data analyses.

Evaluation of the model's performance for this episode was completed using available air quality measurements and the model performed reasonably well. Sensitivity tests were carried out to examine the model's responses to uncertainties in inputs and to changes in the OCS emissions inventory.

GMAQS BUDGET

A breakdown of the study's major components:

Study Component	Budget ($1,000)
Modeling and field planning	333
Field study	2,879
Modeling	960
Emissions inventory preparation	386
Program coordination and quality control	557
Data management	87
Program management	292
TOTAL	**5,494**
Amount spent as of report date	3,500

Dr. Mark Yocke, Vice President of Systems Applications International (SAI), received his PH.D. degree in civil engineering from the University of California at Berkeley after completion of his research on numerical modeling of wind fields and experimental model verification. During his postgraduate study, he also investigated the processes of turbulent entrainment and dispersion of thermal plumes. Dr. Yocke has been a principal contributor to the development of several models at SAI including the Regional Transport Model, the Reactive Plume Model, the Complex Terrain Wind Model, the PARIS and Urban Airshed photochemical grid models, the Regional Oxidant Model (RTM-III), the Night Sky Glow Model, the Gaussian Puff Model, and most recently, the UAM-V. He as applied these and other models to the assessment of regulatory compliance of proposed developments and development of regional/urban air quality management plans both in the United States and abroad. He has held primary responsibility for several large projects involving the modification, improvement, testing, and evaluation of sophisticated models for government and industry, including the Lake Michigan Ozone Study, the San Joaquin Valley Study, and the Taiwan Blue Sky Study. These projects have also involved development of comprehensive user guides, sample problems, and installation of large sophisticated software systems on a variety of computers.

SEA TURTLE BEHAVIOR RELATIVE TO OFFSHORE STRUCTURES IN THE WESTERN AND CENTRAL GULF OF MEXICO

Dr. Warren E. Stuntz
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Pascagoula, Mississippi

GOAL

Define the nature of any attraction of turtles to platforms. To meet this goal the following objectives must be completed:

1. Evaluate the diel and seasonal behavior and movements of sea turtles within the study areas.
2. Characterize preferred turtle habitat within the study area.

HISTORY OF THE EFFORT

The initial plan for this study was to track turtles via tracking methods, putting personnel on many platforms and obtaining cross bearings to obtain turtle position data. This plan was, however, deemed unmanageable and inaccurate. After considerable effort it was agreed that we should build and deploy a system for this study like the Retransmitted Loran (RTL) system being developed by the U.S. Forest Service for elk tracking. Modifying and adapting the RTL system for use in the ocean required a full year of work, and the system was not installed and tested until October 1992.

The RTL system consists of a tag placed on the back of a sea turtle and a base station. A base station consists of an antenna, a local tag, a receiver, a multiplexer, and a computer. Each of the system components is described below.

THE RTL TAG

The RTL tag consists of several components built around data needs. When at the surface, the tag receives loran signals and retransmits them at a frequency of 907 MHz to a base station. Other data transmitted by the tag include a tag ID, surface and dive times, and battery data.

The original RTL system was designed for elk. The tag was queried from the base station and it then sent back the data. Such a system was impossible for sea turtles because they surface at unknown intervals. In the final design of the tag, the system detects when the turtle is on the surface through feedback from the antenna, which is tested 10 times per second.

When the turtle surfaces, the tag immediately begins receiving loran data and retransmitting the loran data at a frequency of 907 MHz to the base station. Simultaneously upon surfacing a clock begins counting. This time is stored when the animal dives to be transmitted at the next surfacing. One of our concerns was that a turtle might stay at or very near the surface and the antenna would be splashed on or covered by waves periodically resulting in an artificially large number of surfacings and dives. The tag determines if this is occurring and accumulates as surface time the seconds until the tag has been submerged continuously for 45 seconds. When that happens the 45 seconds are subtracted from the accumulated time and the result is stored for transmission at the next surfacing. The time spent under the water is also stored. The accumulated number of seconds is transmitted upon surfacing.

Each surfacing is considered an event. The tag stores the surface and dive data from the current and five previous events and transmits all six events each time it surfaces. This redundancy allows the data to besaved even should two turtles surface simultaneously and interfere with one another's signals. The data on surface and dive times are transmitted simultaneously with the loran data in a part of the bandwidth not needed for the loran data. In case a turtle remains at the surface for a long period of time, the tag transmits once each hour.

THE BASE STATION ANTENNA

The receiving station antenna should be located as high as possible. We have the antenna mounted on top of a 180' tall tower located near the south end of the Chandeleur Islands. The height of the antenna is important because the frequencies available all transmitted in line-of-sight only. Given the curvature of the earth, the line-of-sight distance in miles is approximately the square root of the antenna height, times 1.23. Thus a tower 100 feet high would have a line-of-sight range of 12.3 miles, and the tower we are working from will have a line-of-sight distance of 16.5 miles. The receiving antenna is omni-directional and thus covers an area of 855 square miles. In practice, however, the reception distance is normally somewhat less because of wave motion, etc. A reception range under average conditions of 12 nautical miles is more realistic.

THE BASE STATION LOCAL TAG

An RTL tag identical to the tags on the turtles is located on the platform with the base station. This tag differs only in two ways. First, it receives power from an external source, and second, it can be turned on from the base station computer. The local tag is at a precisely known location and is used to correct the loran data received from the turtles. During normal operation, loran data from the local tag indicate that the loran data wobble somewhat. This wobble can amount to as much as 40 or 50 meters but is normally within less than 20 meters. Applying these corrections gives an accuracy of about 10 meters to the turtle tags. Accuracy will vary from area to area depending on the geometry of the loran stations.

THE BASE STATION MULTIPLEXER

The multiplexer is designed to collect data from up to three remote stations through a microwave link and the data from the receiver at the base station. The hardware in the multiplexer separates the loran signal from the data on surface and dive times, tag ID, etc., converts the loran data back to 100 kHz, and passes the data on to the computer. The multiplexer also contains an oscillator that is used to obtain precise timing data.

THE BASE STATION COMPUTER

The computer has special cards for handling the 9610 loran chain, for the 7980 loran chain, and an A/D (analog to digital) converter card. As the loran data come in, they are digitized with samples taken at a rate of 16 times per cycle. Loran signals have a base frequency of 100 kHz. During the 10 seconds that the tag transmits, enough loran signals are received that in fact we are able to obtain about 1,000 sets of the loran data. These data are averaged, and a computer program determines the third cycle zero crossing points for each of the loran systems as the point in the signal from which to measure the time differentials and thus the position. The turtle's position in terms of eastings and northings is calculated based on the averaged data, and that position is then corrected based on data from the local tag.

The data from the tag and the calculated positional information are stored in files on the computer hard disk. Mobil's Main Pass 6 and Main Pass 73 towers have telephone communication with the Mobil offices in New Orleans. We have a telephone number at the New Orleans office that rings in the radio room on the platform. A software package allows me to call that number and take total command of the base station on the platform. Data are downloaded daily to my computer in Pascagoula. Analysis and much of the trouble shooting of problems that occur can be accomplished from my office.

Just after the system was installed, lightning struck the base station antenna and caused extensive damaged in several components of the base station. Isolating the components that were damaged and replacing them took nearly nine months, largely because climbing the tower was a problem.

Attempts to capture turtles began in September 1992. Turtle capture in open water requires the combined efforts of an airborne spotter and a vessel equipped with an encircling net. Following the lead of the marine mammal aerial surveys we began flying at an altitude of 750 feet. Over time we have changed this to 1,500 feet depending on cloud heights and haze density because the turtles show little response to the airplane at that altitude and the observer can search a larger area from that altitude.

Spotting turtles from the air is very weather dependent. Wind in excess of 10 mph when small white caps begin to appear makes seeing a turtle very difficult. Low clouds, haze, rain and thunderstorms also cause visibility problems. The only times that we have had success in capturing turtles have been under nearly calm conditions.

To date, one leatherback and eight loggerhead turtles have been encircled by the net. The leatherback and five loggerheads were captured (the leatherback was released as soon as it was identified properly). The other three loggerheads escaped from the net by going out under the vessel while the net was being brought back aboard. These escapes taught us not to begin rolling the net aboard until the turtle entangles itself in the netting.

The four RTL tags placed on turtles failed due to a leak in the antenna. This problem seems to have been resolved although further testing is being carried out to be certain of that. One turtle tagged with an ARGOS transmitter on 13 August 1993 is still being received. A standard radio tag was placed on a turtle captured on 3 August. That turtle has remained within a radius of 5 miles of the capture site. It was last heard on 8 December 1993.

THE PRESENT SITUATION

Two complete Retransmitted Loran (RTL) base stations have been built. One is located on a Mobil Oil Platform in their Main Pass 6 area, and the other one is in Austin, Texas at Starlink, Inc., where it is used to test tags as they are built. That station is also used as a source of backup gear for failures encountered on the platform-based system. A third system is under construction and is intended for installation on a platform at main pass 73 and then for use in the Texas study area.

The vessel R/V Caretta was purchased and has been outfitted to conduct all of the necessary sea-going operations for this project including setting and retrieving a strike net, and carrying out the necessary trawling operations. Caretta, a steel-hulled vessel, just under 60' in length, was a used shrimp fishing vessel. She is now equipped to operate anywhere in the Gulf of Mexico or Atlantic and can house up to seven people including the crew of four. The boat is equipped with a power block to fish the strike net for turtles and is also equipped for trawling operations.

Dr. Warren Stuntz has been with the National Marine Fisheries Service in Pascagoula, Mississippi, for the last twelve years. He has worked on protected species including sea turtles and marine mammals throughout his career. Dr. Stuntz has B.S., M.S., and Ph.D. degrees in zoology from the University of Wisconsin (Madison).

ENVIRONMENTAL AND ECONOMIC ASSESSMENT OF DISCHARGES FROM GULF OF MEXICO REGION OIL AND GAS OPERATIONS

Dr. David A. Gettleson
Dr. Alan D. Hart
Mr. Bruce D. Graham
Continental Shelf Associates, Inc.
Jupiter, FL

OVERVIEW

In June 1992, the U.S. Department of Energy (DOE) contracted with Continental Shelf Associates, Inc. (CSA) and its team of subcontractors and independent consultants to conduct the multi-year study entitled *Environmental and Economic Assessment of Discharges from Gulf of Mexico Region Oil and Gas Operations*. CSA's subcontractors include Arthur D. Little (ADL), Core Laboratories, Florida Institute of Technology (FIT), ICF Resources Incorporated (ICF), and Steimle and Associates, Inc. (SAI); independent consultants include Drs. Bruce Honeyman and Wayne Isphording. This research effort is being supported under DOE Contract Number DE-AC22-92MT92001. This presentation outlines the technical approach being used to meet DOE study objectives and summarizes the current status of each technical task.

GENERAL TECHNICAL APPROACH

The study is designed to increase the present state of scientific knowledge concerning the following topics:

- The fate and environmental effects of pollutants found in produced water;
- The economic impacts of current and potential future regulations on offshore oil and gas producers of the Gulf of Mexico region; and
- The catch, consumption, and human use patterns of seafood species collected from coastal and offshore waters of the Gulf of Mexico.

The research implemented to address these topics will allow for creation of data bases pertaining to

- The fate and environmental effects of naturally occurring radioactive materials (NORM), trace metals, and organics in water, sediment, and biota near several offshore oil and gas facilities;
- The characteristics of produced water and produced sand discharges as they pertain to NORM, trace metals, and organics variably found in association with these discharges;
- The recovery of three terminated produced water discharge sites located in wetland and high-energy open bay environments of coastal Louisiana;
- The economic and energy supply impacts of existing and anticipated federal and state offshore and coastal discharge regulations; and
- The catch, consumption, and human use patterns of seafood species collected from coastal and offshore waters.

Guidance and expert technical input has also been provided by the DOE Contracting Officer's Representative, members of the scientific community, other agencies, and experts on the program team to further refine various aspects of the program, particularly the field component. Based on DOE's data needs, an eight-task research plan was implemented in mid-1992.

SUMMARY AND STATUS OF TECHNICAL TASKS

Task 1: Organize and Coordinate a Scientific Review Committee

The objective of this task is to organize and coordinate a Scientific Review Committee (SRC), whose main purpose is to review and critically evaluate all aspects of the research program. The SRC was established in July 1992. A total of 25 members comprise the SRC, representing industry groups, the scientific community, and the government sector (federal and state agencies). As one of their first official duties, the SRC reviewed and commented upon the Sampling and Analysis Plan (Task 2), submitted in August 1992. SRC comments were pertinent to a series of topics, including 1) data needs for the human health and ecological risk assessments, both of which will be completed separately by Brookhaven National Laboratory; and 2) suggested revisions to study design. The SRC also supported enhanced coordination between CSA, DOE, and other federal agencies or interests.

Task 2: Preparation of the Sampling and Analysis Plan

The objective of this task is to develop a Sampling and Analysis Plan which describes the research to be conducted in Task 3 (Environmental Field Sampling and Analysis of NORM, Heavy Metals, and Organics), Task 4 (Monitoring of the Recovery of Impacted Wetland and Open Bay Produced Water Discharge Sites in Coastal Louisiana), and Task 5 (Assessment of Economic Impacts of Offshore and Coastal Discharge Requirements on Present and Future Operations in the Gulf of Mexico Region). The draft Sampling and Analysis Plan was issued in August 1992 and reviewed by the SRC. Based on SRC comments, as well as comments and recommendations from DOE and other agencies and individuals, further revisions to the Sampling and Analysis Plan have been completed and integrated into the study design.

Task 3: Environmental Field Sampling and Analysis of NORM, Heavy Metals, and Organics

The objective of this task is to gather data necessary to characterize the extent of radionuclide contamination in water, sediment, and biota at produced water and produced sand discharge points. Heavy metals and petroleum hydrocarbon data are also being collected. NORM, heavy metal, and petroleum hydrocarbon data are to be used to evaluate the risks associated with produced water and produced sand discharges to human health and the environment. This risk assessment process involves following the discharge of pollutants from the source through its transport in the receiving environment, including indigenous fauna and humans.

Eight platform sites and six reference sites (Table 3C.6) located in OCS waters off Texas and Louisiana were selected following a rigorous review of 53 candidate offshore facilities. Task 3 sampling was initiated in June 1993 and continued into the summer months. The numbers and types of samples collected at primary and secondary platform sites and reference sites are summarized in Table 3C.7. A matrix summary of the analyses to be performed on these samples is provided in Table 3C.8. Radionuclides of interest include Ra^{226}, Ra^{228}, Pb^{210}, Po^{210}, and Th^{228}, while a total of 14 metals, three petroleum hydrocarbon classes (VOA, SHC, PAH), and six other elements are also to be determined in effluent, water, sediments, and tissues according to the analyses outlined in Table 3C.8.

Task 4: Monitoring of the Recovery of Impacted Wetland and Open Bay Produced Water Discharge Sites in Coastal Louisiana

The objectives of this task are to 1) identify and characterize the rates of ecological recovery at terminated produced water discharge sites located in select coastal wetlands and open bay environments of Louisiana; and 2) study the geochemical mobility of radionuclides, heavy metals, and organics in sediment and water. In addition, samples of water, sediment and commercially- and recreationally-important fish and shellfish tissues have been or will be taken in the vicinity of terminated discharges and analyzed for radionuclide content; results of these analyses will be used to support a separate health and environmental risk assessment for radionuclides discharged in produced water and sand.

Oil and gas facilities located in wetland and bay environments of Texas and Louisiana were screened as potential sampling locations using similar methods to those employed in establishing Task 3 sampling sites. Candidate facilities included those which had proposed the termination of their respective produced water discharges coincident with the current program schedule. A review of facility-specific produced water discharge data was also completed. Based on these evaluations, three sites in coastal Louisiana (i.e., one canal site, two open water bay sites) were selected for sampling (Table 3C.9). Pre-termination sampling was completed in April, May 1993 at Delacroix Island and Bay de Chene, and in November 1993 at Four Isle Dome. The numbers and types of samples collected at each coastal site are summarized in Table 3C.10. A matrix summary of the analyses to be performed is provided in Table 3C.11.

Table 3C.6. Platform and reference sites, Task 3.

	Water Depth (feet)	NORM Loading ^{226}Ra & ^{228}Ra (μCi/day)
Primary Platform Sites		
South Marsh Island 130B	215	1,411
South Marsh Island 236A	20	1,758
Vermilion 214A	127	1,022
High Island 595CF	400	1,280
Secondary Platform Sites		
Eugene Island 313A	236	75
High Island 382F	341	345
High Island 323A	235	38
Matagorda Island 703A	167	6
Reference Sites (platform - no produced water discharge)		
South Marsh Island 229C	18	---
Vermilion 298 and 305 (Sonnier Bank)	66	---
Reference Sites (non-platform)		
West Cameron 448	120	---
South Marsh Island 195	210	---
Galveston 90	132	---
Galveston 204	210	---

Table 3C.7. Types of samples and data, Task 3.

Primary Platform Sites

Produced Water
- initial collection (6 collections)
- monthly for 6 months

Produced Sand
- 3 replicates

Hydrography and Currents
- profiles and continuous

Discharge Plume Water
- 3 replicates at 5 distances – 5, 10, 30, 50, and 100 m

Sediments
- 25 stations (replicates at selected stations)

Pore Water
- 3 stations

Biological Tissues
- 1 invertebrate biofouling species
- 2 invertebrate soft bottom species
- 4 fish species

Harvestable Biota
- 3 trawls

Secondary Platform Sites

Produced Water
- 1 collection of 3 replicates

Biological Tissues
- 1 invertebrate biofouling species
- 2 invertebrate soft bottom species
- 4 fish species

Reference Sites (non-platform)

Ambient Water
- 1 collection of 3 replicates

Sediments
- 1 station with 3 replicates

Reference Sites (platform - no produced water discharge)

Ambient Water
- 1 collection of 3 replicates

Biological Tissues
- 1 invertebrate biofouling species
- 2 invertebrate soft bottom species
- 4 fish species

Table 3C.8. Analyses to be performed, Task 3.

	Produced Water	Produced Sand	Discharge Plume	Ambient Water	Sediments	Pore Water	Biological Tissues
Radionuclides							
Ra^{226}	X	X	X	X	X	X	X
Ra^{228}	X	X	X	X	X	X	X
Pb^{210}	X	X	X	X	X	X	X
Po^{210}	X	—	—	—	—	—	—
Th^{228}	X	—	—	—	—	—	—
Metals							
Al	—	X	—	—	X	—	—
As	X	X	—	X	X	—	X
Ba	X	X	—	X	X	—	X
Cd	X	X	—	X	X	—	X
Cr	—	X	—	—	X	—	X
Cu	X	X	—	X	X	—	X
Fe	X	X	—	X	X	—	X
Pb	X	X	—	X	X	—	X
Mn	X	X	—	X	X	—	X
Hg	X	X	—	X	X	—	X
Mo	X	X	—	X	X	—	X
Ni	X	X	—	X	X	—	X
V	X	X	—	X	X	—	X
Zn	X	X	—	X	X	—	X
Hydrocarbons							
VOA	X	—	X	X	—	—	—
SHC	X	X	—	—	X	—	—
PAH	X	X	—	X	X	—	X
Other Elements							
Calcium	—	—	—	—	X	—	—
Chloride	X	—	—	X	—	—	—
DOC	X	—	—	X	—	—	—
Sulfate	X	—	—	—	—	—	—
Grain Size	—	X	—	—	X	—	—
TOC	—	X	—	—	X	—	-

Table 3C.9. Study sites and sampling, Task 4.

Site	Termination of Discharge	Environment	Radionuclide Ra^{226} and Ra^{228} (pCi/l)		Discharge (bbl/day)
			Ra^{226}	Ra^{228}	
Delacroix Island Tank Battery #1	May 1993	Saline, Open-Water	273	—	1,397
Bay de Chene	October 1993	Saline, Open-Water	106	—	4,016
Four Isle Dome	January 1994	Canal	295	448	1,340

Table 3C.10. Types of samples and data, Task 4.

Produced Water
- pre-termination survey only

Hydrography and Currents
- profiles (discharge and two reference stations)

Sediments
- 14 surficial sediment stations (7 stations with 3 replicates)
- 3 deep sediment stations (pre-termination and second post-termination surveys only, three replicates at 20 to 25 and 35 to 40 cm depths)
- 6 marsh sediment stations (canal site, pre-termination survey only)

Pore Water
- 3 stations (pre-termination and second post-termination surveys only, three replicates at 0 to 5, 20 to 25, and 35 to 40 cm depths)

Biological Tissues
- 3 stations (pre-termination and second post-termination surveys only)
- 5 species (1 oyster, 2 fish, 1 shrimp, and 1 crab) with 5 replicates each

Macroinfauna
- 14 stations (6 replicates collected with 3 replicates analyzed)

Harvestable Finfish and Shellfish
- gill net, cast net, and trawl (if possible)
- crab traps
- oysters (presence/absence within 500 m of discharge)

Table 3C.11. Analyses to be performed, Task 4.

	Produced Water[1]	Surficial Sediments (SS[2])	Surficial Sediments (SS[3])	Deep Sediments[2]	Pore Water[2] 0-5 cm	Pore Water[2] 20-25 and 35-40 cm	Biological Tissues[2]
Radionuclides							
Ra^{226}	X	X	X	X	X	X	X**
Ra^{228}	X	X	X	X	X	X	X**
Pb^{210}	X	—	—	—	—	—	—
Po^{210}	X	—	—	—	—	—	—
Th^{228}	X	—	—	—	—	—	—
Metals							
Al	—	X	X	—	—	—	—
As	X	X	X	—	X	—	—
Ba	X	X	X	—	X	—	—
Cd	X	X	X	—	X	—	—
Cr	—	X	X	—	—	—	—
Cu	X	X	X	—	X	—	—
Fe	X	X	X	—	X	—	—
Pb	X	X	X	—	X	—	—
Mn	X	X	X	—	X	—	—
Hg	X	X	X	—	X	—	—
Mo	X	X	X	—	X	—	—
Ni	X	X	X	—	X	—	—
V	X	X	X	—	X	—	—
Zn	X	X	X	—	X	—	—
Hydrocarbons							
VOA	X	X*	—	—	—	—	—
SHC	X	X	X	—	—	—	—
PAH	X	X	X	X	X	—	—
Other Elements							
Calcium	—	X	X	—	—	—	—
Chloride	X	—	—	X	X	X	—
DOC	X	—	—	X	X	X	—
Si	—	—	—	—	—	—	—
Sulfate	X	—	—	X	X	—	—
Grain Size	—	X	X	—	—	—	—
TOC	—	X	X	X	—	—	—

* - Only at discharge during pre-termination survey
** - Pending available funds
1 - Pre-termination survey
2 - Pre-termination and second post-termination surveys
3 - First and third post-termination surveys

Task 5: Assessment of Economic Impacts of Offshore and Coastal Discharge Requirements on Present and Future Operations in the Gulf of Mexico Region

The objective of this task is to assess the economic and energy supply impacts of recent effluent limitation guidelines and New Source Performance Standards (NSPS) on oil and gas operations in offshore and coastal areas, both alone and in comparison to other regulatory requirements at the state and federal level. These impacts are to be assessed and presented in terms of the cost to the petroleum industry, current offshore oil and gas production which could be abandoned, future potentially recoverable oil and gas reserves that could become uneconomic, and future leasing in the Gulf of Mexico that could be diminished.

Progress to date on this task includes 1) development of a detailed plan for completion of the proposed effort; 2) acquisition of all historical production data for coastal state waters and Federal OCS fields in the study region; 3) preliminary evaluation of model methodology; 4) development of a forecast for production for Louisiana coastal and state water fields; and 5) acquisition of the platform database for federal OCS fields.

Task 6: Synthesis of Gulf of Mexico Region Consumption and Use Patterns

The objective of this task is to gather and assemble information regarding the seafood catch, consumption, and use patterns for the Gulf of Mexico region. In meeting this objective, descriptive field surveys (e.g., via interviews, questionnaires) and a detailed review of pertinent general literature and government and research data are being conducted to develop the database. Design and field testing of all surveys, with the exception of the oyster producers survey, have been completed. As field surveyors completed their training, the summer fisherman surveys and retailers surveys were completed. Surveys of wholesalers and processors have been mailed, and replies are presently being evaluated. The survey of Louisiana restaurants was released to the Louisiana Restaurant Association for distribution to its members.

Task 7: Technology Transfer Plan

The objective of this task is to facilitate dissemination of the information collected during this study. To this end, the program has adopted a three-tiered approach to make data available quickly and in a usable form. The three primary elements of technology transfer include 1) preparation of short, succinct progress reports or public abstracts; 2) presentation of progress reports and study results at MMS Information Transfer Meetings (ITM); and 3) presentation of study results at scientific conferences and preparation of study results for publication in peer-reviewed literature. In addition to presentation at the 1993 MMS ITM, a presentation on the objectives, sampling design, and progress on Task 3 was made in November 1993 at the Society of Environmental Toxicology and Chemistry.

Task 8: Project Management and Deliverables Preparation

The objective of this task is to ensure proper project management, including routine oversight of CSA and subcontractor staff, strict adherence to established quality assurance and quality control procedures and protocols, and timely and thorough preparation of technically sound deliverables. Given the modified technical approach realized since June 1992, revised management and cost plans and milestone schedule have been developed. An expanded quality assurance/quality control program specific to radioactive nuclides has also been developed.

Dr. David Gettleson is President and Scientific Director of Continental Shelf Associates, Inc. (CSA), located in Jupiter, Florida. He has 17 years of scientific management experience with major research programs for federal, state, and industrial clients. He has been involved in the preparation of numerous environmental assessment documents covering a wide range of human activities in the marine environment, including oil and gas operations, dredging and dredged material disposal, beach restoration, artificial reef siting, power plant effluents, sewage outfalls, and waste incineration. Dr. Gettleson received a B.A. degree in biology from Rollins College in 1971 and earned his Ph.D. degree in biological oceanography from Texas A&M University in 1976.

Dr. Alan Hart has worked at Continental Shelf Associates, Inc. (CSA) for 12 years, presently as a Senior Scientist. He has been involved in the study design, field, laboratory, data analysis, and data interpretation phases of numerous projects conducted for private, industry, and government entities. He received his Ph.D. degree in oceanography from Texas A&M University in 1981.

Bruce Graham is a Marine Biologist/Senior Staff Scientist at Continental Shelf Associates, Inc. (CSA) located in Jupiter, FL. He has 10 years' experience with major research programs for federal, state, and industrial clients and has served as Project Manager and/or Chief Scientist on numerous marine sampling projects. He has been involved in various projects including oil and gas lease block photodocumentation, dredge disposal monitoring, beach restoration, power plant effluents, and oil and gas biological monitoring. Mr. Graham received his M.S. degree in biological sciences from Florida Institute of Technology in 1983.

SESSION 3D

LATEX PLUME STUDY PROGRESS REVIEW

Session: LATEX PLUME STUDY PROGRESS REVIEW

Co-Chairs: Dr. Murray Brown and Dr. Stephen P. Murray

Date: December 15, 1993

Presentation	Author/Affiliation
Introduction	Dr. Murray Brown Minerals Management Service Gulf of Mexico OCS Region
Acoustic Doppler Current Profiler Study of the LATEX Coastal Plume	Dr. Stephen P. Murray Coastal Studies Institute Louisiana State University
Hypoxia Studies in the Mississippi River Plume Area, 1993	Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium
Light Conditions in the Coastal Boundary Layer of the Northern Gulf of Mexico	Dr. R. Eugene Turner Department of Oceanography and Coastal Sciences Coastal Ecology Institute Louisiana State University Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium
Satellite Observations of Circulation in the Northern Gulf of Mexico Since January 1992	Dr. Nan D. Walker, Dr. Lawrence J. Rouse, Jr. Dr. Oscar K. Huh Coastal Studies Institute Louisiana State University
Fate of Chemicals in the Mississippi River Plume: Transport and Three-Phase Partitioning in the Shallow Coastal Shelf of the Gulf of Mexico	Dr. Jay C. Means Ms. Debra J. McMillin Aquatic Toxicology Laboratory School of Veterinary Medicine Louisiana State University
Review of LATEX B Hydrography During 1992 and 1993	Dr. Curtis C. Ebbesmeyer Evans-Hamilton, Inc.

ACOUSTIC DOPPLER CURRENT PROFILER STUDY OF THE LATEX COASTAL PLUME

Dr. Stephen P. Murray
Coastal Studies Institute
Louisiana State University

The combined freshwater discharge of the Mississippi and Atchafalaya Rivers form an extensive coastal plume of low salinity, turbid water that extends well over 500 km to Galveston and Corpus Christi and, even at times, to the U.S.-Mexican border. The baroclinic structure of this coastal plume, combined with local wind driving, produces the distinct and highly energetic Louisiana-Texas Coastal Current.

The hydrographic component of the LATEX B project has a principal objective to determine the spatial and temporal structure of the velocity field in the entire Louisiana-Texas coastal current, as well as understanding the role of specific circulation features, such as convergence, intrusions, and meanders in the current.

Five 10-day cruises are programmed to investigate the physical, biological, and chemical characteristics of this ecosystem, which generally lies within a band 50-70 km from the coast. The first two cruises, in April and October 1992, are discussed in this presentation. Underway acoustic doppler current profiling (ADCP) and standard CTD stations were the principal data collection techniques.

Area 1 (Figure 3D.1) extends from Section S1 at 90° 30' westward to about halfway between S3 and S4. It principally displays the conditions upstream (east) of the Atchafalaya River mouth and the flow pattern off the mouth itself. Figure 3D.2 shows the ADCP velocities at the 3 m depth in Area 1. The ADCP data on Section S1 is of low quality and was rejected. T2, however, shows a strong inflow of high salinity water over almost its entire length. We suspect this inflow bifurcates into east-going and west-going branches, flowing toward S1 and S2, respectively. At section S2 the coastal current collected from S1 and T2 is a well-defined westward jet on a collision course with the southeastward flowing Atchafalaya River outflow jet. A study of the salinities along these lines indicates that the coastal current is deflected sharply seaward from this impact and returns shoreward along the westward half of T4. The coastal current augmented by the addition of the Atchafalaya River outflow is seen flowing westward on S3 and T7.

At the 6 m level the same basic flow pattern is clearly evident, except that the seaward retroflection of the coastal current is less pronounced. The northward inflow of high salinity water (33-35 psu) continues through T2. The northeastward flow directions along T2 suggest that much of this water is escaping eastward through S1.

The flow pattern at the 10 m level (Figure 3D.3) is less clear. The northward flow through T2 persists. It is plausible that it bifurcates at the submarine headland formed by the 10 m isobath with some flow eastward through S1 and the balance through S2 as observed. The northwestward flow along T5 under and counter to the outflow plume of the Atchafalaya River suggests strong upward entrainment into the plume. The eastern quarter of line T4 is in an onshore flow zone, but the remainder of T4 exhibits offshore flow, the source of which remains unclear. The apparent divergence in the area between T4 and T5 at this level could result from tidal aliasing, or perhaps be compensated by vertical motion from above or below.

The data at the 14 m level is relatively scant, obviously caused by shallow bottom depths, but the basic flow pattern is similar to the 10 m level. It is interesting to note that all the northeastern flow coming through section T2 cannot squeeze through the short length of S2 (about 20 km) available at this depth. It must escape either by massive upwelling, or downwelling. More likely, this flow is deflected back to the northeast by the 14 m isobath headland. The southeastward outflow remains strong through T4, and its source remains unclear.

The central sector is centered at the Sabine Pass area. The flow at S4 at the 3 m level is weak and disorganized, perhaps related to the dropout of the southeasterly winds, which were prevalent for the previous 10 hours. S5 has degenerated into small-scale flow structures with the northerly wind driving, except at its inshore end where a coherent westward current developed. There is a prevalent northward flow component at S5 against the wind stress, perhaps representing a breakdown of the coastal current into

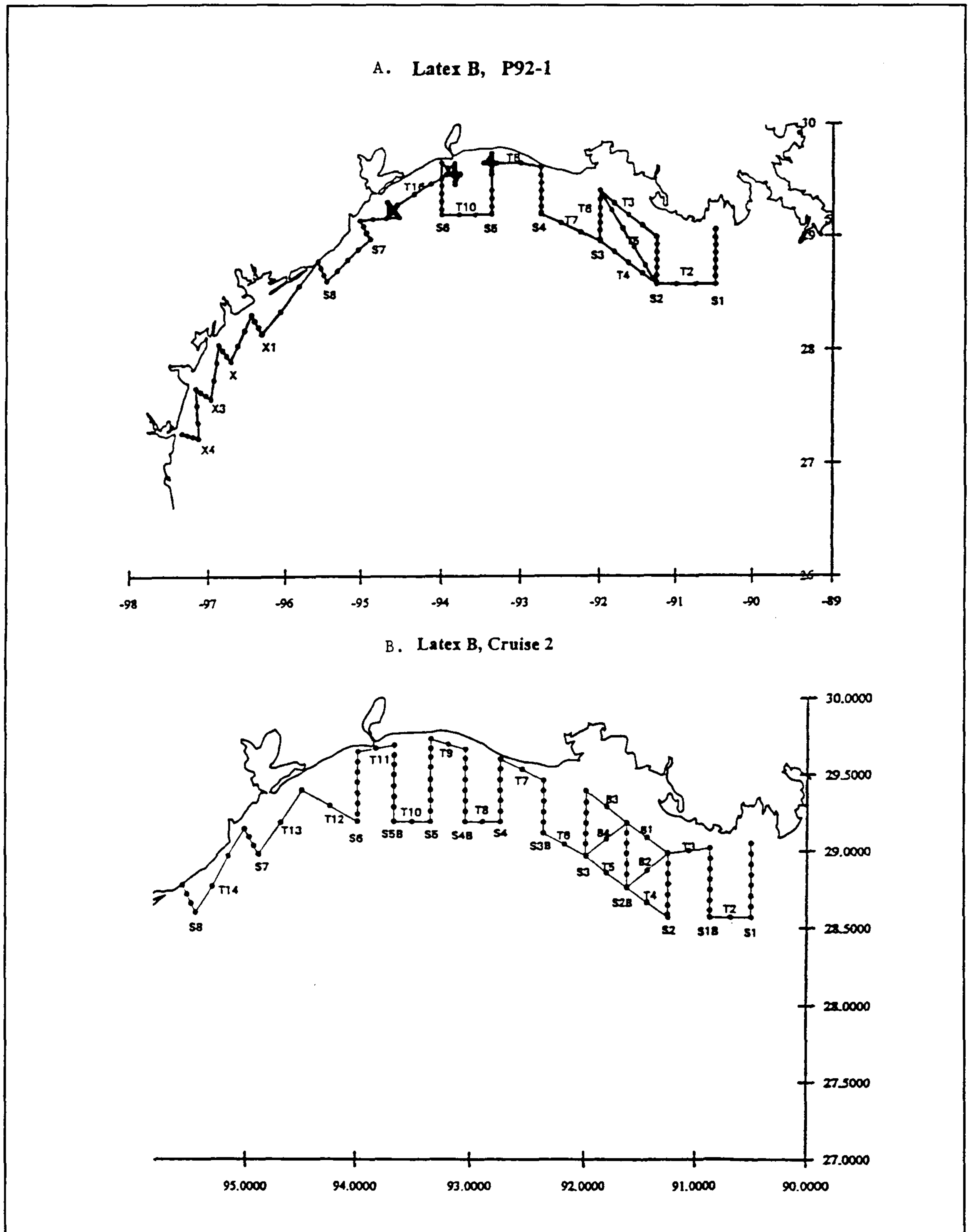

Figure 3D.1. Area 1, from Section S1 at 90° 30' westward to about halfway between S3 and S4.

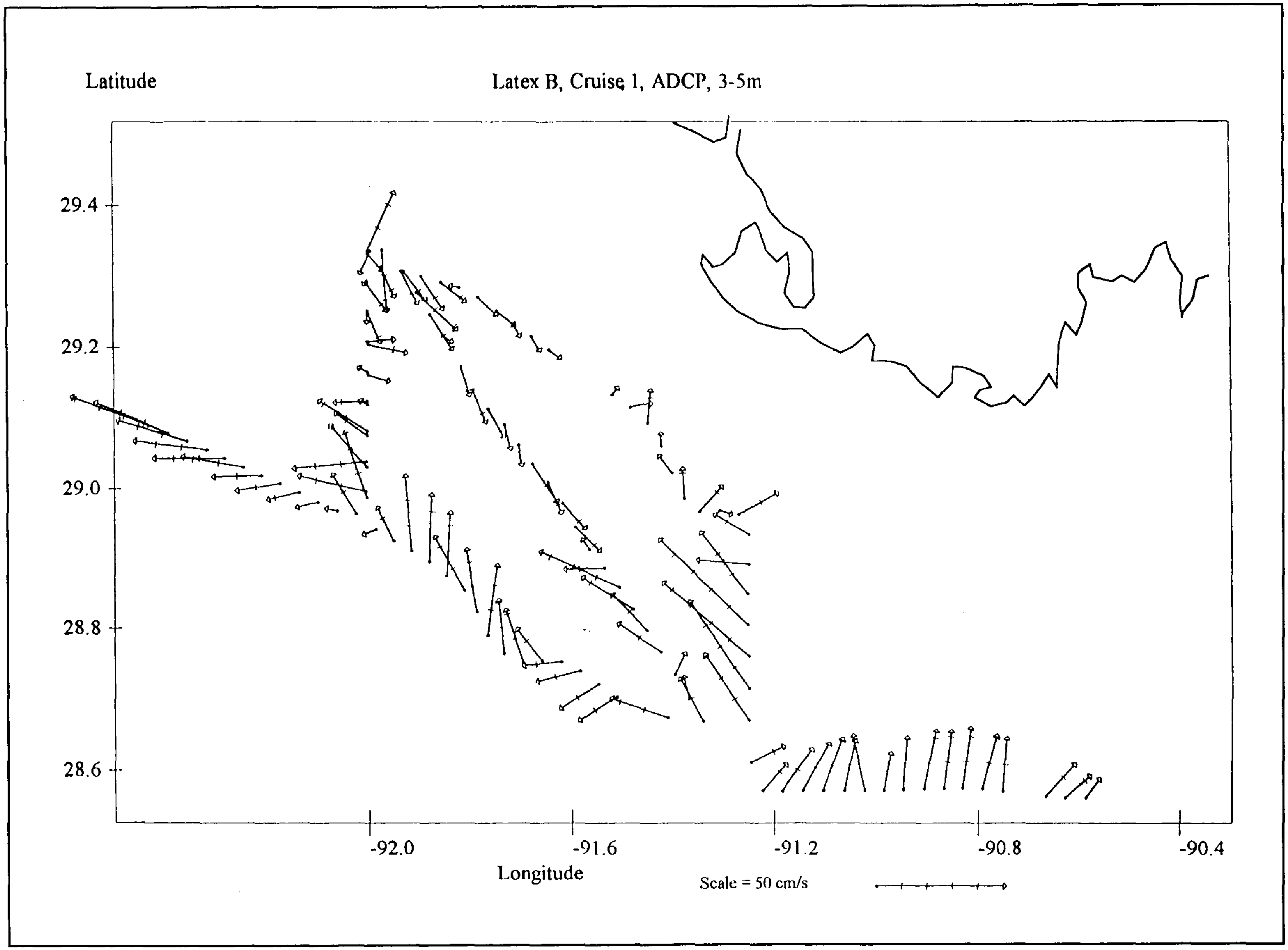

Figure 3D.2. ADCP velocities at the 3 m depth in Area 1.

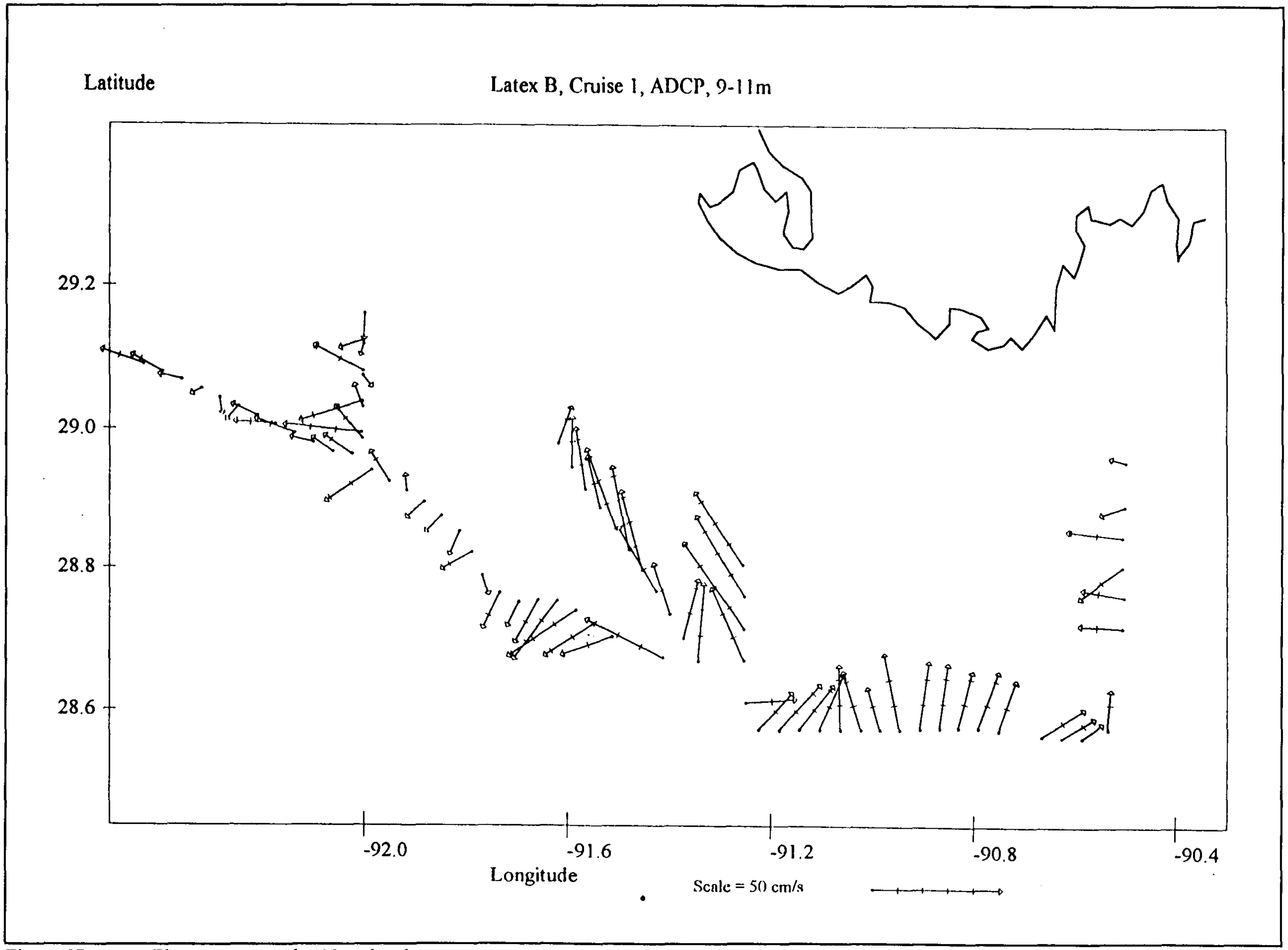

Figure 3D.3. Flow pattern at the 10 m level.

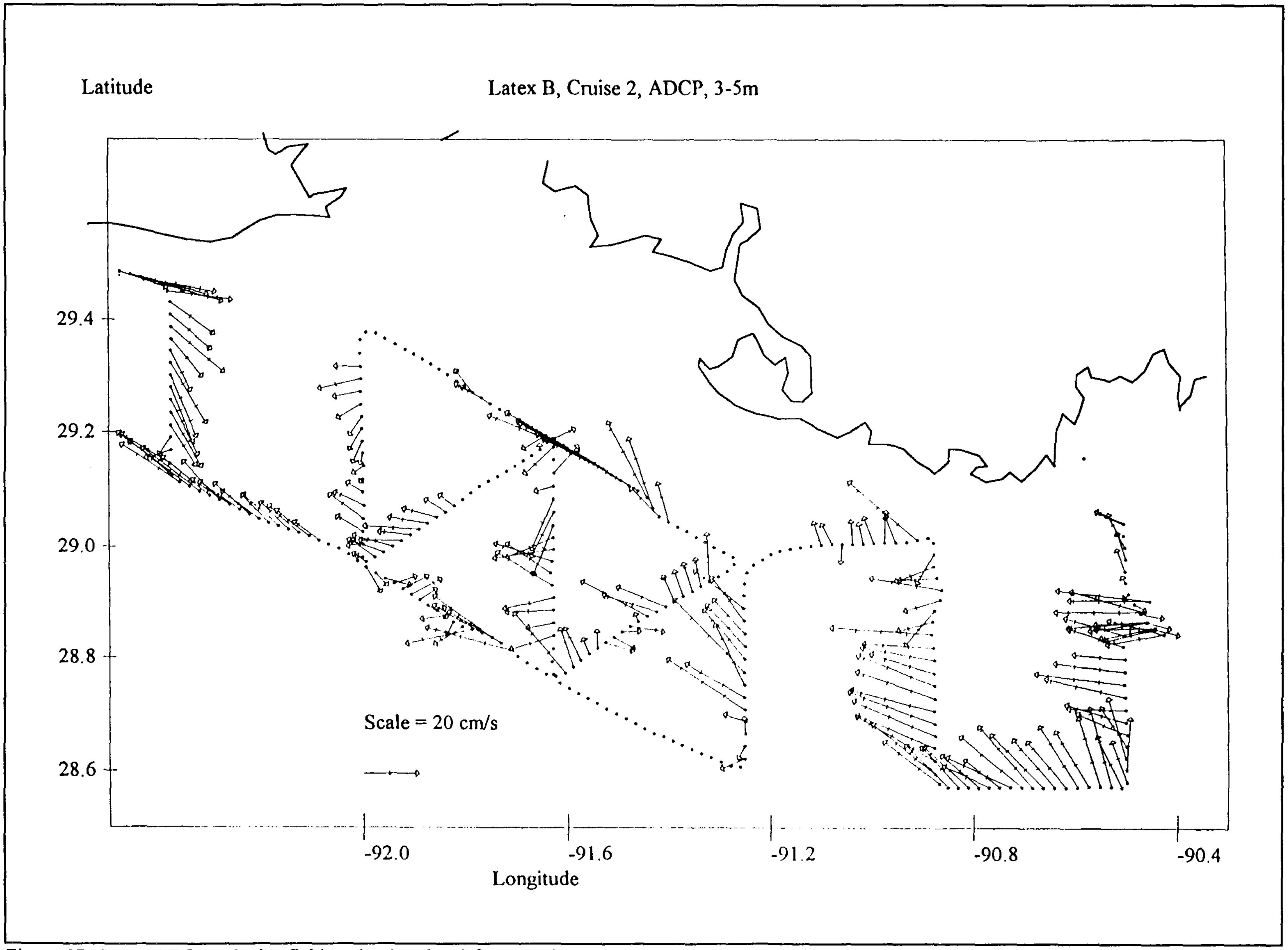

Figure 3D.4. ADCP velocity field at the 4 m level from Cruise II.

gyres of various scales under northwind conditions. The 3 m level flow at T10 appears to reflect meandering or wave-like structures.

It is surprising to note at S6 a coherent, well-developed coastal current with a jet reaching 35 cm/sec in the usual location. The wind is strong from the northwest, in opposition to the current. The dynamics driving this current at S6 remain unclear. At the 6 m level the flow picture remains essentially the same. At the 10 m level there is good evidence for a clockwise circulation (meander or gyre) along the outer half of S5, along T6, and along the outer half of S6.

Figure 3D.4 shows the ADCP velocity field at the 4 m level from Cruise II. Winds have been very strong from the east and clearly drive the Coastal Current westward at 30-40 cm/sec. The strong onshore flow persists on T2. The Atchafalaya River discharge is reduced by one-third from the April 1992, cruise and there is little signature of the outflow plume in the velocity field. The flow is reversed to the east in line 3b due to a frontal passage and shift to northwesterly winds. Discharges in the coastal current are in the range of 60,000 m^3/sec.

Dr. Stephen P. Murray has 25 years of research experience in coastal and shelf waters. He is past Director of the Coastal Studies Institute at Louisiana State University, where he is presently employed working on research projects on the physical oceanography of shelf, sea straits, and coastal waters. Dr. Murray received his Ph.D. in dynamical oceanography from the Department of Geophysical Sciences, University of Chicago in 1966.

HYPOXIA STUDIES IN THE MISSISSIPPI RIVER PLUME AREA, 1993

Dr. Nancy N. Rabalais
Louisiana Universities Marine Consortium

INTRODUCTION

A band of nearshore hypoxia (< 2 mg O_2/l) is found in the bottom waters of the Louisiana shelf during most summers. A break in the longshore continuity of hypoxic bottom waters is often observed near the Atchafalaya River delta. Spatial and temporal variability in the distribution patterns exists and is at least partially related to the amplitude and phasing of Mississippi River discharge, subsequent nutrient flux to the coastal waters, and a close coupling with net productivity. The occurrence of stratification, mediated by a river-induced halocline is a necessary prerequisite for the development and maintenance of hypoxia. The vertical extent of the hypoxic region is often limited by a secondary weak pycnocline associated with a near-bottom thermocline. Weather events are an important determinant of the structure and severity of hypoxic conditions.

STUDY DESIGN

Monthly monitoring cruises along a transect off Terrebonne Bay, a multi-instrumented array in the core of the hypoxic zone, and several shelfwide survey cruises documented the distribution and dynamics of hypoxia on the Louisiana-Texas shelf during 1993. The following summary draws from research conducted as part of the NOAA Nutrient Enhanced Coastal Ocean Productivity (NECOP) study, the MMS LATEX-B physical oceanographic studies of the Mississippi River Plume, and a NOAA National Undersea Research Center (NURC) cruise.

RESULTS

Shelfwide cruises were conducted in April 1993 during high river flow, and again in mid-summer during a period of unusually high sustained freshwater inflow from the Mississippi and Atchafalaya Rivers when flows are usually minimal. Three disjunct areas of near-bottom oxygen deficiency were documented on the April NECOP shelfwide cruise, although the total area was not near the size of the usual mid-summer hypoxia extent. The hypoxic water mass south of Terrebonne Bay and Ship Shoal (90_30'W to 91_15'W) was persistent, with similar areas being mapped during the MMS LATEX-B cruise (4-22) and the NECOP shelfwide cruise (4-27).

At the site of the instrument mooring, station C6B on transect C, hypoxia occurred for much of the record in April and from late May through mid-June. Heavy winds and seas, resulting from the tropical depression which crossed the Gulf of Campeche and came to shore on the south Texas coast, reaerated the water column in late June. Hypoxia re-established in early July at station C6B, and hypoxic/anoxic conditions prevailed through early October.

On a shelfwide-scale, surface water signatures of less saline, nutrient-rich, and high chlorophyll biomass waters paralleled the sustained and high summer freshwater outflows of the flooded Mississippi River. Persistent westerly and southwesterly winds for much of July through mid-August helped to retain large volumes of this freshwater on the Louisiana shelf and upper Texas coast. An oxygen-depleted lower water column prevailed over large areas of the Louisiana-Texas shelf for extended periods of July, August, and September.

Several mid-summer surveys of hydrographic conditions on the Louisiana-Texas shelf documented the extent, severity, and persistence of hypoxia. During July and August, hypoxia was mapped between the Mississippi River Delta and the upper Texas coast, with the distribution shifting as the summer progressed. Hypoxia extended well onto the upper Texas coast in early July (NECOP, Bratkovich *et al.*) but was diminished in size on the southeastern Louisiana shelf compared to previous year's surveys. During mid-July (LATEX-B), the upper Texas coast continued to be affected, but the hypoxic water mass has shifted somewhat towards the east. The NECOP mid-summer survey covered the period of 24-29 July 1993 and mapped a large, continuous area of hypoxic waters between the Mississippi River Delta and the Calcasieu estuary. Although the grids were not similar for all three cruises, it appears that the hypoxic water mass that extended onto the upper Texas coast in early to mid-July was pushed back onto the Louisiana shelf by late July as a result of persistent westerly and southwesterly winds. The maximal extent of hypoxia was documented to be an area approximately twice as large as the average area mapped in previous mid-summer periods (1985-1992) over the same sampling grid. In 1993, hypoxic waters extended from very near shore along most of the Louisiana coast out to 50 km off the southeastern shelf and 130 km off the southwestern shelf. The lower water column was hypoxic in water depths of 5 to 40 m. Most of the stations identified as "hypoxic" were severely depressed in dissolved oxygen (< 0.5 and often < 0.1 mg/l). Hypoxic conditions worsened during the first week of August over a more restricted geographic area studied off Terrebonne Bay, with the zone of hypoxia extending farther offshore, concentrations of dissolved oxygen becoming lower, and anoxic conditions becoming more prevalent as indicated by the detection of hydrogen sulfide in bottom waters of many stations.

The influence of the continued high freshwater inputs was evident during the NECOP cruise which mapped, among other parameters, surface salinity, surface chlorophyll-a as an indicator of phytoplankton biomass, and surface nutrients. Salinities between 15 and 25 ppt covered much of the shelf surface waters, where values are usually 25 to 30 ppt. Phytoplankton biomass, as measured by chlorophyll *a*, was also much greater than typical mid-summer values. Nutrient concentrations at the Mississippi River end member were 50% greater than the long-term summer average (1975-1985), and much higher nutrient concentrations than usually found during mid-summer were found over large areas of the shelf.

Mid-month CTD surveys (August and September) coupled with other cruises and data from a continuously recording oxygen meter situated off Terrebonne Bay indicated that an extensive and severely depressed low oxygen zone persisted on the southeastern shelf along transect C and extended well into the Mississippi River Delta Bight, but was diminished in size immediately west of the delta. Mid-August and mid-September 1993 hypoxia distribution along this transect was larger than most distributions mapped in previous years (i.e., consistent with the late July and early August "larger than usual" hypoxic zone size). Severely oxygen-depleted bottom waters persisted at the site of the oxygen meter (off Terrebonne Bay) into early October. Subsequently, a series of frontal passages with high winds and seas, thermal cooling of the surface waters, and subsequent breakdown in the strength of water column stratification led to the dissipation of hypoxia.

Video and/or diving operations documented large areas of the seabed that were devoid of demersal finfish, shellfish, crabs, and shrimp for the entire period of hypoxia. In many areas there was evidence of anoxic sediments (black muds and sands) and extensive bacterial mats (primarily sulfur-oxidizing bacteria). Stress responses of benthic organisms were evident with: 1) polychaete worms out of their burrows lying on the sediment surface moribund; and, 2) brittle stars observed up from below the sediment surface, also exposed at the seabed. There were extensive areas where scientists were unable to document any living organisms. These areas were also characterized by the presence of dead and/or decaying polychaete worms bivalves, ghost shrimp, other invertebrates, and a few fish.

Acknowledgments are due to NECOP and NURC collaborators, Drs. R. Eugene Turner and William J. Wiseman, Jr., Louisiana State University, and Dr. Donald E. Harper, Jr., Texas A&M University at Galveston.

Dr. Nancy N. Rabalais is an Associate Professor at the Louisiana Universities Marine Consortium where she has been employed since 1983. She received her B.S. and M.S. in biology from Texas A&I University in Kingsville and her Ph.D. in zoology from The University of Texas at Austin in 1983. She has been involved in several large, multi-institutional, multi-investigator studies of the influence of large rivers on continental shelves, the distribution and dynamics of hypoxic environments, and fate and effects of petroleum industry discharges.

LIGHT CONDITIONS IN THE COASTAL BOUNDARY LAYER OF THE NORTHERN GULF OF MEXICO

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The Coastal Boundary Layer (CBL) is characterized by strong turbidity gradients and well-defined density structure responsive to local winds, freshwater supplies, and weather fronts. The CBL therefore has a relatively unstable structure over periods of days to weeks, as shown by remotely sensed images of turbidity in the surface layer. Visual observation of only the surface layers is substantially inadequate for descriptions of the CBL, because the physical structure is not homogenous with depth. Light conditions within the CBL vary temporally along the three spatial axes and can be used to both define its location and to quantify its variability.

Turbidity, quantified as light transmittance, attenuation, extinction coefficients, etc., has both physical and biological components. Suspended sediments and phytoplankton pigments are the main contributors to the extinction coefficient (K) in coastal systems, although dissolved materials, such as humics, may be significant inhibitors to light transmittance at some wavelengths. The biological components may be less responsive to variations to the forcing functions than the physical components, because, for example, growth and decay rates are involved. Some geophysicists may view the biology as a regrettable complication to elegant mathematical modeling of the CBL, but the facts show that the light attenuation by phytoplankton may be significant, even within and near the Mississippi River delta CBL.

The light field within the CBL, regardless of cause, has important biological consequences. Microbes, zooplankton and fish are dependent on the phytoplankton whose accumulation and production is responsive to the same forces delimiting the physical structure of the CBL. Low oxygen zones, or hypoxia (<2 mg/l) are extensive seaward of the Louisiana

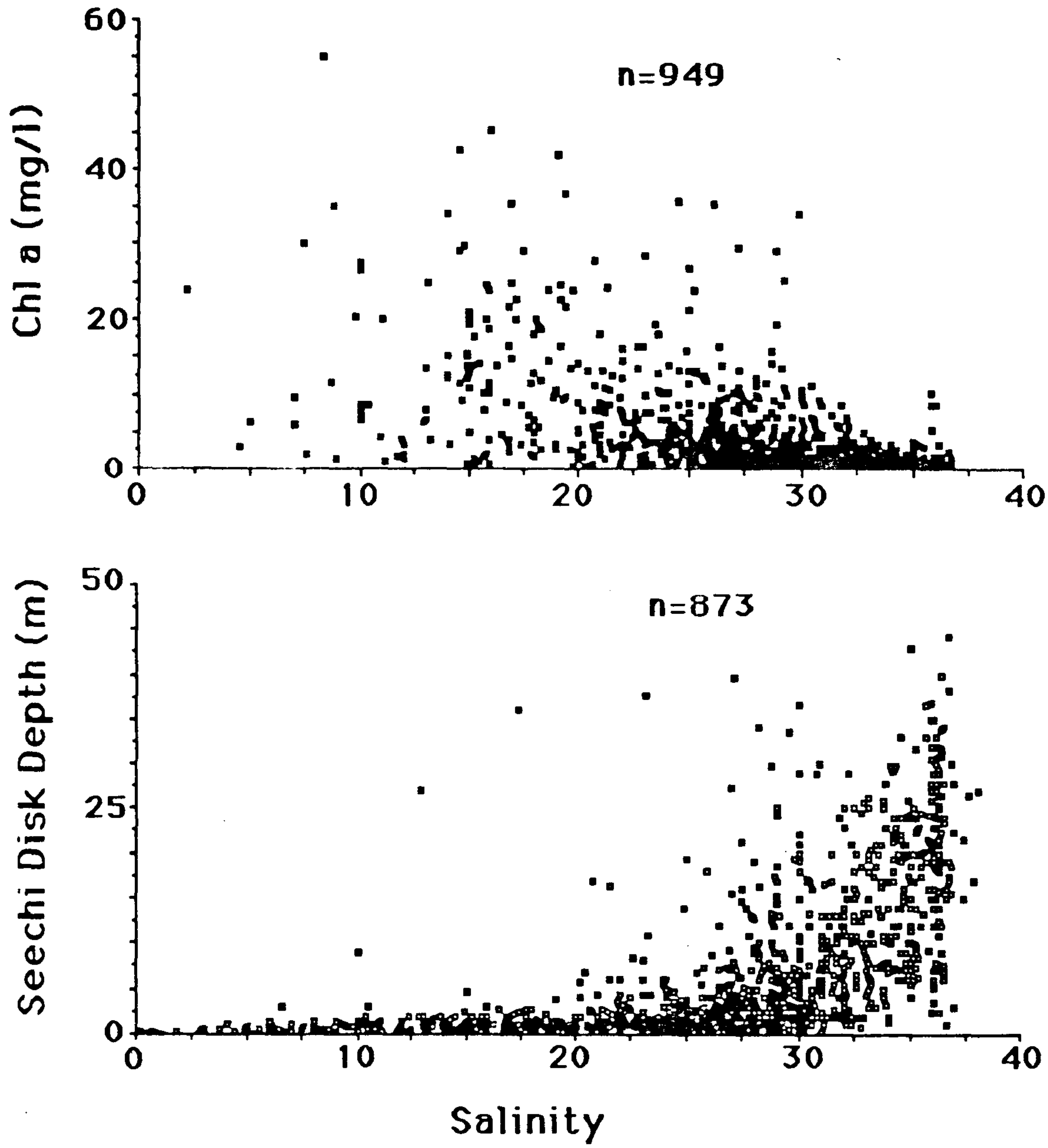

Figure 3D.5. Changes in secchi disk depth with salinity for data from the 1960s to 1990, northern Gulf of Mexico continental shelf.

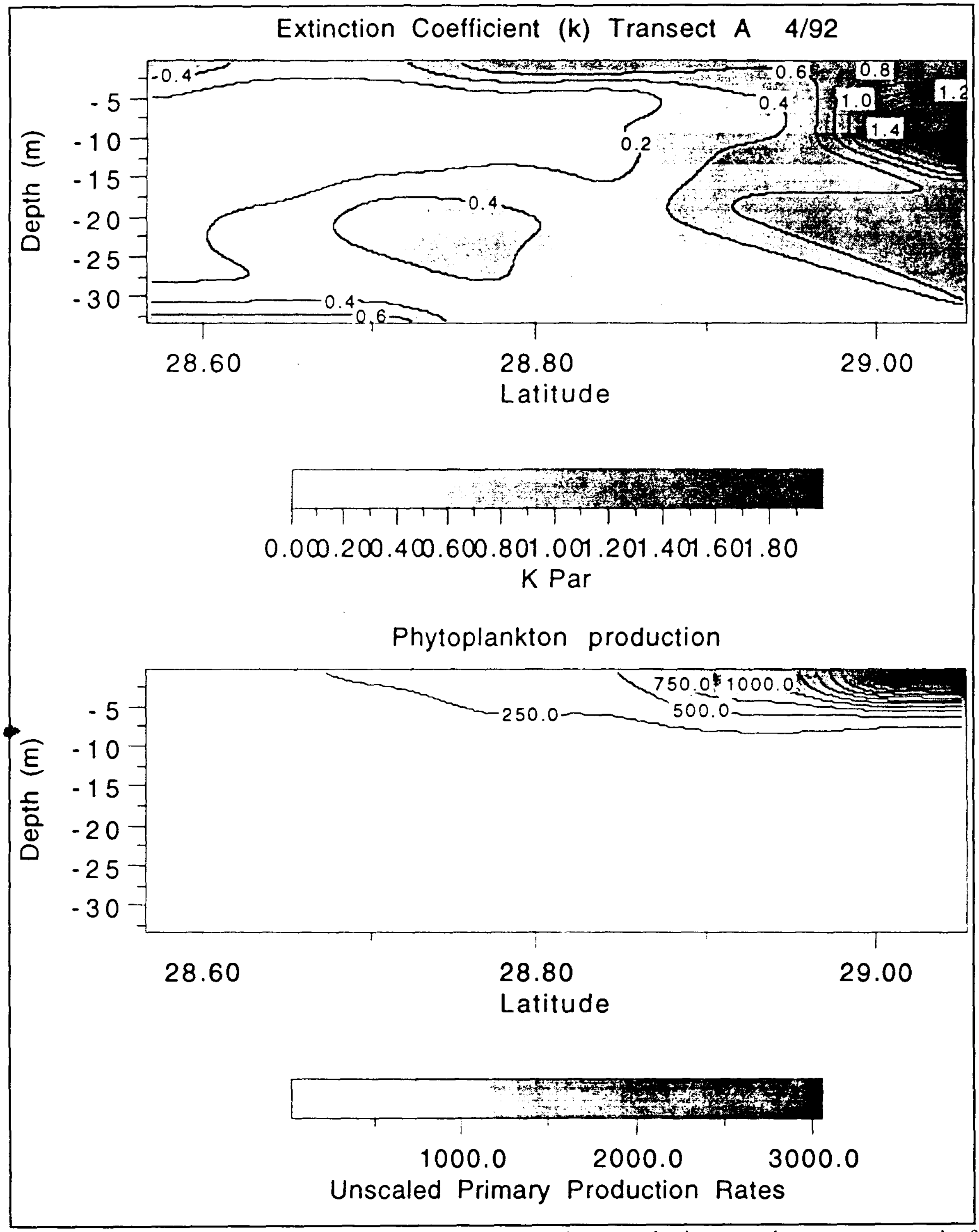

Figure 3D.6. Changes in the extinction coefficient (k) and primary production rates along a transect south of Grande Isle, in April 1992, taken on LATEX B, cruise #2.

CBL, and are the largest in the United States. One of the tasks of LATEX (Part B) is to define the light field of the CBL and to establish quantitative relationships between the physical and biological components. We have begun this investigation using traditional methodology: i.e., data from transmisometers, secchi disks, PAR sensors, suspended sediment measurements, and satellites. Data from moored instruments, and other data, are being obtained from the NECOP program and from historical records. Other tasks include determination of nutrient concentrations to assist interpretation of the biological variability. This is the first data reduction exercise, and is therefore limited to discussion of a few examples of the variability found on the first two cruises.

The secchi disk is the 'Model T Ford' of light measurement methodology, being first used in the Adriatic before this century, and in the Gulf of Mexico in the 1930s. Modern instrumentation may easily cost 100 times more and is worth it. The secchi disk, whose measurement is a variable depth estimator of a variable source strength (sunlight), has been around longer and used routinely, compared to the newer instrumentation. Its simplicity, low cost and frequent use has provided many measurements of turbidity that should not be ignored for superficial reasons. Measurements from secchi disk depths and optical measurements (from an in situ light meter) are well correlated. In situ measurements of the compensation depth (defined as where phytoplankton production is zero) are also well correlated. Secchi disk measurements are therefore potentially valuable sources of information on the light field within the CBL.

The light field of the CBL is, of course, strongly structured because of the density gradients. The extinction coefficient varies tremendously with depth and turbidity layers often found at the surface and bottom of a water column. Also, the light conditions at one station, even within one month, vary. The noontime light available for photosynthesis ranged 20 fold during one month at the moored light meter, south of Terrebonne Bay.

An example of the relationship between salinity and turbidity is shown in Figure 3D.5. Water clarity increases dramatically around 30 ppt. The explosion of chlorophyll a, which is very low in the Mississippi River source end member, increases as low as the 15 ppt isohaline. Because of the high nutrients in the riverine end member, coastal phytoplankton are most often light-limited, not nutrient limited. Thus, small increases in light (enough to extend the euphotic zone to 1 m) are important determinants of phytoplankton productivity.

An example of the extinction coefficient across a transect south of Grande Isle, Louisiana, is shown in Figure 3D.6. The CBL is shown in the right side, looking westward. Light at the surface does not penetrate below 10 m anywhere along the transect. Placed between the turbid layer and the illuminated water column further offshore is a region of high phytoplankton production.

The light regime in the LATEX B study area shows substantial variability across the shelf in three directions: over days, week and seasonally. There is also the possibility that decadenal changes have occurred in the light regime, for two basic reasons. First, the suspended load of the Mississippi River has changes with land use, water control structures and water delivery patterns. Land use changes began in the 1800s with European settlement, and soon led to flood protection measures, including dam construction. Water diversions from the Mississippi River to the Atchafalaya River began in the 1920s. Thus the seasonal timing, the quantity and the allocation of water supplies and therefore sediment supplies have changed in the last 200 years. The second basic influence on decadenal light regime changes involve the nutrients necessary for phytoplankton growth, largely following agricultural practices. The concentration of nitrogen in the Mississippi River doubled since the 1950s, whereas the concentration of silicate declined by 50 percent. These nutrient changes affected the quantities and qualities, and therefore the pigments, of phytoplankton in the CBL.

This is the first year of LATEX B. We are working to integrate the various measures of light field in the CBL, and to quantify the contribution of phytoplankton to the light field. The opportunity to couple the variability of the physical and biological elements within one field study is a large challenge for such a dynamic area. We look forward to presenting the results in future ITM meetings.

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SATELLITE OBSERVATIONS OF CIRCULATION IN THE NORTHERN GULF OF MEXICO SINCE JANUARY 1992

Dr. Nan D. Walker
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INTRODUCTION

The Remote Sensing Task of LATEX B is responsible for monitoring circulation events in the northern Gulf of Mexico using real-time acquisitions of satellite data obtained at the Earth Scan Lab from the NOAA satellites' Advanced Very High Resolution Radiometer (AVHRR). This information is then disseminated in the form of frontal analyses and GIF (Graphic Interchange Format) image files to LATEX researchers, the general oceanographic research community, and the private sector via the OMNET bulletin board, GULF.MEX. In addition, we provide information on oceanographic features in support of specific data collection programs of LATEX A, B, and C. Another component of our task is to analyze ongoing data acquisitions and historical data within the Earth Scan Lab archive to better understand the behavior of coastal and shelf currents, shelf -slope exchange of water (squirts) and the movement of Loop Eddies. This paper highlights some of the major circulation events in the northern Gulf of Mexico since 1992 as detected from satellite imagery, with supporting "surface" truth measurements where available.

METHODOLOGY

Satellite data of the NOAA Advanced Very High Resolution Radiometer (AVHRR) is obtained several times each day at the Earth Scan Laboratory, Coastal Studies Institute, Louisiana State University. These data are captured and archived using a SUN Sparc II computer running the Terascan™ software from Seaspace, San Diego, California. After capture, the thermal and visible channels are calibrated from count values to science units. The thermal infrared channels are converted to brightness temperatures in Celsius and the visible channels are calibrated to percent albedo. The Gulf of Mexico portion of the image is automatically cut out of the of the raw data and placed on the Earth Scan Lab's newest computer, the S.G.I. Crimson server with 85 mips and 144 mb RAM. All further processing and analysis of the satellite data is performed on this computer, accessed by Tektronix X-11 terminals. Each of the 8-12 images/day is screened for cloud cover and general image quality over the Gulf of Mexico. If an image is sufficiently free of cloud-cover over an area of interest, the dataset is run through additional processing procedures which include calculation of sea surface temperature (SST), calculation of reflectance (to reveal surface suspended sediment), and navigation/registration of the image to a standard rectangular map projection. Sea surface temperatures are computed using the multi-channel algorithms of McClain *et al* (1985). Reflectance is obtained from the bias correction technique of Stumpf (1992). Estimates of suspended sediment concentrations are made using a calibration equation developed specifically for Mississippi River plume waters (Walker and Rouse 1993). Frontal analyses are routinely performed with the assistance of the Sobel filtering method and digitizing software within the Terascan™ image processing package. Further processing of the image data for GULF.MEX is performed on a PC using the OPCPLOT software package (Dr. Murray Brown, personal communication). GIF images are routinely provided (for each frontal analysis posted to GULF.MEX) covering either the LATEX area or the entire Gulf of Mexico. In support of the LATEX cruises or overflights, more detailed information is provided in either GIF image format, as line drawings (faxable), or as color prints and slides. Since January 1992, over 100 frontal analyses have been posted to the GULF.MEX bulletin board in quasi-real time. Interpretations of the frontal analyses are also provided when necessary.

RESULTS

Since the beginning of the LATEX program (October 1991), an unbelievable amount of eddy activity has been observed and documented in the northern Gulf of Mexico (GOM) using satellite data, drifting buoy data, ships observations (Ken Schaudt, personal communication; Doug Biggs, personal communication), and altimeter data (Bob Leben, personal communication). In November 1992, Eddy Triton was observed near 26 N, 90 W, on the western side of the Loop Current. It moved slowly westward, and by early July 1992, there was evidence that Eddy Triton was close to the eastern shelf margin off Texas, as its anticyclonic circulation was actively entraining cooler shelf water in an offshore direction. During the latter part of July, Unchained Eddy separated from the Loop Current which had surged northward into the central GOM in May and June 1992. Due to the high atmospheric water vapor levels during the summer over the Gulf of Mexico, a good view of the Eddy was not obtained until October 1992 when two large warm core eddies (300 km in diameter) were observed in the northwestern and north central GOM. The general conclusion reached from drifting buoy data and ships observations (Doug Biggs, personal communication; George Foristall, personal communication) was that the two eddies had originated from Unchained Eddy. The westernmost Eddy was named Eddy Vasquez (near 26 30' N, 94 W) and the eastern eddy remained Unchained Eddy (near 25 30' N, 90W). If this conclusion is correct, then Eddy Vasquez had displaced Eddy Triton in the northwestern GOM. Perhaps Eddy Triton had moved southward, however, the satellite data was not entirely conclusive in this regard.

The most clearly observed case of eddy separation from the Loop Current occurred in early June 1993 when Eddy Whopper, named for its dimensions (550 X 300 km), was shed from the Loop on 6 June 1993 (Walker *et al.* 1993). On 1 August it had taken on a "dog bone" shape, oriented north-south along 91 30' W longitude (Figure 3D.7). By mid-August, the eddy had separated into two anticyclonic eddies with a distinct cyclonic circulation separating them. The Loop Current surged northward in July, and there is good evidence from satellite data and drifting buoy data that another warm core was shed from the Loop Current during August or September 1993. This eddy was named Xtra Eddy (Ken Schaudt, personal communication). By early December, Xtra Eddy's center was located near 27 N, 91 W.

The presence of Loop eddies in the north-central and northwestern GOM can greatly affect circulation over the continental shelf and slope. Seaward entrainment of cool shelf water, or "squirts," were observed during 1992 and 1993 along the northern margin of Eddy Triton and Eddy Vasquez. During early May 1993, a fairly wide band of shelf water (in excess of 70 km wide) was advected southward along the east side of Eddy Vasquez. By 3 May this squirt was 250 km long (Figure 3D.8). Average velocities, just west of the squirt at the east margin of Eddy Vasquez, were 0.33 m/s over nine days in early May. During November 1993, two squirts were observed in the satellite imagery. One was again observed along the east side of Eddy Vasquez; however, this squirt was only a few kilometers wide. Average velocities associated with this squirt were 0.5 m/s from 17 November to 24 November. Further east, cool Mississippi River and shelf waters were observed moving southward along the eastern margin of Eddy Xtra on 28 November 1993. This cool surface water feature was relatively wide, approximately 100 km at its widest. Between 28 November 1993 and 6 December the cool feature moved 210 km southward, suggesting an average velocity of 0.34 m/s.

The most energetic "squirt" observed during the study period was the Mississippi "jet" of October 1992. In this case, a low pressure system moved northward from the Yucatan. The pressure gradient which resulted between continental high pressure and the low pressure system resulted in very strong and sustained north-northeasterly winds in the Mississippi delta region. Surface wind speeds of 12-14 m/s from 1 to 3 October forced river and coastal waters towards the southwest, producing a narrow near-surface "jet" current which converged over the Mississippi River Canyon, disrupting operations at an Ensearch Corporation platform. Personnel on the platform estimated current speeds at 150-200 cm/sec. Information collected at the LATEX A current meter mooring # 14, located 50 km west of the rig, revealed current speeds of 100 cm/s at 11 meters water depth.

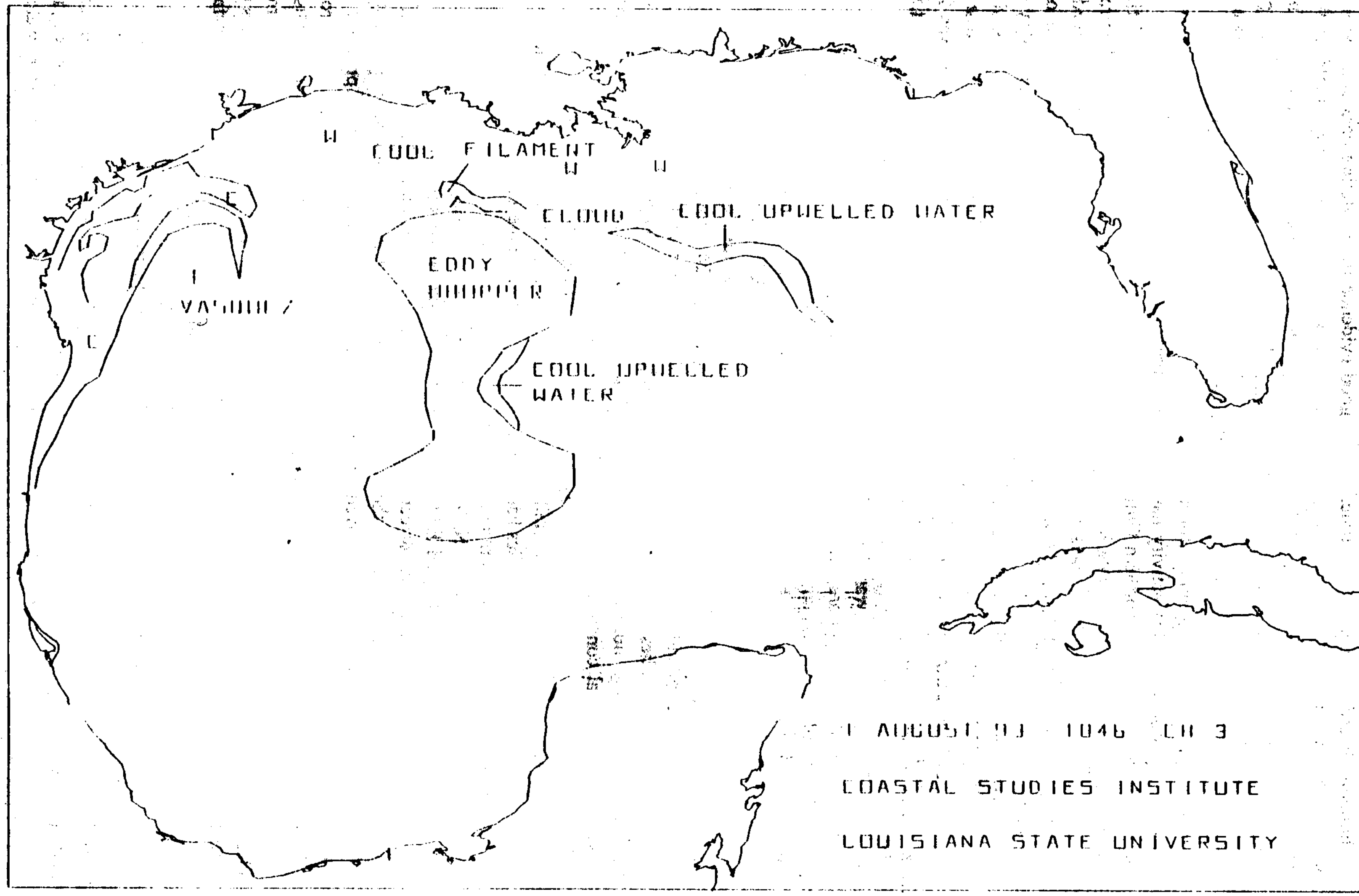

Figure 3D.7. 1 August 1993 frontal analysis (posted to the OMNET bulletin board, GULF.MEX) illustrating Eddy Whopper, before it separated into two separate anticyclonic eddies a few days later.

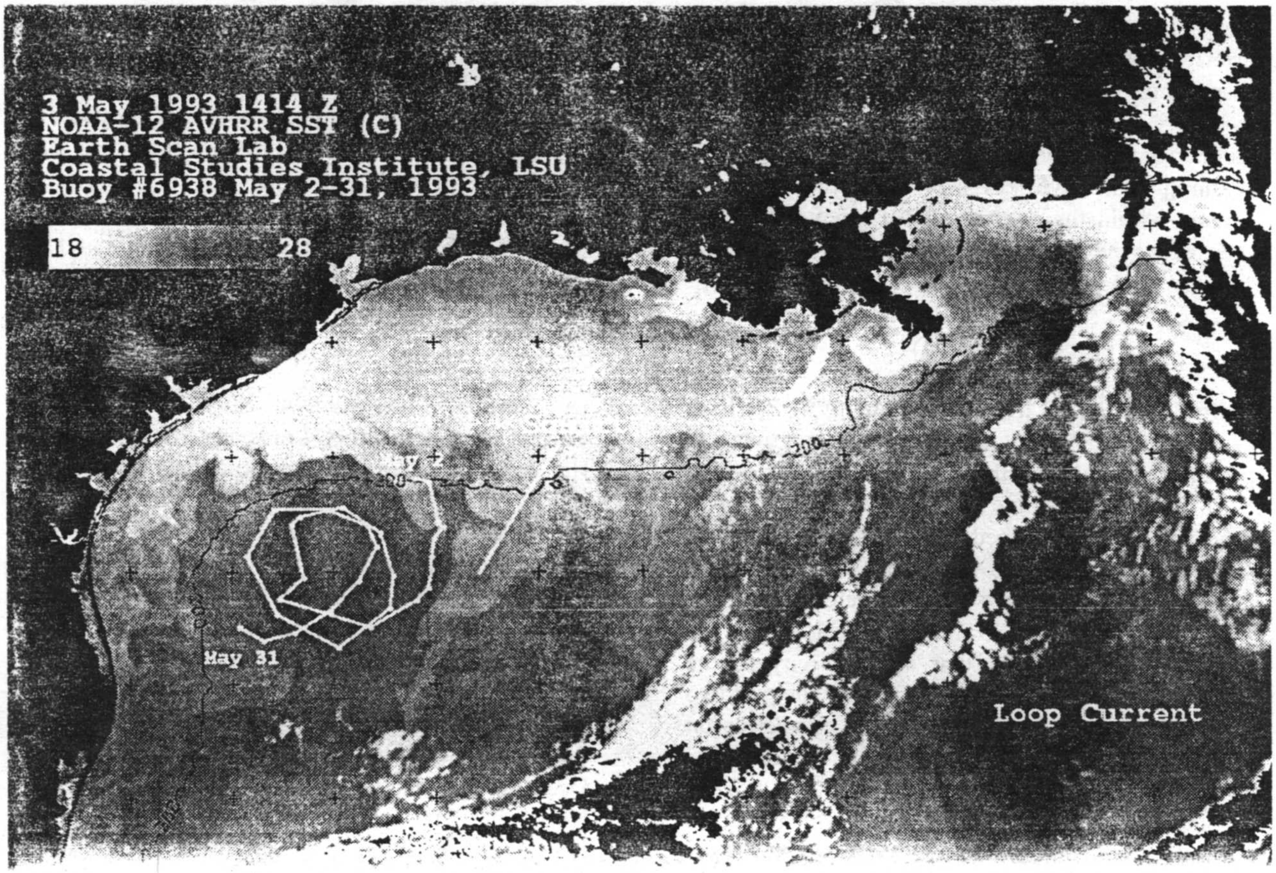

Figure 3D.8. A black and white GIF image of 3 May 1993 NOAA AVHRR SST data which depicts cool shelf water being entrained offshore by the warm core eddy named Vasquez and the daily positions of a drifting buoy from 2 May - 31 May 1993.

The intrusion of cool, low salinity, low density water was well-documented by the mooring data. In addition, the October 1992 LATEX B cruise crossed the northern margin of the cool plume, as it was undergoing buoyant spreading. Their measurements reveal that, even on the outer edges of the plume, temperature, salinity and density were affected to 22 meters water depth. This event is, to our knowledge, the first documented occurrence of high speed, offshore currents generated by wind forcing of Mississippi discharge and coastal waters, which halted drilling activities for several days.

Another interesting circulation event occurred during the 1993 summer. In association with the Great Flood of Summer 1993, river discharge along the Louisiana coast was anomalously high. In addition, the direction of flow of river water on the shelf was unusual. Generally, much of the river discharge moves westward along the Louisiana shelf, driven by the prevailing easterly wind regime. However, persistent eastward flow was observed in satellite imagery from late July through late August 1993. The presence of westerly and southerly winds, as well as the proximity of anticyclonic Loop Current Eddy transport near the Mississippi delta, appear to have been the main driving forces for the eastward transport of river water. Drifting buoy data collected by LATEX A (Texas A&M University) indicate that flow over the continental shelf in the northeastern and eastern GOM from late July through mid-September was conducive to the movement of river water from the delta to the Florida Key region, where low salinity water was reported in August and September (David Forcucci, personal communication; Peter Ortner, personal communication).

Within the Earth Scan Lab's historic data archive, several interesting images of the inner shelf coastal current have been analyzed. Circulation along the coast is highly wind-dependent. However, persistent easterly wind forcing can result in a fairly continuous meandering coastal current from Atchafalaya Bay to at least Matagorda Bay. Comparisons of recent satellite data with the LATEX B ADCP current meter measurements have revealed that the strongest currents within the coastal current often correspond well with the sharpest sea surface temperature gradients along the inner shelf.

SUMMARY

Satellite image data from the NOAA AVHRR have revealed circulation processes on a variety of time and space scales in the northern Gulf of Mexico during 1992 and 1993. Five warm-core Loop Current eddies: Triton, Unchained, Vasquez, Whopper, and Xtra were active in the northern GOM at various times during this period. The research of Vukovich (1988) revealed eddy shedding every 11 months on average, which suggests that eddy activity in the GOM has been greater than normal over the past two years. These warm core eddies affect circulation on the continental shelf and slope in the western and northern GOM. Typically, they entrain shelf water seaward as "squirts," a process which occurs frequently in the northwestern GOM, along the Texas shelf, and in the vicinity of the Mississippi River delta. Current speeds associated with these squirts are on the order of 0.5 - 1.0 m/s. Historic and ongoing acquisitions of satellite data reveal that circulation on the inner shelf is highly dependent on wind speed and direction. The prevailing easterly wind regime along the northern GOM drives a westward flowing coastal current which the satellite imagery sometimes reveals as a continuous meandering stream from Atchafalaya Bay to Matagorda Bay, Texas. Cold front passages can disrupt the normal westward flow of water, particularly in the nearshore region.

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FATE OF CHEMICALS IN THE MISSISSIPPI RIVER PLUME: TRANSPORT AND THREE-PHASE PARTITIONING IN THE SHALLOW COASTAL SHELF OF THE GULF OF MEXICO

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INTRODUCTION

The Minerals Management Service is charged with determining and evaluating environmental impacts of the development and production of oil and gas in the Outer Continental Shelf (OCS) regions of the nation's coasts. Historically, the Gulf of Mexico has been an area of intensive exploration and production of oil and gas and is therefore a region where impacts might be expected to be the greatest if they occur. Impacts of production may result from chronic discharges of drilling muds, surfactants, produced waters and other chemicals used in the production process, or they may result from accidental or catastrophic releases of oil as the consequence of spills, blowouts, fires or breaks in transportation lines.

In order to investigate the potential fate of chemical discharges into Gulf of Mexico waters, a fairly complex set of physical and chemical oceanographic processes must be elucidated and understood. Among these are the bulk transport or advective processes of the water masses themselves. This includes mixing of fresh and saline waters, current direction and velocities, and temperature and salinity gradients and stratification. All of these forcing functions drive the dilution of chemical species in discharges. Along with these bulk-phase physical processes, pollutant chemicals may undergo partitioning processes with suspended particulates (Means *et al.*, 1980) which may have their origins in either allocthonous (riverine) or autochthonous (resuspension/biological production) sources. The partitioning of both metals and organic compounds that occurs in this dynamic hydrologic environment is a function of compound/metal solubility and changes in salinity, temperature and redox potential. Sedimentation of particulates to the sediment bed is the major removal process of chemicals that may be introduced in discharges. Resuspension and bed load transport of materials may also occur in tidally energetic areas or as the result of strong weather events. Photolysis and hydrolysis reactions resulting in the decomposition of the chemical may be important for some chemical classes.

In recent years, a competing partitioning process with colloidal-sized, organic-rich micro-particulates has been recognized as a potential factor in the facilitation of transport processes in aquatic systems (Sigleo and Means 1990). Because these colloidal solids can bind both metals and organic compounds, and because they are relatively stable in the water column, they result in increasing the apparent "dissolved phase" transport of bound substances. The present study represents the first large geographic scale evaluation of the three-phase partitioning model that was developed in the laboratory.

Attempts to study such a complex array of transport processes using the low level chronic discharges from single sources in the Gulf of Mexico have been only partially successful in determining the fate of chemicals. At most, the range of reliable information has extended only a few hundred meters from the discharge source (Rabalais *et al.* 1991). In the present study, the large and relatively intense chemical signatures of the Mississippi River and Atchafalaya River plumes as well as other smaller riverine inputs to the Gulf of Mexico from the Calcasieu, Sabine and Galveston estuaries have been used to investigate transport processes over much greater distances. They may provide the necessary information to develop long-range fate and transport models for the Gulf of Mexico that MMS can use in fulfilling their mandate to assess real and potential environmental impacts of chronic and catastrophic chemical releases during oil and gas production.

STUDY OBJECTIVES

The objectives of Pollutant Chemistry/Pollutant Transport Modelling Subtask are

1. To make pollutant chemical measurements on samples collected on the hydrographic cruises whose geographic focus is the Mississippi-Atchafalaya plume (M-A plume), referred to as the Louisiana/Texas Coastal Current, from the Mississippi River to the south Texas coast, with special attention given to the area from the Atchafalaya River to the north Texas coast. The

pollutant samples for measurements were acquired at 34 selected stations and two depths.

2. To use these measurements to characterize the pollutant plume in the study area.

3. To trace the movement and mixing of pollutants in particular water masses within the plume in conjunction with the data from the other parts of the study, particularly the remote sensing and current data.

4. To assist in the interpretation of the importance of changes in water mass characteristics within the plume and offshore to pollutant and sediment transport.

5. To use phytoplankton and zooplankton systematics to determine source of the organic material controlling colloidal phase biogeochemistry.

6. To identify and trace specific chemical pollutants as they enter into and mix and advect through the plume.

Based on our knowledge of the hydrography of the LATEX shelf, we designed and undertook a hydrographic sampling plan to meet the above objectives. We have begun to characterize—chemically, physically, and biologically—the hydrographic conditions of the plume and to determine the pollutants present and their speciation between the dissolved, colloidal and particulate phases in the plume. In addition, we collected and analyzed 52 sediment samples from coastal areas adjacent to estuaries between the mouth of the Mississippi River and the Galveston Bay estuary. The goal of sediment analyses was to characterize the scope of pollutants being deposited in surficial sediments in the coastal current region.

During each cruise, a total of 68 samples of plume water were collected for pollutant analysis. These samples were fractionated on board the ship using filtration and ultrafiltration techniques into a total of 408 dissolved, colloidal or particulate samples. In addition, 2L dissolved fraction water samples were extracted for organic pollutant analysis on the ship using solid phase extraction (SPE) techniques. This approach to the sampling of the plume had several advantages:

1. The time between sampling and extraction was minimized to prevent degradation and changes in phase distribution of the pollutants.

2. Contamination of the samples was minimized.

3. Storage of large volumes of water on the ship was eliminated. Typically, a twenty liter water sample could be reduced to the following in three-five hours:

   a. A set of 0.4 μm filters containing the particulate sample fraction, stored in a small glass jar at -20°C.
   b. A liquid sample of 100X enriched colloidal fraction, stored in a 250 mL bottle at 5°C.
   c. A liquid sample of ultrafiltrate, acidified to pH <2 and stored in a 250 mL glass bottle at 5°C.
   d. An SPE extraction disc, stored in a 30 mL glass ampule at -20°C.

4. Transportation of large volumes of water back to the laboratory was thus eliminated.

5. Preparation for analysis was largely accomplished in the field, thus saving time in the laboratory on shore and reducing the time between sampling and analysis.

Sample collection and processing on the ship went flawlessly, and all samples were obtained without any losses.

Chemical analysis in the laboratory utilized multi-elemental inorganic analysis by Inductively Coupled Plasma/ Mass Spectrometry and multi-component organic analysis using selected ion monitoring gas chromatography/mass spectrometry techniques. The elements measured include: As, Al, Au,Ba,Be, Bi, B, Ca, Cd, Cu, Cr, Co, Ce, Fe,Hg, Ir, K, Li, Mg, Mn, Mo, Na, Ni, Os, P, Pd, Pb, Pt , Ra, Sb, Se, Si, Sn, Sr, Th, Tl, Ti, U, V, Zn. The organics included 59 (51 resolved by GC) aromatic hydrocarbons, PCBs in six chlorination groups, 19 selected chlorinated pesticides and six selected herbicides.

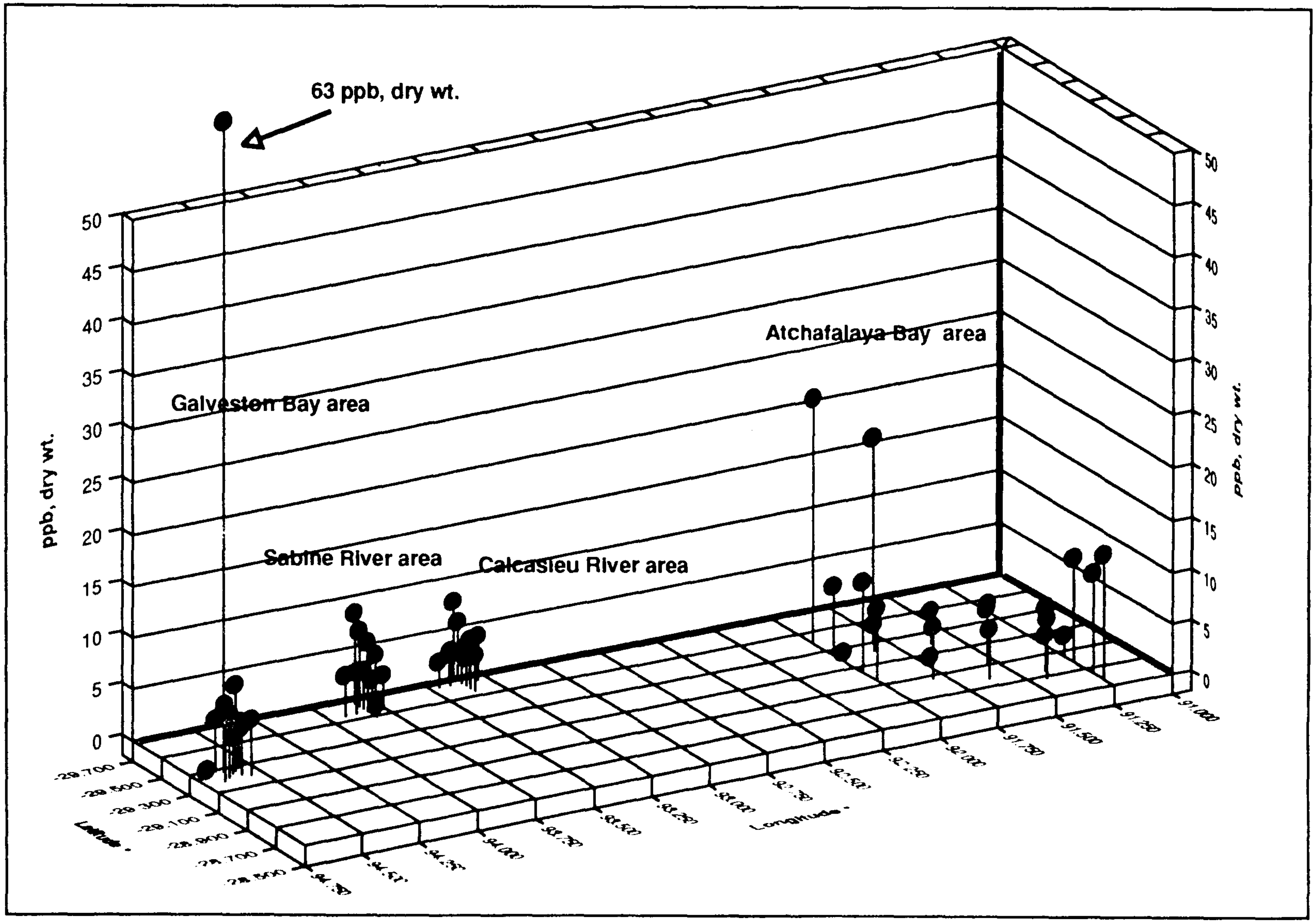

Figure 3D.9. Distribution of C2-alkyl phenanthrenes in sediments.

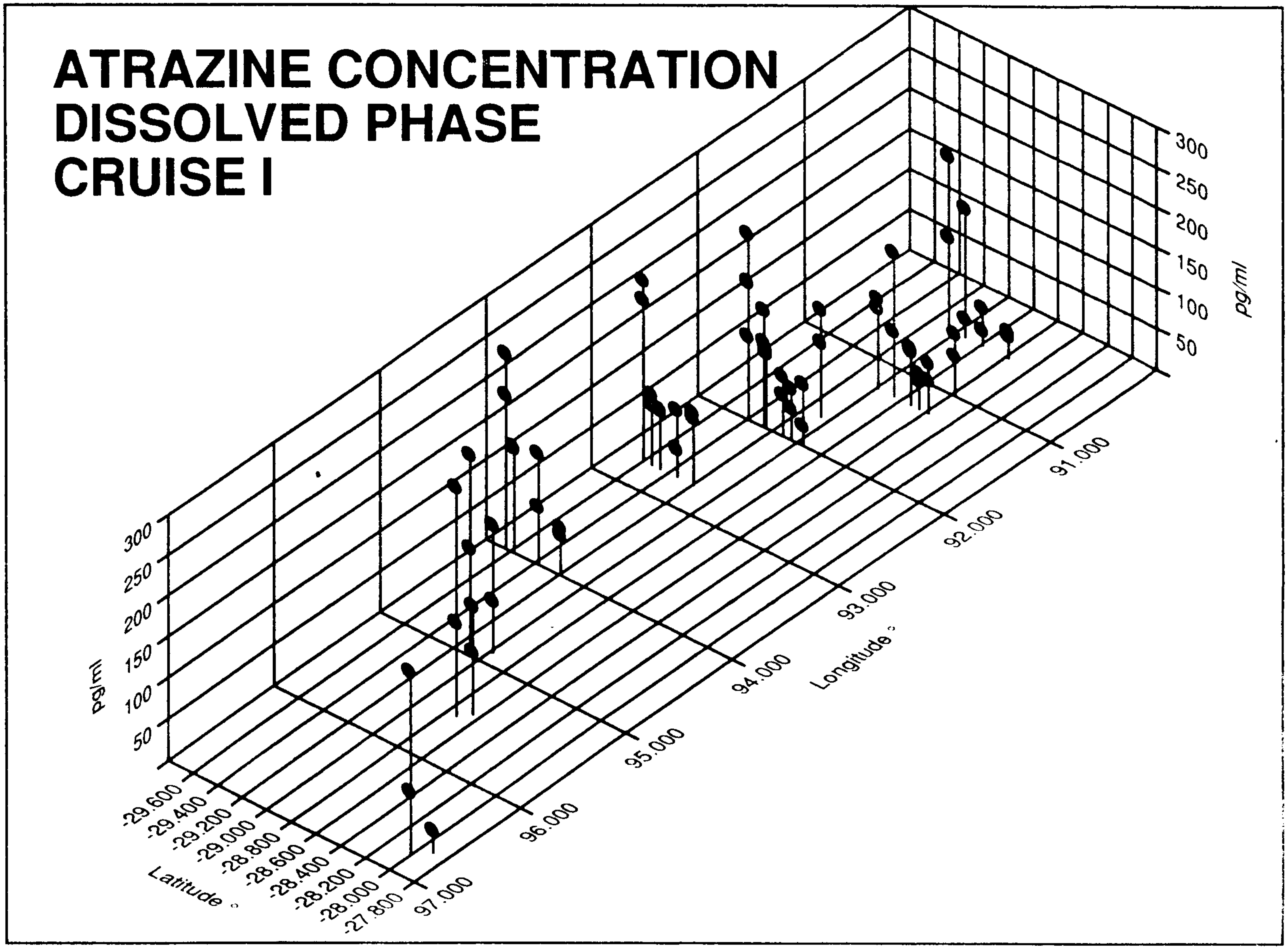

Figure 3D.10. Spatial distribution of atrazine concentrations along the LATEX shelf.

RESULTS

The results of the sediment surveillance at the mouth of each river system showed that several classes of organic compounds were present in the sediment record. The spatial trends observed in the sediment data for most components yielded highest concentrations in sediments collected at stations closest to shore; declining concentrations were observed moving offshore. Figure 3D.9 shows the distribution of C2-alkyl phenanthrenes in sediments. This pattern was typical of aromatic hydrocarbons in these sediments. One station near the Houston Ship Channel contained very high levels of almost all the organics compounds quantified. This may be due to dredge spoil disposal at this site. Among the classes of chemicals measured, the triazine herbicides were absent from all sediments. Elemental analysis of these sediments yielded detectable amounts of all elements assayed. While similar trends to those observed for organics were seen, differences in grain size and texture resulted in less clear spatial patterns.

Analysis of the 408 samples collected during the first two cruises yielded some interesting spatial distributions along the coastal shelf of Louisiana and Texas (LATEX). All of the chemical classes of organic compounds except herbicides and PCBs were detected in all three phases at one or more stations. Herbicides were detected only in the dissolved and colloidal phases but were absent from the particulate phases. Figure 3D.10 shows the spatial distribution of atrazine concentrations along the LATEX shelf. Distributions show that each estuary contributed atrazine to the total herbicide loading on the shelf. Somewhat surprising was the observation that the dissolved and colloidal phases contributed significantly to the overall transport of organic contaminants along the shelf. Elemental analyses of the samples revealed detectable amounts of all elements in all three phases analyzed. In contrast to the organic data, the particulate phases were much more important for the transport of most elements relative to the dissolved and colloidal phases.

A box model of contaminant transport along the LATEX shelf is being developed employing current data and concentrations data. Sedimentation rates will be derived from data obtained from sediment trap analyses. The model is still in early stages of development.

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Dr. Jay C. Means, Professor of Environmental Chemistry and Aquatic Toxicology at Louisiana State University (LSU) School of Veterinary Medicine, is recognized nationally for his work on the fate and transport of hydrocarbons and other hydrophobic contaminants such as polychlorinated biphenols and chlorinated hydrocarbons in aquatic environments, including estuarine and coastal marine systems. His laboratory group pioneered the research on the predictive modelling of sorption/desorption processes on sediments and also on estuarine colloids. He was the principal investigator responsible for pollutant chemistry and bioavailability of a Cooperative Agreement entitled "Fates and Effects of Nearshore Discharges of OCS Produced Formation Waters", as well as principal investigator of two other projects related to impacts of produced waters in coastal Louisiana. He is also co-principal investigator of a three-year grant under the Minerals Management Service University Research program entitled Biochemical Indicators and Genotoxicity of Produced Waters.

REVIEW OF LATEX B HYDROGRAPHY DURING 1992 AND 1993

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Evans-Hamilton, Inc.

INTRODUCTION

In this review I will discuss the hydrography observed during the first four cruises of the LATEX B program. Table 3D.1 lists the dates of these cruises, as well as those of the last two cruises to be conducted during 1994. The six cruises consist of three during April, two during July, and one during October. To address the seasonal variation of the hydrography, I will describe in order of months the four cruises conducted so far, i.e., Cruises P921 and P931 conducted during April, followed by Cruise P932 during July, and Cruise P922 during October.

These cruises consist of a grid of stations repeated during each cruise as well as intensive surveys of particular oceanographic phenomena: plumes from coastal embayments; fronts between water masses; convergence of coastal waters; and surveys off the south Texas coast. In the brief time allotted for this review, I will discuss the patterns evident from the repeated surveys and describe recent surveys of plumes from Calcasieu Lake and Galveston Bay and a convergence off Galveston Bay. To conclude, I will relate some observations made in July 1993 to the great Mississippi River flood.

Table 3D.1. The six cruises of LATEX B.

Cruise Number	Dates
P921	22 April-1 May 1992
P922	5-15 October 1992
P931	13-22 April 1993
P932	13-22 July 1993
P941	13-22 April 1994
P942	11-20 July 1994

REGIONAL PATTERNS

To gain an overview, the regional patterns of the four surveys thus far conducted are described using MIDAS salinity measurements at 1-2 meters depth. During the two April surveys the Mississippi plume could be traced westward to approximately Galveston Bay. In the vicinity of Galveston Bay a sharp transition was noted between the coastal plume flowing westward and south Texas waters flowing to the northeast. The transition between these two water masses was particularly dramatic during April 1993. The plume was evident as a highly baroclinic flow, whereas waters southwestward of Galveston Bay consisted of two well-mixed layers separated by strong current shear. The upper and lower layers were separated by 3.5 sigma-t units and the currents abruptly shifted from north to south near a depth of 12 meters.

During July 1993 the convergence shifted to the east of Galveston Bay and a survey was conducted. Water discharged from Galveston Bay entered this convergence, effectively serving as a tracer. During the October 1992 cruise the coastal plume could be traced westward to the coast between Sabine Lake and Galveston Bay. Apparently, the convergence lay off Galveston Bay at this time. In summary, the four cruises conducted during 1992 and 1993 suggest a transition between water masses in the vicinity of Galveston Bay having relatively short length scales.

PLUME SURVEYS

During the first two years of the LATEX B program, plumes of water discharged from Calcasieu Lake and Galveston Bay were surveyed. The Calcasieu Lake plume was surveyed during October 1992 and the Galveston Bay plume during July 1993 as part of cruises P922 and P932, respectively. Because the results are quite different for each plume, they are discussed separately.

The Calcasieu Lake plume was mapped on 10 October 1992 using a CTD profiler and MIDAS. Contours of the MIDAS data revealed a plume, evident as lower temperature and more turbid water. The contours showed the plume extending approximately five miles offshore and approximately fifteen miles along shore. Within the plume temperatures were depressed by approximately 0.5°C, and light transmission was depressed by 25 percent compared with water in the coastal plume.

The southern or offshore edge of the Calcasieu plume was marked by a sharp density gradient. Centered on this gradient was a core of westward flowing water with speeds of 15 centimeters per second, whereas speeds within the plume were directed eastward, and speeds south of the core were also directed eastward.

The Galveston plume was surveyed during 19-20 July 1993. During the survey three water masses were evident in maps prepared from MIDAS salinity data. The first water mass was a nearshore plume of relatively fresh water. The Galveston plume generally lay offshore of this nearshore plume and inshore of more saline waters. In general it appears as though the plume was moving offshore and sandwiched between two other water masses. The MIDAS data showed that the Galveston plume could be traced at least 20 nautical miles southeastward from the mouth of Galveston Bay.

CONVERGENCE

Fortuitously, a convergence occurred at the time and location of the Galveston plume survey. Two satellite tracked drifters showed the convergence occurring between Sabine Lake and Galveston Bay during Cruise P932 (drifters 6937 and 6935 illustrated in the LATEX newsletter covering 21 June-4 July 1993). Apparently, as Galveston Bay water moved to the southeast it was entrained in the convergence. This convergence may be investigated using as tracers Galveston Bay water, as well as drifting buoys.

MISSISSIPPI RIVER FLOODING

The cruise conducted during July 1993 is particularly interesting because it occurred when Mississippi River flood waters were accumulating over the continental shelf. As we were completing our survey on 21 July we received a radio report from a vessel transporting scuba divers offshore. The vessel's captain was unable to locate clear water suitable for tourist scuba diving. The captain mentioned that "dirty" water was found a hundred miles offshore. Apparently, flood water from the Mississippi River was located quite far offshore. As we headed to LUMCON, we kept a sharp eye out for visual discontinuities at the sea surface. At 91°40.59'W, 28°48.32'N we made a CTD cast and measured a surface salinity of 10 percent. When we had sampled this location a week earlier, a salinity of approximately 24 percent was measured. At this location some 40 miles offshore, the flood waters had lowered the surface salinities by half.

Dr. Ebbesmeyer has 27 years of experience investigating physical oceanography of estuarine, coastal, and oceanic phenomena; for the past 20 years he has worked at Evans-Hamilton, Inc. in Seattle. He has been appointed by the governor of Washington to serve on two panels guiding oceanographic investigations of Pacific Northwest marine waters. Dr. Ebbesmeyer received his B.S. in mechanical engineering from California State University in 1965, and M.S. and Ph.D. degrees in physical oceanography from the University of Washington in 1968 and 1973, respectively.

SESSION 4A

DEEPWATER DEVELOPMENT ISSUES

Session: DEEPWATER DEVELOPMENT ISSUES

Co-Chairs: Mr. Doug McIntosh and Ms. Connie Landry

Date: December 16, 1993

Presentation	Author/Affiliation
Deepwater Development Issues	Mr. Doug McIntosh Ms. Connie Landry Minerals Management Service Gulf of Mexico OCS Region
Document not submitted	Mr. Tom Bourgeois Shell
The DeepStar Project: An Overview	Mr. Alan Verret Texaco
DeepStar Riser Studies	Mr. Chuck Alexander Mobil
Deepwater Economics	Mr. Curtis Burton Texaco
DeepStar: What's Next?	Mr. Curtis Burton Texaco

DEEPWATER DEVELOPMENT ISSUES

Mr. Doug McIntosh
Ms. Connie Landry
Minerals Management Service
Gulf of Mexico OCS Region

Deepwater Gulf of Mexico development involves high costs and long lead times. The financial risks are compounded even further by market price fluctuations such as we are experiencing now. The recent decline in oil prices will certainly pose additional challenges to Gulf of Mexico deepwater development; some projects now on the drawing board will either be delayed or scrapped.

The water depth zone is the focus of this session of the ITM. It is that area that cannot be developed with conventional fixed platforms. Two different types of deepwater development options will be discussed during this session.

Tom Bourgeois, with Shell,discussed their Auger TLP development in 2,860 feet of water in Garden Banks Block 426. This $1.3 billion dollar project is their largest and most complex offshore facility to date.

The next four presentations focused on the DeepStar program. The purpose of DeepStar is to establish a cooperative industry-wide effort to develop options for deepwater drilling and development. The aim of the project is to evaluate innovative systems, identify technological needs, and promote the evolution of a conceptual cooperative deepwater strategy which will provide for the economic development of the large number of deepwater fields that do not have sufficient reserves to justify individual development by current methods.

The MMS has established a Deep Water Production Group which is evaluating the need for change in MMS's current operating regulations based on the environmental differences of the deepwater arena. In that regard, MMS is working closely with the DeepStar group since many recommendations for regulatory change coming out of the DeepStar work focus on the same general areas that MMS has highlighted for analysis.

Alan Verret with Texaco presented an overview of the DeepStar Research project which is a joint research effort involving 16 oil companies, approximately 40 vendors of oil industry sources and equipment and the MMS.

Chuck Alexander with Mobil discussed deepwater risers. Mr. Curtis Burton with Texaco discussed deepwater economic considerations and told us what's next for the DeepStar program.

Mr. Doug McIntosh is the Chief of the Technical Assessment and Operations Support Section of Field Operations in the Minerals Management Service, Gulf of Mexico OCS Regional Office. He received his B.S. in Petroleum Engineering from Louisiana State University in 1966. Prior to his employment with the U.S. Geological Survey in 1970, he worked in the oil and gas industry. His work within the USGS/MMS includes reservoir engineering and tract evaluation, activities, District Drilling Engineer in the New Orleans District, Chief of the Pipeline Section, and Supervisor of the Regulations Section prior to his present assignment.

Ms. Connie Landry is an Environmental Studies Program Specialist and has been with the Environmental Studies Section since 1985, working with the logistics of the Information Transfer Meetings each year. She served as Contracting Officer's Technical Representative for the ITM contract 1989-1991. Connie worked as an Administrative Assistant in the U.S. Geological Survey before the formation of MMS. Connie attended University of Southwestern Louisiana and Northeastern Louisiana State University.

THE DEEPSTAR PROJECT:AN OVERVIEW

Mr. Alan Verret
Texaco

The deepwaters of the U.S. Gulf of Mexico represent one of the best remaining domestic opportunities accessible to the industry and are believed to contain significant reserves of producible hydrocarbons.

Production strategy and equipment to produce these reserves are being developed by the Texaco-led DeepStar Project.

The participating companies presently include nine major oil companies and Texaco Inc. Rapid progress is being made toward the common goal of having an economic deepwater production strategy and equipment ready for field use by 1996. This project brings together the industry's leading experts in a common multi-disciplinary forum to address technical issues that are barriers to economically viable deepwater production. The project has also established a working relationship with the Minerals Management Service to resolve potential regulatory issues which impact the design, implementation, and operation of future deepwater production systems.

The project identified phased subsea production systems operating as extensions of shallow water platforms as a key potential mechanism for commercial development of deepwater prospects. A small number of shallow water platforms (600-800 feet water depths) tied to subsea production systems offset up to 60 miles into deepwater is capable of developing a high percentage of deepwater GOM leases. Since there is limited production experience to date from deepwater finds, incremental production/development is seen as a key to controlling risk and minimizing capital exposure. Field delineation wells will be completed and produced rather than abandoned following exploration. The production experience from these initial wells will allow subsequent full field development to be optimized. Modular equipment, used in this initial production program, will integrate into any subsequent field development, utilizing all assets placed into service. This strategy should give world-class economic returns for deepwater domestic production opportunities.

The technology goals for DeepStar include production in 6,000 foot water depths; production of a broad range and rate of crude oils from various reservoirs; subsea satellite production to host platforms up to 60 miles distant (platform depths to 800 feet); minimum maintenance requirements; remote operated vehicle service; and all production operations remotely controlled from the host platform. Achievement of these technical goals will make this exciting deepwater frontier area accessible for development in an environmentally safe, and economic manner.

The DeepStar Project was initially funded wholly by Texaco, its Eastern Operating Region, and its international affiliates. Initial work on the project was completed within Texaco's Central Offshore Engineering Group with contracted work being completed by Intec Engineering.

Texaco is pleased to host this meeting of the DeepStar participants. Our vision for development of the deepwater Gulf is closely tied to the concept of cooperation and evolution of a synergistic relationship with other members of the oil community. In today's competitive business environment development of the deepwater Gulf will be difficult, if not impossible, outside a jointly funded, cooperative effort. This partnering may take many forms -- it can include joint exploration (something already common in the Gulf) and joint research (JIP's), but it can also be expanded to areas in which we do not now normally cooperate -- joint research into basic engineering problems, joint development of hardware, software, and other new tools, joint ownership of central processing facilities, production sharing operations, and other innovative concepts.

The challenges offered by the deepwater Gulf are considerable -- both commercially and technically. One of the ways we must adapt to deepwater is through a change in the way we do our business -- working smarter, harder, leaner, and with less risk. One way to accomplish all these objectives is by staged development, feeling our way into deepwater, identifying boundary conditions, carefully proceeding with development only after evaluations of potential risk and return are quantified by production test and knowledge. Staged production using subsea techniques allows us to control risk and allows us to avoid major financial commitment until production capability has been proven. Our enthusiasm for DeepStar is that it may provide the entire community with a way to commercially access deepwater.

We, at Texaco, are entering into our second year of DeepStar-sponsored work. We believe it to be the best tool available to industry to address the myriad of drilling, completion, strategic, regulatory, and hardware challenges confronting us in deepwater.

Mr. Allen Verret is a 1970 graduate of the University of Southwestern Louisiana with a B.S. in civil engineering. He began his career with Texaco in Morgan City, Louisiana in 1970 and held positions of increasing responsibility within the division until his transfer to New Orleans operations. He has recently been promoted to Engineering Advisor in the New Orleans office and has been Texaco's operations representative on the DeepStar project during Phase I & II of the program.

DEEPSTAR RISER STUDIES

Mr. Chuck Alexander
Mobil

The DeepStar Project was initiated to determine the most cost-effective methods of developing deepwater Gulf of Mexico fields using subsea technology. The original DeepStar scenario consisted of either a light crude (Jolliet) or a heavy crude (Hercules) which needed to flow via a two-phase pipeline a distance of 40 to 60 miles back to a shallow water facility. The case of the heavy crude was problematic. The companies in DeepStar did not have full confidence that existing technology could be used to flow this crude back to a shallow water facility without primary separation. Hence, as a backup position, DeepStar chose to develop a preliminary cost estimate for an overhead floating production system and its attendant system of risers.

The DeepStar Phase II program included work to flesh out the floating production systems which had been only sketchily analyzed to generate system costs in Phase I. Key to this effort were both riser and mooring system studies. A preliminary meeting to generate the scope of work for DeepStar Phase II was held in February 1993. This meeting initiated the definition of the problem to be solved. A system of risers to accommodate the flow of production, export and well maintenance streams emanating from/to a subsea manifold was required. Environmental criteria for a suitable Gulf of Mexico location needed to be established. Water depths to be investigated included 3,000 feet, 4,500 feet, and 6,000 feet. Several candidate riser systems were identified and efforts were initiated to contact their developers to determine interest in sizing the risers for the DeepStar scenario. The minimum base case production option, potentially ranging from 25,000 to 50,000 BOPD needed to be chosen. At this time Texaco sought volunteers for the chairmanship of the riser committee.

Mobil agreed to chair the Riser Committee (CTR 400) and offered a riser system for consideration. The other participants were also invited to propose riser designs. Over the course of the summer, the riser committee carried out preliminary review and screening of all candidate riser systems. Several systems were to be studied by their vendor proponents.

In particular Coflexip, as part of their DeepStar contribution, agreed to perform a scope of work which sought to determine the applicability of flexible risers for the DeepStar production rates, water depths and environment. That work remains ongoing with completion is anticipated in early 1994.

Wellstream, another vendor of flexible risers also volunteered to contribute analyses of risers suitable for the DeepStar scenario. As an added twist, Wellstream teamed up with a manufacturer of composite materials with the intent to develop lighter weight designs anticipated as necessary for the greater water depths. Southwest Research, another contributor to the program, is providing oversight and audit functions for the Wellstream composite material testing program. This effort is presently ongoing.

A third vendor contribution was offered by Cooper industries, who have agreed in principle to develop the Placid Green Canyon Block 29 rigid riser concept to accommodate the DeepStar scenario. This consists of a rigid riser, supported by syntactic foam and steel buoyancy cans. The top of the riser, located 150 feet beneath the surface, is tethered to the semisubmersible above. Flexible jumper lines run between the individual riser pipes, which are placed in slots of the structural riser. This effort is presently ongoing.

As another effort to come up with a workable riser solution, the committee sought to investigate alternative hybrid riser concepts. This involved an open presentation and review of any riser concept deemed worthy of presentation to the committee. Eight candidates were considered for review. A screening process was carried out to reduce the alternatives under consideration. Riser concepts which did not readily fit the DeepStar production scenario were eliminated. The committee selected three systems for further study. These were the Tension Leg Riser (TLR), the Single Leg Hybrid Riser

(SLHR) and the Steel Catenary Riser (SCR) such as being used for Shell's Auger TLP.

The TLR consists of nine steel catenary risers running from the sea surface to a buoy submerged 500 feet below the surface. This buoy is tethered on four corners by steel cables. Flexible jumpers run from the buoy to the semisubmersible. The components of this concept are being fleshed out in an ongoing study contracted to Aker/Omega.

The SLHR concept involves individual rigid steel risers for each production string. The steel buoyancy can supporting the riser is also located 500 feet beneath the surface. A flexible jumper connected to the riser beneath the buoy provides the flow path back to the semisubmersible. For one alternative under consideration, the steel risers have been fitted with buoyancy material to achieve 90 percent buoyancy. The components of this concept are being developed as part of a joint TLR/SLHR conceptual studied carried out by Aker/Omega.

Prior to awarding conceptual design work to Aker Omega, Mobil performed basic riser sizing using their own Excel spreadsheet program. This basic sizing software accommodates features such as static modeling of the offset of the structure due to current loads, sizing the riser with respect to collapse requirements, and sizing a stress joint required at the bottom of a riser fixed like a cantilever at the sea bed. Following completion of the conceptual work, a preliminary riser analysis scope of work will be performed to validate both the concepts and the existing riser sizing spreadsheets. Phase II analysis efforts are expected to be completed by early March. Upon completion of the conceptual design studies, the DeepStar Riser Team will identify and carry out further conceptual work.

A scope of work is also being developed for the SCR concept. The SCR is thought to be fatigue sensitive for the water depths of interest when attached to a heaving, floating production vessel. Our analysis effort will seek to determine the fatigue life of the steel catenary riser and make design modifications including material substitution if necessary to develop a workable rigid catenary riser system.

Mr. Chuck Alexander earned his B.S. in Mechanical Engineering at Purdue University, and his M.S. in Underwater Physics at the Naval Postgraduate School, Monterey. Chuck spent several years as a Naval Officer, and served as Executive Officer, Chief Engineer, Diving Officer and Navigator on ships in the Western Pacific.

In 1974, Chuck joined Santa Fe Engineering and Construction Co., and from 1975-1980, Chuck worked in London and Aberdeen as a project engineer for the development of the Thistle Field in the North Sea, working on tanker loading systems, pipelines and platform installation. He joined Mobil in 1980, and served as Engineering Manager for the North Sea Beryl-B Tanker Loading Platform. In 1981, Chuck returned to Dallas to join the Subsea/Marine Section of Mobil's Dallas E&P Engineering (DEPE).

Chuck has worked in both the Subsea and Marine Groups at DEPE, and served on the Hibernia Project Task Force in 1984-85 as Lead Subsea Facilities Engineer. In 1990, he became the DEPE Marine Group Leader. He is the Chairman of the Production Riser Committee for DeepStar.

DEEPWATER ECONOMICS

Mr. Curtis Burton
Texaco

Although many unknowns are associated with the deepwater environment, there exists one known element:the deepwater Gulf of Mexico will only be developed if it is commercially viable. Operators in the '90s are more cost conscious and internationally focused than they have been at any point during the history of oil production. Accordingly, for a deepwater development to move forward, it must be cost and return competitive with other opportunities available on a worldwide basis.

Historically, economic viability for an offshore project has been driven largely by the size of the recoverable reserves. The larger the projected reserves, the more likely the prospect was of being commercial. In many shallow water examples, this is still true in the vast majority of cases. However, in deepwater, economic viability is a more complex issue. In part this is due to the higher cost of facilities for water depths over 2,000 feet. In part it is due to the cost of well intervention following initial capital development. For example, in relatively shallow water, say 500-600 feet, the industry has extensive experience building and operating platforms in the Gulf of Mexico. The capital and operating costs, risks, and rewards are generally well defined and contain few unknowns or unpredictable elements. In deepwater, 2,000-6,000 feet, industry has much more limited experience and far less confidence that costs, risks, and rewards, are as well defined. When capital development costs in deepwater can easily exceed a billion dollars for a large project, the margin for error is extremely small. Because of this, as we have moved forward on the DeepStar Project, we have been very interested in those factors that will improve the commercial viability of a given prospect. This paper briefly reviews four of these variables.

RESERVES

As with shallow water prospects, reserve size is important. The evaluations completed to date, however, show that simple size alone is not adequate to ensure a prospect of commercially viability. It is a question of quality as well as quantity. Put another way, a 100 million barrel reservoir with characteristics requiring few drainage points, potentially a superior candidate to a 200 million barrel deposit with features such as isolated production zones, multiple stacked pays, and problematic produced fluids.

RATE

Deepwater will, without question, require higher production rates from individual wells than have typically been seen in the shallow water Gulf. Sustained initial rates are the second most important factor in realizing economic viability for a deepwater prospect. Acceptable minimums will vary on a case by case basis, but it is difficulty to identify many opportunities in water depths beyond 32,000 feet where initial well rates would not be measured in thousands of barrels per day.

WELL COUNT

Well count, more than any other factor, will control the viability of deepwater. This is the case because will count substantially controls the capital cost of a deepwater project. In most deepwater projects, anywhere from 40-70 percent of the total project cost is committed to drilling and completion of wells. It is this factor that makes the statements on reserve size and quality true.

RECOVERABLES PER WELLBORE

Another way of talking about well count is to talk in terms of recoverables per wellbore. Our studies to date indicate that minimum recoverables per wellbore must exceed two million barrels per wellbore to give a prospect any significant chance of being commercial in deepwater.

Each operator will have different definitions of what is and is not commercial in any given development opportunity. For this reason, it is important to focus, not on the absolute numbers discussed in this material, but on the trends it identifies.

Mr. Curtis D. Burton is a Senior Staff Engineer with Texaco's Central Offshore Engineering Department and is the Project Manager (PM) of the DeepStar Project. As the PM, he is responsible for all administrative and technical liaison activities between the operators, government agencies, and vendor representatives who are involved with DeepStar. He has worked in the subsea arena for over 15 years. These projects have included BP's Buchanan, Occidental's Claymore Field, Texaco's Highlander, Sun Oil's Balmoral, Saga's Snorre, Petrobras' Marlin/Albacora, and numerous Gulf of Mexico projects. He is a graduate of the University of Texas.

DEEPSTAR:WHAT'S NEXT?

Mr. Curtis Burton
Texaco

For the past two years the oil industry has been involved in a unique experiment called DeepStar. It is unique because it has offered a new approach to technology development, encouraged cooperative dialogue between operators/vendors/service companies/regulators, and has attacked the issues raised by deepwater through an integrated systems approach. The DeepStar Project has existed from its inception as a multi-year effort. Initial plans called for a five-year program with years one and two focusing primarily on paper study issues. Current plans are for a third year of activity to be launched in mid-1994 and for results from the 1992 and 1993 phases to be used as foundation studies for ongoing development work.

The cooperative efforts at work in DeepStar have generated a number of major issues for follow-on programs. Although final details have not yet been agreed, it is probable that the 1994 program will contain some or all of the following elements:

DRILLING

Drilling-related costs for deepwater developments continue to be an issue attracting industry attention. DeepStar's coming program will maintain a focus on ways to lower drilling/completion costs for deepwater operators through dialogue with drilling contractors, equipment suppliers, and specialist contractors. Cost reduction goals of 10-15 percent are targeted for deepwater drilling costs. One potential area of work is in composite drilling riser technology. This offers the promise of a low weight, high strength riser that could positively impact many aspects of DeepStar.

PRODUCED FLUIDS ISSUES

Produced fluids issues such as paraffin, hydrates, and solids production have been identified as some of the more challenging and potentially difficult ones confronting the potential deepwater producer. The committee currently charged with this topic within DeepStar is working to identify a preferred course of action to mobilize industry resources along common lines. Plans are being laid for a discussion forum in 1994 to offer operators, universities, and service companies an opportunity to meet and discuss critical issues. DeepStar's 1994 budget is currently projected to be heavily focused on this key issue.

SUBSEA COMPONENTS (TREES,CONTROLS, MANIFOLDS, INTERCONNECTIONS)

Work will continue in this key arena in an attempt to identify and standardize those subsea components which can lower system costs and provide manufacturers an opportunity to provide a wide variety of "off-the-shelf" items to the subsea industry. Key development work remains to be done on a limited number of subsea components.

PIPELINES/FLOWLINES

This past year's work spent heavily in this area. Next year promises to be an active time for this topic as well, although probably lower funding levels will be allocated here than is currently the case. Primary work will focus on pipeline/flowline installation, repair, and maintenance. It is probable that further work will be pursued on tooling developed during the current program.

MULTIPHASE FLOW ISSUES

Long distance, multiphase flow in very deep water continues to be a priority item on the DeepStar agenda. Discussions are underway to test a number of subsea components in this area next year. Dialogue is ongoing as well on hydrate prediction, control, and elimination. Our goal is to develop, over the coming two years, commercially viable means to extend our current deepwater reach capabilities by 25 percent. Hydrate issues will be a focus activity for this committee.

DEEPWATER RISERS

Much work will have been accomplished by the deepwater riser group by the close of Phase II. It is our expectation that screening studies will be complete and the industry will be poised to explore in design detail promising new riser concepts during the Phase III program. New materials may also be considered as optimizations of the risers.

REGULATORY ISSUES

Our dialogue with the MMS to date has been very positive. It has provided both the operators and the MMS a forum in which to meet and discuss in depth regulations requiring review. Regulations will have as great an impact on the viability of deepwater as any of the hardware components currently in work. It is important that the industry's dialogue with the regulatory community be continued so that issues can be addressed in advance of actual applications in deepwater.

OTHER INTEREST AREAS

Some of the upcoming work will be guided by the interests and needs of the community at large. Currently, a number of potential focus areas have been mentioned as possible targets. These include remote vehicles, industry forums on special interest topics, instrumentation technologies, expansion of the program to include smaller JIP's, prototype field developments.

Our primary plans are to continue to evolve DeepStar so that it can meet the industry's needs for deepwater technology development, information dispersal to the vendor community and provide a forum for industry to meet and cooperate in development of key technologies.

Mr. Curtis D. Burton is a Senior Staff Engineer with Texaco's Central Offshore Engineering Department and is the Project Manager (PM) of the DeepStar Project. As the PM, he is responsible for all administrative and technical liaison activities between the operators, government agencies, and vendor representatives who are involved with DeepStar. He has worked in the subsea arena for over 15 years. These projects have included BP's Buchanan, Occidental's Claymore Field, Texaco's Highlander, Sun Oil's Balmoral, Saga's Snorre, Petrobras' Marlin/Albacora, and numerous Gulf of Mexico projects. He is a graduate of the University of Texas.

SESSION 4B

CHEMOSYNTHETIC COMMUNITIES I

Session: CHEMOSYNTHETIC COMMUNITIES I

Co-Chairs: Dr. Robert Avent and Dr. James M. Brooks

Date: December 16, 1993

Presentation	Author/Affiliation
Introduction	Dr. Robert Avent Minerals Management Service Gulf of Mexico OCS Region
The Chemosynthetic Ecosystems Study: An Introduction	Dr. James M. Brooks Geochemical and Environmental Research Group Texas A&M University
Near-surface Geology of Gulf of Mexico Hydrocarbon Seeps	Mr. Changshik Lee Dr. William Sager Department of Oceanography Texas A&M University Dr. Ian MacDonald Geochemical and Environmental Research Group Texas A&M University Dr. William W. Schroeder Dauphin Island Sea Lab Marine Science Program University of Alabama Mr. James Reilly Enserch Exploration Inc.
The Geochemistry of Hydrocarbon Seeps	Dr. Mahlon Kennicutt II Geochemical and Environmental Research Group Texas A&M University
Growth of Symbiont-Containing Fauna at Hydrocarbon Seeps in the Gulf of Mexico	Dr. Charles Fisher Department of Biology Pennsylvania State University

THE CHEMOSYNTHETIC ECOSYSTEMS STUDY: AN INTRODUCTION

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

Planning for this study was initiated by MMS shortly after the 1984 discovery of chemosynthetic fauna at natural hydrocarbons seeps on the continental slope in the Gulf of Mexico. From a management point of view, the study was called for because of the agency's concern that energy exploration and production could harm an important component of the slope ecosystem.

The Geochemical and Environmental Research Group (GERG) of Texas A&M University, was awarded the contract in July 1991. GERG brought to the study a mature program of research that included investigators from several research universities in the Gulf region and elsewhere. As a result, the team was able to proceed immediately to the fieldwork stage of the program and to build upon an existing data base acquired through several previous years of field sampling and analysis.

The study is tasked with determining the abiotic factors that determine whether communities of chemosynthetic fauna become established and persist at hydrocarbon seeps and with estimating the relative importance of the communities to the slope ecosystem. To address the question of possible harm due to human activity, the Study has examined the growth rates of the major faunal groups, the record of the community accessible to analysis by paleolotologists, and the incidence and causes of short-term change.

Because the communities occur at depths of 500 m or greater, and because they tend to be small in area, the investigations have relied heavily upon research submarines for sample collection and exploration. Initially, five sites located in water depths of 500 to 720 m were selected for study on the basis of their faunal composition and geographic location. MMS contracted for 18 dive days with the submarine *Johnson Sea-Link* and her surface support ship. Additional in-kind contributions of submersible time with both *Alvin* and the U.S. Navy *NR-1*, which were facilitated through GERG, have been crucial to the success of the field program. For example, use of the *Alvin* led directly to discovery the deepest known seep community in Alaminos Canyon (2,220 m depth); and use of *NR-1*, has been responsible for initial discovery of many of the study site locations.

The program is now less than two quarters from completion. The presentations at this meeting will inform the agency and the public as to our findings over the past three years and earlier. In general, we will conclude that the seep communities are a unique and important component of the slope ecosystem of both the regional and national EEZ. Although susceptible to damage through carelessness, this ecosystem can be protected through application of good scientific knowledge and appropriate management oversight. Discussion at this meeting may help further to focus the investigators as they turn their attention to preparation of their final report.

Dr. James M. Brooks is one of the foremost marine chemists in the country. One of the modern discoverers of natural marine hydrocarbon seepage, Dr. Brooks has been a leader in both basic and applied research on this topic. As founder and director of Texas A&M University's Geochemical and Environmental Research Group, he has built an organization that is currently active in environmental sciences throughout the world—most recently in the former Soviet Union, but also in Antarctica, Africa, the Arctic and South America as well as the U.S. Author of well over 100 peer-reviewed articles and book chapters, he is also a productive graduate educator and all-around nice guy.

NEAR-SURFACE GEOLOGY OF GULF OF MEXICO HYDROCARBON SEEPS

Mr. Changshik Lee
Dr. William Sager
Department of Oceanography
Texas A&M University

Dr. Ian MacDonald
Geochemical and Environmental Research Group
Texas A&M University

Dr. William W. Schroeder
Dauphin Island Sea Lab
Marine Science Program
University of Alabama

Mr. James Reilly
Enserch Exploration Inc.

INTRODUCTION

Using high resolution geophysical, submersible, and core data, we studied the geology of several hydrocarbon seeps on the Louisiana continental slope. This slope is a well-known site of hydrocarbon seepage and chemosynthetic communities (Brooks *et al.* 1986; MacDonald *et al.* 1990). The study area includes heavily-studied seeps in Lease Blocks Green Canyon 184/185, Green Canyon 234, Garden Banks 386, Garden Banks 424/425 and their surrounding area (Figure 4B.1). The primary objective of this study is better to understand how geological processes constrain the location and abundance of chemosynthetic communities in the area.

DATA BASE

The primary data base consists of 77 kHz side-scan sonar records, 25 kHz seismic reflection profiles, bathymetry data, and video tape photography, which were obtained by the research submarine *NR-1* in 1990 (GC 184/185, GC 234, and GB 386) and 1993 (GB 424/425). Other data available for these areas are push cores (GC 184/185, GC 234, and GB 386; *Johnson Sea-Link* 1992), piston cores (GC 234, GB 386 and GB 424/425; *R/V Gyre* 1992), 3.5 kHz and 12 kHz echo sounder records (GB 386 and GB 424/425; *R/V Gyre* 1992), and proprietary oil company hazard-survey data (GC 184/185 and GB 386). The industry data include 3.5 kHz echo sounder records and selected multi-channel seismic lines.

PHYSIOGRAPHY OF STUDY AREA

A cone-shaped mound in GC 184/185 site, named "Bush Hill," is located in 540 to 580 m of water, and occurs on a terrace at the base of relatively steep, fault-controlled slope. Horizontal dimension of the mound is about 600 m, and the slope ranges three to 17 degrees. The GC 234 site is along a part of a fault-controlled escarpment located within a network of salt diapirs and a region of widespread seismic wipe-out features (Behrens 1988). A flat-topped semi-circular mound in GB 386 site has a diameter of about 750 m and stands about 20 m above the surrounding seafloor. The mound is located at a depth of 600 m and the slope of the edge ranges three to eight degrees. A flat-topped elliptical mound in GB 424/425 site has a long axis of about 1,100 m and a short axis of 750 m in horizontal dimension. It stands 30 to 50 m above the surrounding seafloor. The mound is located at depth of 575 m and the slope of the edge ranges five to nine degrees. All mound structures are located at the edges of large salt domes.

RESULTS AND IMPLICATIONS

Detailed bathymetry maps of each study area were made using NR-1 depth data. Slant-range corrected side-scan sonar mosaics were also made for each site. These provide acoustical images of seafloor features. Also acoustic reflection characters ("acoustic facies") seen in 25 kHz subbottom reflection records were mapped. The acoustic facies variation is due to changes in the character of the seafloor and sediments. The acoustic facies mapping results were correlated with video records from submersibles and core samples.

Classification of Acoustic Facies

Figure 4B.2 shows six representative echo types seen in 25 kHz subbottom reflection records collected from the study area. Echo Type I shows a sharp reflector at the seafloor and no acoustic penetration. It is mainly due to carbonate layers (or perhaps gas hydrate) on the surface, whose thickness is about 10 cm or greater. Echo Type II shows shallow penetration with abrupt termination. It is interpreted

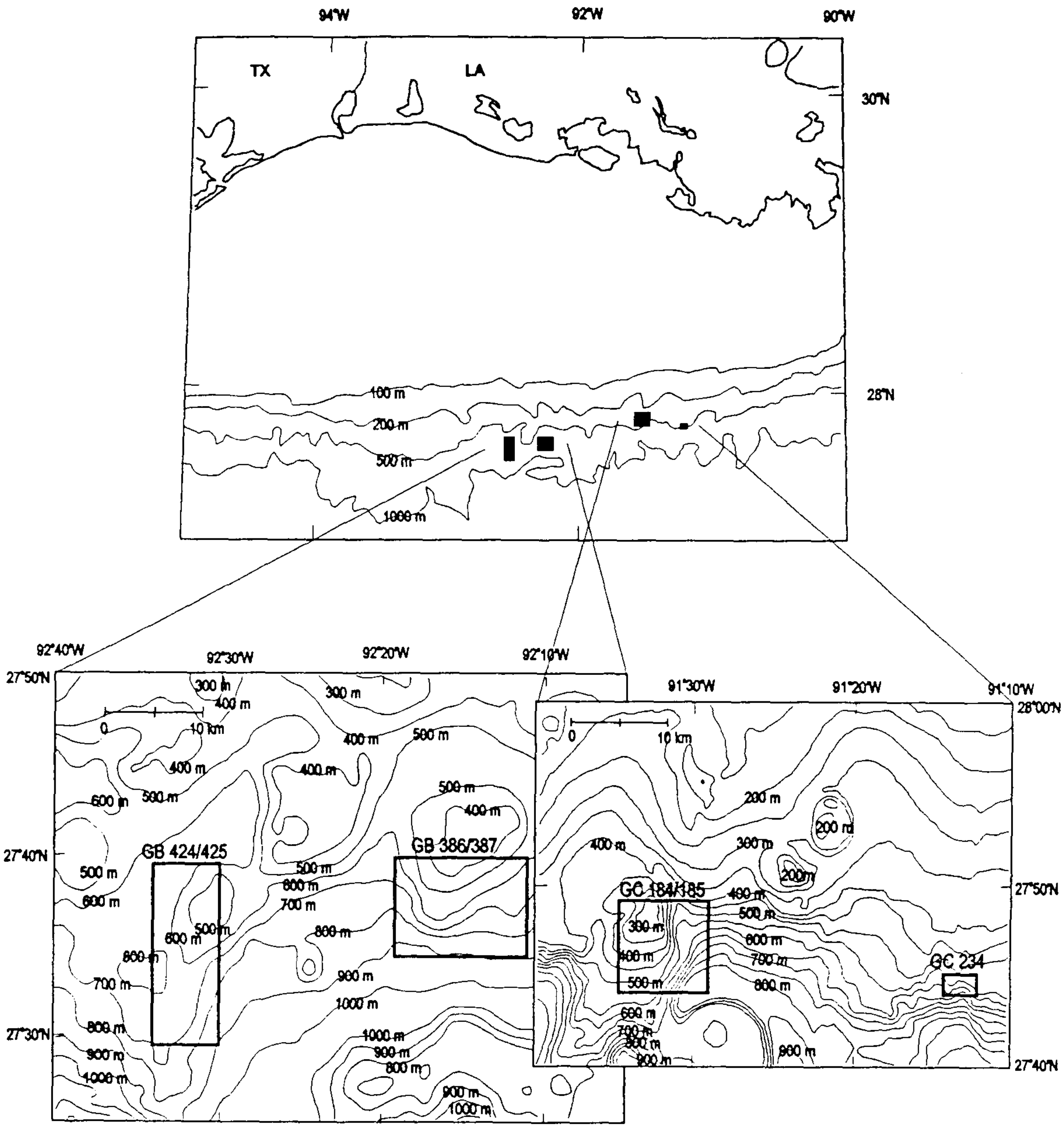

Figure 4B.1. Location of study area.

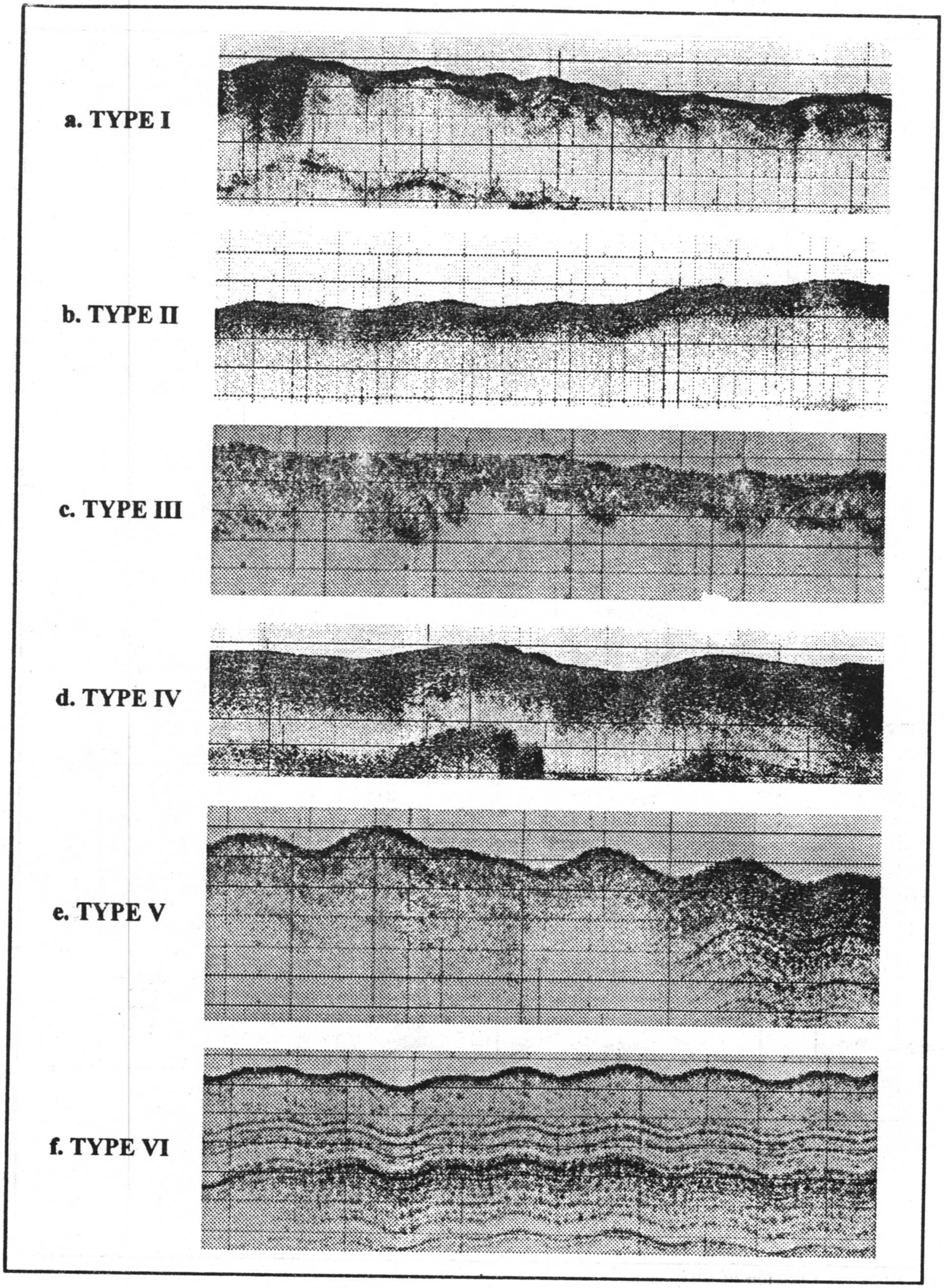

Figure 4B.2. Examples of echo types seen in 25 kHz subbottom reflection profiles.

as a two to eight ft mud layer below which a carbonate-rich or possibly gas hydrate layer occurs. The mud layer often contains gas, oil and shells. Echo Type III shows turbid subbottom echoes with no distinct reflectors. It is attributed to a mud layer disturbed by oil, gas or carbonate precipitates. Echo Type IV shows scattered subbottom echoes with indistinct reflectors. It may be layered sediments disturbed by oil, gas, shells and carbonate precipitates. Echo Type V denotes acoustic wipe-out features in which nearby subbottom reflectors are abruptly terminated. It is due to scattering or absorption by gas bubbles in sediment layers (Anderson and Bryant 1989, 1990). Echo Type VI shows parallel, multiple subbottom reflectors. It is interpreted as normal, silt-sized, hemipelagic slope sediments which are sometimes intercalated by shell layers or carbonate layers.

Acoustic Facies Mapping

Acoustic facies mapping results of 25 kHz subbottom reflection records of GC 184/185 and GC 234 sites show significant differences from those of GB 386 and GB 424/425. The flat mounds of GB 386 and GB 424/425 show mostly Echo Type I and II, associated with solid or porous carbonate rocks. In contrast, GC 184/185 and GC 234 sites show more variable features, less hard bottom and richer chemosynthetic communities. Figure 4B.3 shows an example of an acoustic facies map and correlation of facies with chemosynthetic community locations from the GC 184/185 site. Chemosynthetic communities are strongly coupled with Echo Type I, interpreted as porous or semi-consolidated carbonate precipitates in this area.

Side-Scan Sonar Mosaic

Side-scan sonar mosaics show acoustic backscatter and give an acoustic image overview image of each site to help understand spatial relationships of features in the study area. Figure 4B.4 shows a side-scan sonar mosaic of the GC 184/185 site. Strong (dark) backscatter features over the mound are due to large-scale rough bottom topography like large carbonate outcrops or ridges. In contrast, the eastern edge is characterized by normal hemipelagic sediments (Figure 4B.3) and shows a weak, monotonous backscatter pattern.

Core Analysis

Push cores collected from the submersible Johnson Sea-Link and piston cores collected from R/V Gyre were analyzed. Water content, bulk density, porosity and carbonate percentage with depth were measured. The analysis result and visual description of the cores were used to interpret the acoustic facies of study sites. Several piston cores collected from the GB 424/425 site showed violent gas expansion inside the cores when brought on deck. This may have been caused by gas hydrates.

Active Mud Vents

Active mud slides and sediment flows on flanks of the mound in the GB 424/425 site were observed. Following these features upslope, we found active mud vents discharging gas, oil and mud at the perimeter of the mound top. Both active vents were located within Echo Type I area. Sediments entrained by this discharge have probably contributed to the formation of the mound. Gas and droplets of oil were observed to be escaping from the vents. A temperature probe, lowered immediately beneath the surface of the fluid mud within the vent, recorded a temperature of 20°C, about 12°C warmer than ambient sea water.

Mud Mound Structures

Hydrocarbon seeps in the study area are especially related with mud mounds at the edge of salt domes (GC 184/185, GB 386 and GB 424/425). All the mound structures show acoustically amorphous features in 3.5 kHz echo sounder records, resulting from attenuation by gas in sediments or high reflectivity and scattering at the water/sediment interface (Watkins and Worzel 1978; Addy and Worzel 1979; Coleman *et al.* 1989; Anderson and Bryant 1989, 1990; Roberts *et al.* 1990a, 1990b, 1992). They are circular, semi-circular or elliptical in shape and have abrupt or upturned contacts with the surrounding layered sediments. The surrounding area has irregular, hummocky topography consisting of depressions, diapirs, fault controlled terraces, which are related to salt tectonics. Such mound structures have been interpreted to have originated from the upwelling of gaseous muds from depth (Neurauter and Bryant 1989, 1990; Bouma *et al.* 1990). Figure 4B.5 shows a more-detailed working hypothesis for the

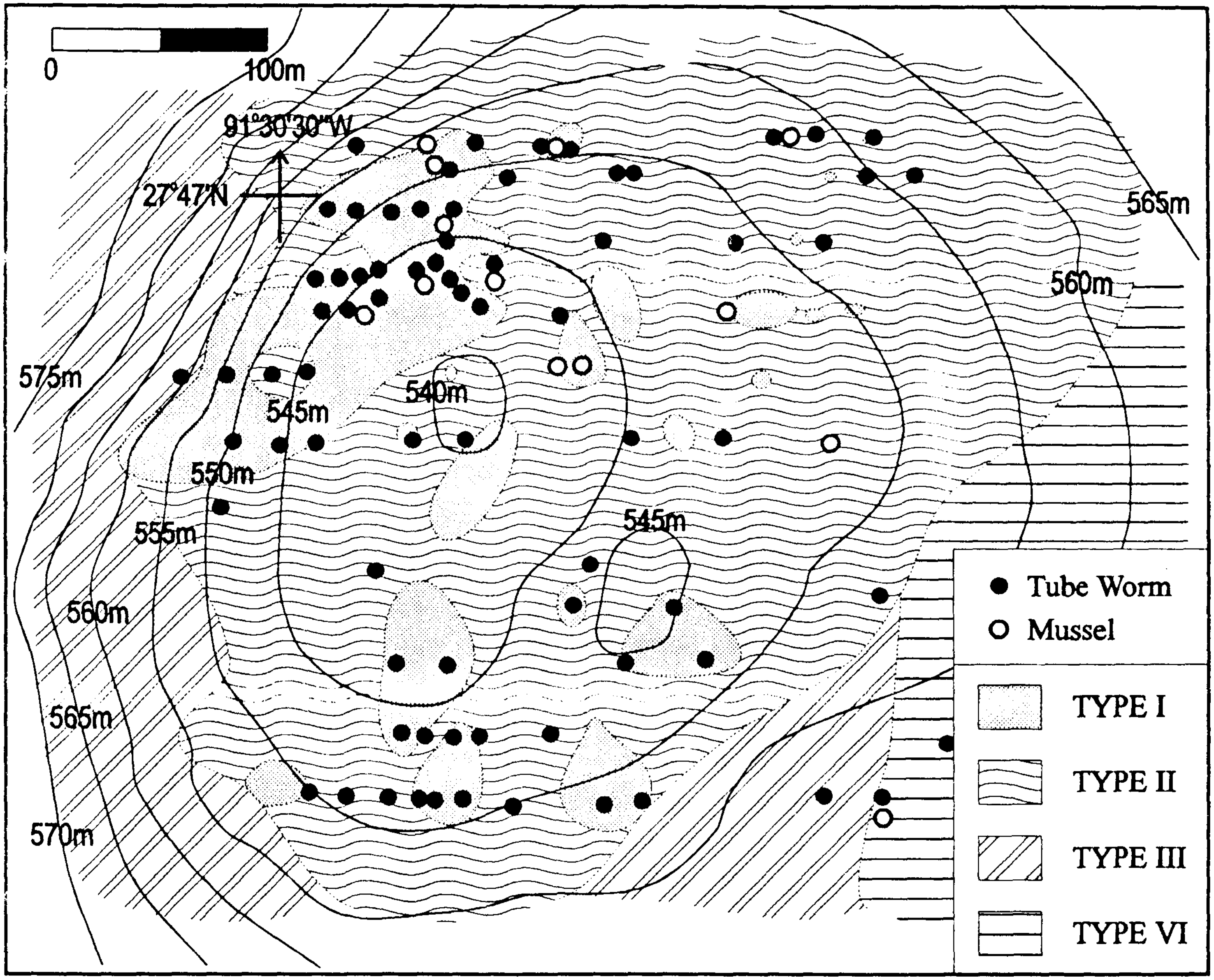

Figure 4B.3. Echo type map of GC 184/185 site, combined with chemosynthetic community locations.

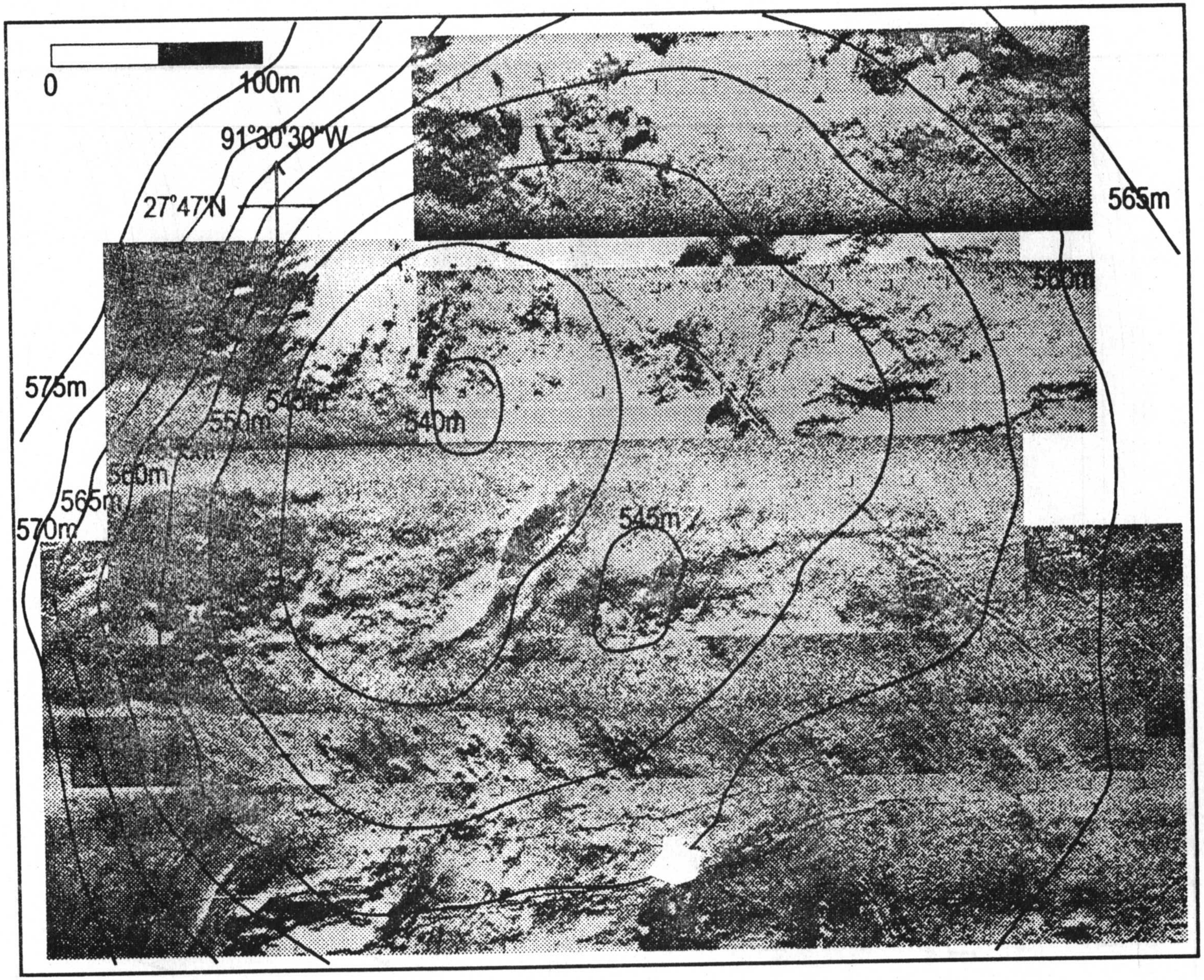

Figure 4B.4. Side-scan sonar imagery of GC 184/185 site.

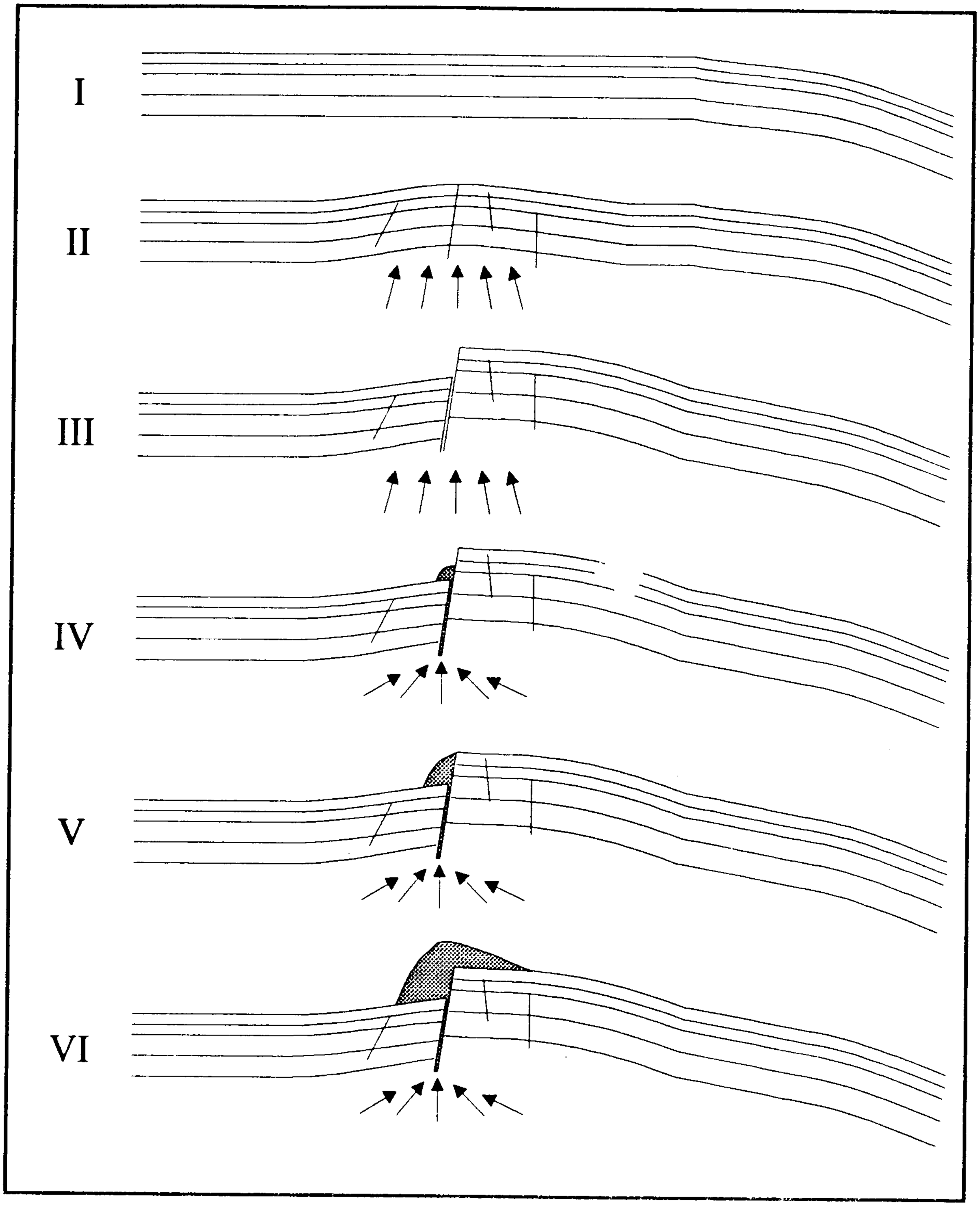

Figure 4B.5. Proposed model for the origin of the GC 184/185 mound.

origin of these mound structures. Normal faulting associated with salt diapirism creates fluid conduits from depth to seafloor within zones of overpressure (Stage II and III). The fluid moving up through conduits carries sediments to the surface (Stage IV). More sediments are deposited on the downthrown side (Stage V), making a mud mound which has a steeper slope to the downthrown side because a fault scarp may act as a barrier to the upthrown side (Stage VI). Chemosynthetic communities are more concentrated over the downthrown side because of proximity to the conduit of fluids. The proposed model explains these observations: abrupt termination of reflectors at the western edge of the mound, upturned layers at the eastern edge, slope changes along the edge of the mound and abundance of chemosynthetic community (Figure 4B.3). Overall shape (cone or flat-topped) of a mound structure are considered to be controlled by the style of fluid expulsion, number of vents, relative positions of vents, bottom currents and viscosity of carried sediments, which are affected by gas, oil and water content.

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THE GEOCHEMISTRY OF HYDROCARBON SEEPS

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Chemosynthetic communities are closely linked to a number of geochemical phenomena or processes. Directly or indirectly, these processes are primarily the result of oil and gas seepage. Historically, the recognition of oil seepage, gas-charged sediments (seismic wipeout zones), and hydrates lead to the discovery of seep communities. This fundamental coupling of biochemical processes and the chemical environment is at best incompletely understood. A common feature at both cold seeps and hot vents is the co-occurrence of anoxic and oxic conditions that allow for the storage of reduced compounds in close proximity to oxygenated waters. This dynamic system can only be maintained through an active supply of reduced compounds. The supply of these reduced compounds can result from seepage or venting (a deep source) and/or bacterial processes (aerobic and anaerobic). The seepage of oil and gas provides an unconventional source of carbon as well as some portion of the hydrogen sulfide needed for the community's energy and nutrition requirements. Oil and gas are readily available to hydrocarbon oxidizing bacteria that naturally occur in the marine environment. Microbial processes form the basis of the ecosystem and provide the mechanism to transform chemical energy into biochemical energy, mediated by free-living as well as endosymbiotic bacteria.

All locations studied have a number of common features, including oil seepage; gas charged sediments; hydrates; authigenic carbonate; active hydrocarbon oxidation; chemosynthetic biomass (not only in the symbiotic organisms but also in background fauna); elevated EOM, TOC, and salinity; and biodegraded oil. While it is still not clear which of the features is essential, it is clear that all of these attributes are closely related. A supplementary source of carbon is provided by oil and gas seepage. The oxidation of hydrocarbons contributes to maintaining anoxic conditions. Most, if not all, carbon and energy transformations are mediated by bacteria. Sulfur, an important element, and hydrate formation/decomposition are intimately associated with the continuous supply of natural gas. It is also clear that pore waters are the main repository of reduced compounds and that bottom waters supply oxygen. Steep gradients are present in almost all chemical properties and areal (including vertical) patchiness and heterogeneity are extremely high.

While it may not be clear what critical, or essential, geochemical requirements are needed for proliferation of communities, the presence of oil and gas seepage is a fundamental process in creating the chemical environment that fosters these unusual accumulations of biomass in the deep ocean.

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GROWTH OF SYMBIONT-CONTAINING FAUNA AT HYDROCARBON SEEPS IN THE GULF OF MEXICO

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Critical to determining the "robustness" of a community of animals is knowledge of the animals' growth rates and the population structure of the community: a community of fast-growing young animals will recover from physical disturbance much more quickly than a community of slow-growing old individuals. In the case of animals which rely on chemoautotrophic or methanotrophic symbionts, another piece of information basic to understanding the community dynamics is the nature of the animals' reliance on the reduced chemicals which are the primary substrates of their autotrophic symbionts. These were the primary goals of this portion of the "Chemosynthetic Ecosystem Study."

There are three main groups of "chemosynthetic metazoans" endemic to the hydrocarbon seep sites on the Louisiana Slope of the Gulf of Mexico: vesicomyid clams, vestimentiferan tube-worms, and bathymodiolid mussels (Brooks *et al.* 1987). Each group uses a different "strategy" to obtain the specific chemical substrates required by its symbionts. Three types of in situ growth experiments were designed (one for each group) based on our knowledge of that group, and the results of two of those experiments are presented here. Another new set of devices were also designed and constructed for this study: small volume water samplers, which were used to obtain high-quality water samples from specific (physiologically relevant points) in the animals' immediate habitat, which were then characterized with respect to the chemical substrates of the symbionts.

The two species of tube-worms present at these sites are in two different families (Escarpidae and Lamellibrachidae) but have similar gross anatomy, physiology, and lifestyles (Jones 1985). The worms attach to hard substrate when they settle and are immobile after metamorphosis to the adult form. The adults have no mouth, gut, or anus and apparently depend entirely on their symbionts to meet their nutritional needs. The symbionts require sulfide, oxygen, and inorganic carbon as chemoautotrophic substrates (Fisher *et al.* 1988) and the immobile host must live in an environment with a constantly replenished supply of these nutrients. It is well documented that the hydrothermal vent relatives of these vestimentiferans take up these dissolved gases across their plumes; however, we believe it possible that these hydrocarbon-seep animals may acquire at least their sulfide through diffusion across the buried portions of their tubes (MacDonald *et al.* 1989, Fisher 1990).

To determine the growth rates of the vestimentiferans, numbered bands were placed around the tubes, close to the anterior ends. The location of the bands was documented using video, and their yearly growth increment determined after subsequent visits either by re-video or collection of the banded animals. The growth rates of both species were determined to be extremely slow. The fastest-growing individual laid down two cm of tube material in a year and the average for both species was near 0.5 cm per year. This is in stark contrast to their hydrothermal vent relatives which can grow one hundred times as fast. Because individuals of Lamellibrachia sp. are routinely collected between two and three meters in length, we conclude that individuals in excess of 200 years old are likely present in many of the large aggregations.

Sulfide was undetectable in eight of nine samples taken around the plumes of the vestimentiferans and in 15 of 17 samples taken between the plumes and the sediment. However, over half of the samples of interstitial water 10 cm below the sediment-water interface contained detectable sulfide, with concentrations ranging from a few micromolar to over one millimolar. These data support the hypothesis that seep vestimentiferans acquire their sulfide by diffusion across the terminal, buried portion of their tube.

The undescribed hydrocarbon-seep mussel contains methane oxidizing symbiotic bacteria in its gills which, apparently provide the bulk of the animal's nutrition (Childress *et al.* 1986) . Because of the relative ease in handling methane (as compared to hydrogen sulfide) and the fact that this mussel can be maintained in the laboratory at ambient pressure for extended periods, this species has proven amenable to laboratory study, and there is considerable information available on the physiology of both the intact mussel and the isolated symbionts (Fisher *et al.* 1987, Cary *et al.* 1988, Fisher & Childress 1992, Kochevar *et al.* 1992, Lee *et al.* 1992) . Although these bivalves are mobile, they occur in dense "beds" attached to rocks or each other by byssal threads. In fact, the results of a transplant experiment conducted as part of this study suggest that appropriate physical substrate as well as high levels of methane are necessary for establishment of a mussel bed.

Experiments were designed to characterize chemically the animals' microhabitat, determine densities and population size structure of the beds, and measure the mussels' natural growth rates in situ. An experimental bed was first marked with a float and then numerous water samples taken from precise locations among the mussels. Collections were then made from within 0.5 m diameter rings temporarily positioned in the mussel beds. All collected animals were measured and then 150 were individually tagged and returned to the point of collection. This procedure was repeated in two subsequent years at several sites. In addition to determining growth rates of all marked and recollected animals, the physiological condition of a subset of each collection was determined using three different indices.

In brief, the results of this study indicate that 1. The mussels flourish in sites with very high levels of methane (1 mM +) immediately below the bed and high levels (60 uM+) among the animals. 2. At active sites the juveniles grow very quickly (up to 2 cm /yr in shell length) and adults grow at rates comparable to healthy intertidal mussels at similar temperatures. 3. Populations at sub-optimal conditions can be in good health and growing at very slow rates, suggesting that these animals can live a long time (50 to 100 years). 4. Because of the high densities of animals in some beds, biomass can be quite high (up to 20 kg/m_2) and the potential methane oxidation rates of these beds are higher than has been recorded for any other environment on the planet (up to 200 g / m_2 / day). 5. Significant differences were found in two of the sites in subsequent years (in chemistry, growth rates, and physiological condition of the animals), suggesting the possibility of significant variability in the habitat on a yearly to decadal scale.

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SESSION 4C

PERSPECTIVES ON OFFSHORE ENVIRONMENTAL MITIGATION SUCCESS STORIES

Session: PERSPECTIVES ON OFFSHORE ENVIRONMENTAL MITIGATION SUCCESS STORIES

Co-Chairs: Mr. Villere Reggio and Ms. Deborah Cranswick

Date: December 16, 1993

Presentation	Author/Affiliation
Perspectives on Offshore Environmental Mitigation Success Stories	Mr. Villere Reggio Ms. Deborah Cranswick Minerals Management Service Gulf of Mexico OCS Region
Sea Turtle Mitigation, Evolution, Development, and Management	Mr. Jerry Brashier Mr. G. Ed Richardson Minerals Management Service Gulf of Mexico OCS Region
Mitigation for the Protection of Sea Turtles During Platform Removals in the Gulf of Mexico	Mr. David A. Dougall Agip Petroleum Co.
Platform Removal - Sea Turtle Observer Program	Mr. Greg Gitschlag Galveston Laboratory Southeast Fisheries Center Galveston, Texas
Document not submitted	Mr. Dan Bourgeois Minerals Management Service Gulf of Mexico OCS Region
Marine Debris Investigation and Surveillance at Padre Island National Seashore	Mr. Sean Baker National Park Service
Introduction to the Site Clearance Issue	Mr. Jerry Brashier Minerals Management Service Gulf of Mexico OCS Region
Platform Removal Site Clearance Verification	Mr. Michael J. Kinsella, P.E. Kinsella, Cook & Associates, Inc.

PERSPECTIVES ON OFFSHORE ENVIRONMENTAL MITIGATION SUCCESS STORIES

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

Inherent in its role as the lead agency for the Federal offshore leasing program, MMS has a major responsibility to assure protection of natural resources. Officially known as "mitigation" MMS uses general OCS regulations, lease stipulations, environment reporting requirements, cooperation, and example to require and encourage lease operations and industry actions that will avoid, minimize, and rectify adverse environmental effects from offshore oil and gas operations.

This session focused on mitigation associated with structure integrity, removal and cleanup operations. Presentations by MMS, cooperating federal agencies, an OCS operator, and a contractor provide recent information and perspectives gained from implementation of upgraded mitigation effecting the placement and removal of offshore oil and gas platforms to protect the natural environment from the extreme forces of man and nature. Specific concerns addressed included avoidance of pollution from structural failures during hurricanes, protection of sea turtles from explosive techniques used in structure removals, and certification that former production sites are free from trawling obstructions. An additional presentation reported on trends of the indirect effects of offshore marine debris loss on Padre Island National Seashore with information on cooperative efforts, led by the National Park Service, at offshore surveillance of marine activities and enforcement of solid waste control laws.

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

Ms. Deborah Cranswick is an Environmental Scientist with the MMS, Gulf of Mexico Region. Ms. Cranswick earned a B.S. degree in Geology from California State Polytechnic University in Pomona in 1979 and has work in the Federal OCS program for 14 years with both the Geological Survey and the MMS. Her responsibilities include coordination of Environmental Impact Statements for the Gulf of Mexico oil and gas lease sales.

SEA TURTLE MITIGATION, EVOLUTION, DEVELOPMENT, AND MANAGEMENT

Mr. Jerry Brashier
Mr. G. Ed Richardson
Minerals Management Service
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On 15 April 1986, the Galveston, Texas, Laboratory of the National Marine Fisheries Service (NMFS) wrote a letter to the Regional Director, Gulf of Mexico OCS Region regarding two major stranding events, one in fall 1985 and the second in March-April 1986. On 22 July 1986, the NMFS reported that some 124 stranded sea turtles and other animals had washed ashore on the upper Texas and Southwestern Louisiana coast since March 1986. Most of the strandings involved the endangered Kemp's ridley sea turtle. Coincidentally, a number of structures in the State of Texas territorial waters were removed during that time frame. The NMFS suggested that a correlation existed between structure removals using underwater explosives and the sea turtle strandings.

As a result of the concerns, the Minerals Management Service's (MMS's) Gulf of Mexico Regional Director sent two letters to lessees and operators in 1986, the first requesting that the Regional Office be notified 30 days in advance of any plans to remove structures and the second requesting additional information to facilitate MMS and NMFS interagency Endangered Species Act, Section 7 consultation for structure removals using explosives.

The Gulf of Mexico Regional Office's Environmental Operations Section prepared a Programmatic Environmental Assessment. Tiering from that document, Environmental Assessments have been prepared on all explosive and non-explosive structure removals, as required by the National Environmental Policy Act since endangered sea turtles could be affected by structure removal activities.

In July 1988, the NMFS issued a biological opinion in response to MMS's request for a generic consultation for structure removals using explosive charges. That document established an incidental take (by injury or mortality) level of one documented Kemp's ridley, green, hawksbill, or leatherback turtle, or ten loggerhead turtles for all removal operations. Further, the level of taking was specified as cumulative for all removals. The document also listed mitigative measures to minimize effects on turtles from removal operations. These included the following provisions:

1. Qualified observer(s), as approved by NMFS, must be used to monitor the area around the site prior to, during, and after detonation of charges. Observer coverage will begin 48 hours prior to detonation of charges. If sea turtles are observed in the vicinity of the platform and thought to be resident at the site, pre- and post-detonation diver surveys must be conducted.

2. On days that blasting operations occur, a 30-minute aerial survey must be conducted within one hour before and one hour after each blasting episode. The NMFS-approved observer and/or NMFS on-site personnel (NMFS employee only) must be used to check for the presence of turtles and, if possible, to identify species. If weather conditions (fog, excessive winds, etc.) make it impossible to conduct aerial surveys, blasting activities may be allowed to proceed if approved by the on-site NMFS and/or MMS personnel.

3. If sea turtles are observed in the vicinity of the platform (within 1,000 yards of the site) prior to detonating charges, blasting will be delayed until the turtles are moved at least 1,000 yards from the blast site. The aerial survey must be repeated prior to detonation of charges.

4. Detonation of charges will occur no earlier than one hour following sunrise and no later than one hour prior to sunset. However, if it is determined by NMFS and/or MMS on-site personnel that special circumstances justify a modification of these time restrictions and that such modification is not likely to adversely impact listed species, blasting may be allowed to proceed outside of this time frame.

5. During all diving operations (working dives as required in the course of the removals), divers will be instructed to scan the subsurface areas surrounding the platform (blasting) sites for turtles and marine mammals. Any sightings must be reported to the NMFS or MMS on-site personnel. Upon completion of blasting, divers must report and attempt to recover any sighted injured or dead sea turtles or marine mammals.

6. Charges must be staggered 0.9 seconds (900 milliseconds) for each group of structures, to minimize the cumulative effects of the blasts. If a removal operation involves multiple groupings of structures, the interval between detonation of charges for each group should be minimized to avoid the "chumming" effect. Whenever such intervals exceed 90-minutes, the aerial survey must be repeated.

7. The use of scare charges should be avoided to minimize the "chumming effect." Use of scare charges may be allowed only if approved by the NMFS and/or MMS on-site personnel.

8. A report summarizing the results of the removal and mitigative measures must be submitted to the MMS Gulf of Mexico Region within 15 working days of the removal. A copy of the report must be forwarded to NMFS, Southeast Region.

Since initiation of Section 7 consultation in the fall of 1986, approximately 540 structures have been removed in the Gulf of Mexico by the use of explosives and 227 by non-explosive measures through September 1993. To the best of our knowledge, only one turtle has been injured by explosives--none killed. The injured turtle was captured, brought to shore, nursed back to health, and returned to the Gulf of Mexico. Another turtle was observed that may have been injured, but water currents carried it away before conclusive observations could be made. Based upon this record, MMS believes the mitigative measures have been very effective.

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Mr. G. Ed Richardson is a Supervisory Environmental Protection Specialist with the MMS, Gulf of Mexico Regional Office. He has more than 20 years of experience working for state and Federal government and for the oil and gas industry. Mr. Richardson received his M.S. degree in microbiology, environmental health, and biochemistry from Clemson University.

MITIGATION FOR THE PROTECTION OF SEA TURTLES DURING PLATFORM REMOVALS IN THE GULF OF MEXICO

Mr. David A. Dougall
Agip Petroleum Co.

INTRODUCTION

This report briefly reviews the issue of the use of explosive charges in platform removal and measures to mitigate potential impact on threatened and endangered sea turtles. This issue arose from public concern and was addressed jointly by MMS, NMFS, and the oil and gas industry. Procedures in place since August 1988 have virtually eliminated any threat this activity may present to sea turtles and marine mammals.

Views expressed in this paper are those of the author and do not represent an industry position.

BACKGROUND

The effects of explosives used in the removal of oil and gas platforms and caissons in the Gulf of Mexico became an issue in May 1986 with a report of strandings of significant numbers of fish, dolphin, and endangered and threatened species of sea turtles in the vicinity of the Bolivar Peninsula near Galveston, Texas. While the actual cause of these strandings was never established, there was substantial concern that platform removal projects being conducted at the time at least played a part.

Since all of the species of sea turtles in the Gulf of Mexico are either threatened or endangered, the issue quickly embroiled the offshore oil and gas industry, contractors, Minerals Management Service (MMS) and the National Marine Fisheries Service (NMFS) in considerations under the Endangered Species Act (ESA). By the end of August 1986, meetings had been held between MMS, NMFS, and members of the Offshore Operators Committee (OOC) to evaluate the seriousness of the situation. (The OOC is an organization of Gulf of Mexico oil and gas operators).

Oil and gas platforms and caissons are required by lease stipulation to be removed within 12 months after cessation of production from the lease. The procedure typically includes the use of explosives to sever pilings and well conductors below the ocean bottom to free the structure for removal. Under some circumstances, mechanical or abrasive cutting or underwater arc cutting are used rather than explosives. These techniques are often limited by accessibility to the location to be cut and other considerations.

It became evident early on that little was actually known about the effects of explosive charges on the sea turtle population or of the relationship between sea turtles and oil and gas structures. A preliminary study conducted in April 1986 confirmed that a Kemp's ridley turtle exposed to a set of four charges of nitromethane totalling 240 pounds at a distance of approximately 150 feet does not survive.[1] In other studies, sea turtles exposed to explosions at 600 yards were stunned but recovered with no apparent lasting ill effects.[2]

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[1]Caillouet *et al.* 1986. Preliminary Evaluation of Biological Impacts of Underwater Explosions Associated with Removal of an Oil Field Structure from the Gulf of Mexico near Crystal Beach, Texas. National Marine Fisheries Service, Southeast Fisheries Center, Galveston, Texas.

[2]Letter from Jack Brawner, Regional Director NMFS, SEFC Galveston Laboratory, to William G. Gordon, Assistant Administrator for Fisheries, NMFS, Washington, D.C. July 25 1986.

The MMS and NMFS concluded that the use of explosives "may affect" sea turtles, triggering the need for a "biological opinion" and an "incidental take statement." The death or injury of even a single turtle in the absence of an "incidental take permit" from the NMFS could be considered a violation of the ESA. Therefore, platform removal projects were reviewed and Incidental Take Statements issued on an individual basis from August 1986 until August 1988. (During roughly this same period of time, the NMFS staff was trying to reduce the much larger "take" associated with the commercial shrimping industry).

BIOLOGICAL OPINION & INCIDENTAL TAKE STATEMENT

On 25 July 1988, the NMFS issued the Biological Opinion and Incidental Take Statement covering explosive removal of oil and gas production structures in the Gulf of Mexico. The document concluded that, while the activity might result in some injury or death to sea turtles, these removals were not likely to jeopardize the continued existence of the species.

The combined document does three things:

1. The Biological Opinion establishes specific criteria to be met in terms of the explosive charge program. Only programs meeting these criteria are covered by the Biological Opinion. Therefore, any program using explosives not meeting these criteria is not protected from prosecution in the event of incidental harm to sea turtles.

Applicable criteria are:

- high velocity explosive (>7,600 meters per second).
- maximum of eight individual charges per set of detonations, staggered at intervals of 0.9 seconds.
- minimum of 15 feet below mud line.
- maximum of 50 pounds of explosive material in any charge.

Together, these criteria assure the minimum potential impact on the surrounding biota while still delivering an effective detonation.

2. The Incidental Take Statement places a number of procedural conditions on the operator. These conditions are primarily aimed at insuring the absence of sea turtles within a 1,000-yard radius at the time of detonation. NMFS-approved observers must be present for 48 hours prior to the planned detonation. The detonation must take place during daylight, and aerial surveys must be conducted prior to and after detonation. If any turtles are observed, they must be successfully removed before detonation may proceed. "Scare charges" are <u>not</u> to be used because they have been found to attract fish and dolphin. Some of these requirements may be waived under extraordinary circumstances.

If the observers believe a turtle to be "resident," pre- and post-detonation diver surveys are required.

Finally, a report of each removal program must be submitted to MMS with a copy to NMFS.

3. The Incidental Take Statement sets a very low number of turtles that may be "taken." A total of one Kemp's ridley, green, hawksbill, or leatherback turtle and ten loggerhead turtles may be taken. This is a <u>cumulative</u> limit for all platform removal activities in the Gulf of Mexico. Exceeding the specified "take" would nullify the Incidental Take Statement and return the industry to the case-by-case review that we experienced prior to the Gulf-wide statement.

INDUSTRY EXPERIENCE SINCE JULY 1988

The only process for accumulating an actual account of experience with platform removal programs is the report required to be submitted to the MMS (copy to NMFS). The following remarks are based upon the author's experience and a sampling of experiences and observations from other operators.

In practice, the operator enters into a Memorandum of Understanding with the NMFS for monitoring services for the platform removal program. The operator provides transportation and accommodations, and NMFS provides approved observers and a written report. The NMFS observer report provides a detailed account of the sightings of turtles and dolphins as well as data on the charges (type, weight, and settings).

The current procedures insure compliance with the ESA, while allowing removal of platforms and caissons to continue. The observers provided by NMFS are professional and helpful insofar as compliance with spotting requirements.

Turtles have been observed during very few platform abandonments. When they are present, there are rarely, if ever, more than one or two.

If a turtle is spotted nearby, the impact can be minor or it can mean a major delay in the removal program and substantial added expense. If a turtle can be observed to move on out of the area, the program may continue. If, on the other hand, a turtle is sighted repeatedly, it must somehow be removed from the area. The operator may be fortunate enough to get confirmation from divers that the turtle has left the area on its own. Failing voluntary departure, the turtle may sometimes be captured or physically persuaded to leave the area. Unfortunately, removal techniques are not altogether successful, and some operators have experienced long delays or given up altogether and utilized mechanical cutters.

OOC SEA TURTLE OBSERVER PROGRAM

To help define the relationship between sea turtles and offshore oil and gas production structures, the OOC coordinated a voluntary Sea Turtle Observer Program. Daily observations were made from 112 platforms over a 15-month period (10/1/89 - 1/31/91). Regular observation results were recorded daily, and random sightings were recorded as they occurred.

Results of the Sea Turtle Observer Program have not yet been published, but preliminary analysis of the data suggests that, in general, very few turtles routinely use offshore platforms as habitat. The association between platforms and turtles, in most cases, is coincidental or, at most, they may be using the platform as a temporary shelter in their wider movements.[3]

[3]Parker *et al.* Unpublished report on the Sea Turtle Observer Program. December 1993.

OTHER STUDIES

1. Efficient Use of Explosives for Platform Removals.[4]

This report, funded by the OOC, examines possible methods to enhance the efficient use of explosives for platform removal. The focus of the inquiry was the selection of explosive type, charge configuration, and mitigation method that would minimize the blast effect on the environment and still safely and reliably sever the target.

The conclusions of the report listed below are conceptual methods that may be used in some circumstances to enhance the "efficiency" of the explosives program.

- Use of a shaped charge in a dry setup. Applicable only to piles and caissons that are open to the surface and that can be de-watered during mud plug removal.

- Placement of the bulk charge at a depth greater than 16 feet below mudline. Applicable to piles, conductors, and caissons.

- Use of bulk charge with a blast mat. Applicable to piles, conductors, and caissons. This method could be incorporated into new structures in the modification of mud mats and mudline conductor framing.

- Use of a bridge plug. Applicable to piles and conductors, especially those open to the water.

The report proposes a test program to evaluate the suggested enhancements. Such a test program has not been conducted.

2. Marine Mammal & Sea Turtle Populations of the North-Central Gulf of Mexico.[5]

[4]Twachtman Snyder & Thornton. Final Report-Phase One, Efficient Use of Explosives for Platform Removal. Prepared for the OOC. October 1992.

[5]Lohoefener *et al.* Marine Mammal and Sea Turtles Populations of the North-Central Gulf of Mexico. NMFS Mississippi Laboratories. Presented at the MMS Gulf of Mexico Information Transfer Meeting, November 1991.

This study was conducted using aerial surveys from June 1988 through June 1990 to examine the distribution of sea turtles in several study areas offshore of Louisiana. The authors estimate that 92 percent of the 316 sea turtles sighted were loggerheads, and an overall 78 percent of the sightings were in the vicinity of Breton and Chandeleur Islands.

RECOMMENDATIONS

Under the current program, removal of oil and gas structures is being conducted with virtually no impact on endangered or threatened sea turtles. There are circumstances where time and expense are sacrificed unnecessarily.

The MMS and NMFS should jointly review the information gathered over the last seven-plus years and take steps to relax those requirements that are not essential. The current requirements were developed during a period when little was known about sea turtles and the use of explosives in platform abandonments. We have accumulated considerable knowledge since then, and that knowledge should be applied. Consideration should be given to circumstances where nighttime operations may be allowed and where geographic and seasonal circumstances may affect the likelihood of encountering a sea turtle.

SUMMARY

Obsolete oil and gas structures are being removed from the Gulf of Mexico with minimal impact on wildlife. Current procedures have proven successful in virtually eliminating any harm to marine mammals and sea turtles during removal activities.

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PLATFORM REMOVAL—SEA TURTLE OBSERVER PROGRAM

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INTRODUCTION

The sea turtle observer program began in 1987 as a result of concerns related to the Endangered Species Act. Federal regulations require removal of offshore oil and gas structures within one year after lease termination. The most common and cost effective method of structure removal uses high velocity, plastic explosives. The objective of the observer program is to protect sea turtles in the Gulf of Mexico from impacts of these explosive removals. Costs for the program are passed on to the structure owners and operators. This report summarizes the findings of the National Marine Fisheries Service (NMFS) observer program in the Gulf of Mexico from 1987-1992, plus opportunistic monitoring of six explosive removals in 1986.

METHODS

Oil and gas companies involved in explosive structure removals followed a list of requirements outlined in an Incidental Take Statement prepared by the National Marine Fisheries Service. Since 1988 a generic Incidental Take Statement was used for most salvage operations involving 5-50 pounds of explosives per detonation. Basic requirements included the use of NMFS observers to monitor for sea turtles beginning 48 hours prior to detonations, prohibition of nighttime detonations, 30-minute pre- and post-detonation aerial surveys, diver surveys to be conducted before and after detonations in cases where a sea turtle is observed, and delaying multiple detonations of explosive charges by at least 0.9 seconds to reduce the maximum pressure gradient generated by explosions. Monitoring from vessels and structures occurred during both day and night, but aerial surveys were performed only during the day. Sighting rates for sea turtles were calculated by dividing the number of individual sea turtles observed by the number of monitoring hours. Data were analyzed using the chi-square test to determine differences between treatments.

RESULTS

Through the end of 1992 a total of 33,188 monitoring hours were conducted. Approximately 21,000 hours occurred during the day and 11,000 at night while nearly 1,000 hours of aerial surveys were flown. The sighting rate for sea turtles was more than ten times higher during aerial surveys (26.1×10^{-3}) than during either day (1.7×10^{-3}) or night surveys (2.1×10^{-3}). This difference was statistically significant. Despite greatly reduced visibility at night, the sighting rate was higher than during the day. NMFS observers recorded a total of 225 sea turtle sightings of 80 individuals. Eighty-six percent of identified sea turtles were loggerheads (*Caretta caretta*). Overall, sea turtles were observed at 17 percent of offshore blocks that were monitored. This increased to 28 percent for blocks in depths of 15-30 m. The highest sea turtle sighting rate across the entire study area, which extended from south Texas to Mobile, Alabama, occurred in central Louisiana where 22.1 percent of monitored blocks had turtles. Sighting rates were lowest around noon.

This program provides several benefits that promote and protect sea turtles. The program increases awareness of the presence and vulnerability of sea turtles to explosive salvage operations. In at least a few cases, companies have voluntarily switched from explosive to mechanical removal techniques that have no impact on sea turtles. During the past six years, eight sea turtles were captured (four by divers) to protect them from the impacts of explosives and to evaluate their condition. Since initiation of the sea turtle observer program, only one sea turtle was known to have been injured by explosives. This number is related to both the small size of the sea turtle population as well as to the effectiveness of the observer program. However, it is obvious that the effectiveness of observers monitoring the sea surface is limited, especially in the case of sea turtles, which spend about 95 percent of their time submerged. Despite such limitations, one of the most important direct benefits provided by the program is that it offers protection in areas with high concentrations of sea turtles. It is in these areas that there is the greatest potential for significant mortalities.

SUMMARY

More than 33,000 hours of monitoring were conducted during day, night, and aerial surveys. Sea turtle sighting rates were significantly higher during aerial surveys than during either day or night surveys. Sighting rates also varied significantly by time of day with lowest rates occurring around noon. Loggerheads composed 86 percent of identified sea turtle sightings.

REFERENCES

Renaud, M.L. and J.A. Carpenter. Movements and submergence patterns of loggerhead turtles (*Caretta caretta*) in the Gulf of Mexico determined through satellite telemetry. 1994. Bull. Mar. Sci., In press.

Gregg Gitschlag has worked for NOAA's Southeast Fisheries Center, Galveston Laboratory for the past 15 years as an oceanographer and fishery biologist. His research interests include sea turtle behavior and migration as well as recreational and commercial impacts on red snapper. Mr. Gitschlag completed his B.S. in zoology at the University of Michigan and his M.S. in biological oceanography at Florida State University.

MARINE DEBRIS INVESTIGATION AND SURVEILLANCE AT PADRE ISLAND NATIONAL SEASHORE

Mr. Sean Baker
National Park Service

INTRODUCTION

Padre Island is a barrier island located adjacent to the southeastern coast of Texas. The island is approximately 193 km in length and is the longest undeveloped barrier island in the United States. Padre Island is bordered on the west by the hypersaline Laguna Madre, an estuary that separates the island from the mainland of Texas, and on the east by the Gulf of Mexico. Padre Island National Seashore (PAIS) encompasses approximately 112 km of Padre Island.

PAIS is unique as a marine debris survey area because the Gulf of Mexico (GOM) current patterns converge there. The GOM currents deposit a greater amount of marine debris on PAIS beaches than the total combined marine debris deposited on all other National Park Service (NPS) coastal beaches. The magnitude of marine debris is such that as much as one ton per linear kilometer has been reported. For these reasons, PAIS is a logical area, within the Gulf of Mexico region, to survey marine debris trends and MARPOL Annex V compliance.

PAIS is one of eight National Park Service seashore parks participating in the National Park Marine Debris Monitoring Program. This research endeavor was initiated in 1989 to monitor persistent marine debris on coastal beaches over a five year period. Six 50-meter transects on PAIS were surveyed on a quarterly basis (every 90 days) throughout the five year period.

To supplement the quarterly data, PAIS initiated an ongoing daily marine debris survey in June 1992. The daily survey transects were located on the north and south boundary of two quarterly survey sites. The proximity provided a means of comparing daily marine debris deposition to quarterly debris deposition.

The daily survey was initiated to:

- Determine if there is a preferred area of the beach that, sampled regularly, will serve as an indicator of the effectiveness of MARPOL Annex V regulations.
- Determine if there is a quantifiable difference in marine debris accumulation between sample sites at different locations.
- Determine if it is scientifically valid to conclude that the amount of debris found in a single sample site is representative of the amount of debris accumulated in a larger area.
- Identify the environmental factors that influence the deposition of marine debris.
- Identify point source polluters.
- Determine the sampling interval to obtain an accurate representation of debris deposition at PAIS.
- Determine methodologies that are required to obtain quantifiable data for each sampling site.

METHODS

Quarterly Survey: The types and amounts of marine debris were surveyed quarterly along six transects of PAIS beach. These transects were labeled: Closed Beach 1A and 1B; South Beach 2A and 2B; and, South Beach 3A and 3B. The width of each survey site was fixed at 50 meters, while site length averaged 50 meters during winter months to 100 meters during summer months. This particular report does not detail the marine debris data collected from the five years of quarterly surveys. The quarterly data has been published by the National Park Service and is available from the NPS Washington Office.

Daily Survey: As depicted in Figure 4C.1, daily surveys of marine debris were initiated at four 50-meter transects (sites: 1B [north], 1B [south], 2A [north], 2A [south]) in June 1992. The daily survey sites were located on the north and south of two quarterly transects (e.g. Closed Beach 1B and South

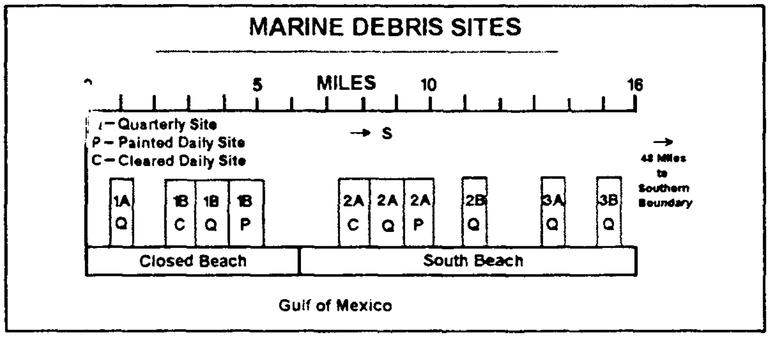

Figure 4C.1. Marine debris sites.

Beach 2A). These daily survey sites are approximately six miles apart (Figure 4C.1).

Debris items encountered within the northern sites (1B [north] and 2A [north]) are counted and removed daily; whereas, each debris item within the southern sites (1B [south] and 2A [south]) is counted and painted daily, but left-in-place. On the day of the quarterly survey, painted debris items are recounted and removed from the site. The total number of painted items remaining on the site, subtracted from the total number of painted items, over the 90 day period, represents the number of items that have been redeposited due to environmental factors (e.g. tides, rain, or wind actions).

All debris items in the two northern transect sites are counted, recorded, and removed from the sites daily. Daily totals are added together for each quarter (90 days) to determine if the quarterly data accurately depict the total amount of debris deposition over a quarterly period.

A survey to identify point-source pollution was initiated by PAIS in 1989 in partnership with the Offshore Operators Committee and Minerals Management Service. This particular survey determines trends, over time, of specific debris items associated with Gulf of Mexico offshore petroleum platforms. Data gathered from this survey indicated that specific debris items could be related to specific point sources. From this previous study, a sampling protocol was developed to identify and track other point sources of pollution.

In July 1992, large quantities of marine debris washed onto park beaches. After analysis, it was determined that the majority of this debris included 11 specific debris items. These items are listed as follows:

- rubber gloves
- onion sacks
- salt bags
- one gallon bottles
- condiment bottles
- beverage cans
- bleach bottles
- wood discs
- egg cartons
- light bulbs
- oil filters

Prior to July 1992, quarterly surveys have not indicated the presence of large numbers of these 11 specific debris items.

In June 1993, in preparation for the opening of the inshore shrimping season, the park cleared all debris items from eight miles of beach. When the shrimping season opened on 6 July 1993, park staff surveyed the eight miles of beach daily for the 11 specific items. This survey was conducted until September 1993.

Various methodologies were utilized in an attempt to determine the best protocol to obtain quantifiable data which would indicate the effectiveness of MARPOL

Annex V regulations. The park utilized volunteers and paid employees, an assortment of transect sizes, various cleaning frequencies, and several debris cleaning methods. It was determined that site preparation involving beach cleaning and flagging must be completed before surveying each site.

RESULTS

After analysis of four quarterly surveys, it was determined that all quarterly surveys greatly underestimated the total amount of debris accumulation. These data suggest that quarterly surveys are not an accurate representation of 90 days of debris accumulation. Rather they appear to represent the amount of debris that was deposited from the preceding high tide and/or uncovered by other environmental influences (e.g. wind, rain).

Quarterly survey data also indicated that the Closed Beach (northern) sites had a larger number of debris items than the South Beach (southern) sites. Contrastingly, the data collected from daily surveys indicated that a greater amount of debris is deposited on the South Beach sites, than the Closed Beach sites.

The order of abundance ranking between the quarterly and the 90-day totals of daily data consistently varied. Consequently, any comparison between quarterly totals, daily totals, and their order of abundance ranking would be inaccurate.

As shown in Figure 4C.2, there is a marked variation in debris deposition between survey sites. This variation may be attributed to a variety of natural and anthropogenic factors. Based on this variation coupled with the analysis of data, the number of debris items at one particular site cannot be extrapolated for other areas of the beach.

As shown in Figure 4C.3, from 6/17/92 thru 9/14/92, the percentage of backshore debris, at four daily transects, varied from 28 to 45 percent. During the first two survey months, large amounts of debris were collected from the backshore areas daily. However, after the clearing of backshore areas over a 60-day period, there was a marked decline in the number of debris items remaining in all surveyed backshore areas. Currently, the amount of debris cleared from the backshore appears to have reached equilibrium and does not vary substantially on a daily basis.

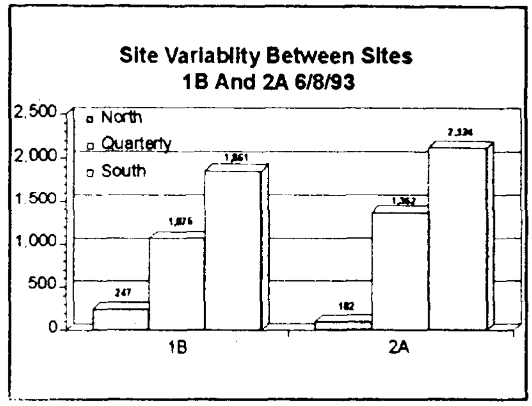

Figure 4C.2. Site variability 6/8/93.

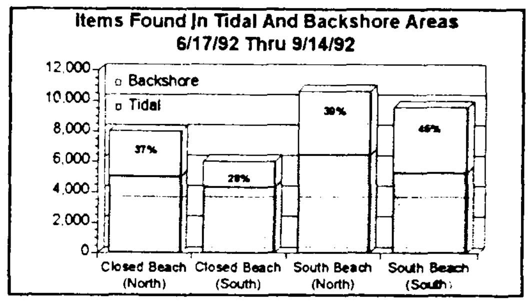

Figure 4C.3. A comparison of percentages of items found within the tidal and backshore areas.

The variation in the amount of backshore debris is attributed to the uncovering of large debris deposited over the past several decades (pre-MARPOL). Debris items are primarily uncovered as a result of environmental influences. The variation in the amount of backshore debris, cleared daily, is related directly to the frequency, duration, and magnitude of the wind, rain, and/or high tides.

As with variations in daily debris amounts, there is not a consistent monthly trend in environmental influences because of the significant role of environmental influences on deposition of marine debris.

The influences include:

- current changes
- tidal fluctuations
- wind speed
- wind direction
- wind duration
- rainfall amounts
- rainfall duration

Analysis of the point-source survey indicated that the shrimping industry is a contributor to GOM pollution. On several occasions, onion sacks washed ashore containing a variety of debris items. The items within the onion sacks were surveyed and found to correspond to six of the 11 specific items. Of these six items, three items are known to be utilized by the shrimping industry. These three items included wood discs, rubber gloves, and salt bags. Including the onion sack, the seven debris items were now matched to a specific source.

Four of the 11 specific items could not be directly linked to a specific source. However, because the four items had also been deposited onto the park's beach at the same locations and times, the park decided to include these items in the survey. Subsequently, these 11 identified items were divided into two categories. The items were categorized as suspected and probable.

Probable Shrimping Industry Related Items

- onion sacks
- rubber gloves
- wood discs
- egg cartons
- salt bags
- light bulbs
- one gallon bottles

Suspected Shrimping Industry Related Items

- oil filters
- condiment bottles
- bleach bottles
- beverage cans

These two categories were than tracked via daily surveys until 1 September 1993.

An increase in deposition of the 11 items appeared to correspond to the opening of the shrimping season, when numerous shrimp boats were observed parallel to the park's shoreline. At the end of August 1992, a marked decrease in the occurrence of these 11 items was noted. This decrease coincided with shrimping fleet movement away from the park's shoreline.

DISCUSSION

Several factors should be considered when planning an accurate survey of marine debris and its relevance to the enforcement of MARPOL Annex V regulations. These factors may include experimental design, data management, and multi-agency approaches and partnerships.

At PAIS, the most accurate survey interval is one day. Surveys conducted at intervals greater than one day will underestimate the amount and types of marine debris that is deposited along a particular stretch of beach. Also, sampling intervals greater than one day are inefficient for tracking point-source pollution and atypical events.

Survey sites must be thoroughly cleaned of all debris prior to initial data collection. Initial cleaning is paramount to insure data are indicative of post-MARPOL Annex V deposition. Due to tidal influences, many debris items are cycled back into the offshore currents and, subsequently, redeposited at another beach location. There is a possibility that redeposited debris may be counted multiple times, thereby resulting in an inflation of the data. For this reason, it is imperative that all debris items be removed form each transect, or survey area, after being counted, to prevent recounting errors.

At PAIS, a majority of backshore debris has accumulated over several decades and does not accurately represent newly deposited marine debris. The majority of backshore debris usually becomes uncovered as a result of fluctuating winds or rain. This debris is not indicative of post-MARPOL debris. If a marine debris survey is initiated to determine the effectiveness of MARPOL Annex V, then the backshore debris cannot be added to the database. For these reasons, at PAIS, previously collected marine debris data which combines both tidal and backshore debris are inaccurate and scientifically questionable in judging the effectiveness of MARPOL Annex V.

Alternatively, debris collected within tidal areas does provide representative data of post-MARPOL Annex V marine debris. However, should preliminary surveys indicate that pre-MARPOL debris is not present in the backshore of the transect, then surveys of debris deposition to the primary dunes should be initiated. Uncovering of the debris is usually a result of abnormally high tides.

To date, PAIS has collected 16 months of debris data from all quarterly and daily transects. PAIS data analysis has indicated that surveys should encompass a minimum of twelve consecutive months. This is due to the fact that debris deposition is variable and dependent on numerous factors. Twelve months of sampling is needed to quantify debris items from point sources and a typical events. If the objective of the debris survey is to determine the effectiveness of MARPOL Annex V, indiscriminate sampling frequency may result in erroneous data.

Mr. Sean Baker has worked at Padre Island National Seashore for the past two years and serves as a Resource Management Specialist, Division of Resource Management. In this position, his responsibilities include environmental compliance, development of planning strategies for managing the park's natural resources, and assisting in the coordination of the park's marine debris program. After receiving his B.S. degree in Maryland, Mr. Baker served three years with the Peace Corps in Yap, Micronesia.

INTRODUCTION TO THE SITE CLEARANCE ISSUE

Mr. Jerry Brashier
Minerals Management Service
Gulf of Mexico OCS Region

Legal and regulatory mandates require structures to be removed. Section 22 of the current oil and gas lease form [MMS-2005 (March 1986)] requires that within a period of one year after termination of the lease, the lessees shall remove devices, works, and structures from the premises that are no longer subject to the lease. Title 30 CFR 250.143 paragraphs a-c require that the lessee remove all structures in a manner approved by the Regional Supervisor, Field Operations; that all platforms be removed by the lessee to a depth of at least 15 feet below the ocean floor; and that the lessee verifies by appropriate means that the location has been cleared of all obstructions. Title 30 CFR 250.114 paragraphs a and b require that the lessee verify site clearance after abandonment, and certify that the area was cleared of all obstructions.

The site clearance issue arose in the late 1980s when shrimpers and the State of Louisiana complained that structure removal sites were not being properly cleared--that shrimp trawls were being damaged or destroyed and that shrimp catch was being lost.

In response to the complaints, the MMS Gulf of Mexico Regional Director established a site clearance committee to investigate and solve the problem. Committee members included shrimpers and one or more representatives from the Louisiana Department of Wildlife and Fisheries, the Offshore Operators Committee, the Jefferson Parish Environmental Department, the International Association of Drilling Contractors, and the MMS.

Several Notices to Lessees and Operators (NTL's) were developed and refined based on committee recommendations; the current NTL was published in May 1992. Site clearance requirements were based on committee recommendations and included:

1. Exploratory or delineation wells drilled with a mobile offshore drilling unit require a high frequency (at least 500 kHz) sonar search to be conducted over a 300-foot radius centered on the wells.

2. Platforms in water depths of 300 feet or less must have their locations trawled in two directions (e.g., north-south and east-west). The area to be covered is a 1,320-foot radius centered on the platform's geometric center.

3. Single well caissons and well protectors in water depths less than 300 feet require the locations be trawled in two directions. The area to be covered is a 600-foot radius centered on the wells.

Other requirements in the NTL include: Any shrimp caught during site clearance must be released; trawling times are limited to 30 minutes; and a procedural plan for site clearance verification of platforms must be developed and submitted to the MMS Regional Supervisor, Field Operations, for approval. There are additional requirements for trawling near pipelines.

In conclusion, "partnering" between committee members resolved the site clearance issue.

Mr. Jerry Brashier is Chief of the Environmental Operations Section, Leasing and Environment, MMS Gulf of Mexico OCS region. He has been employed by the federal government (U.S. Fish and Wildlife Service, Bureau of Land Management, and MMS) for over 16 years and worked for industry an equal number of years. Mr. Brashier received his M.S. degree in fisheries from Louisiana State University.

PLATFORM REMOVAL SITE CLEARANCE VERIFICATION

Mr. Michael J. Kinsella, P.E.
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INTRODUCTION

The "Site Clearance Verification by Trawling" technique has proven to be a highly effective means of confirming that the seafloor is free of trawling obstructions after a structure is removed.

The implementation of this methodology in the summer of 1990 on a trial basis quickly proved that previously relied upon techniques to verify a clean seafloor were not effective.

The results of the early trawling activity determined that significant amounts of debris remained on the seafloor, that sometimes very substantial objects were missed by inadequate verification processes, and that often times snags for trawl nets still existed at sites.

The use of shrimp trawl nets to verify that a site is free of snags has evolved into a dual role of actively clearing the site, as well as verifying that a site is "trawlable." The use of shrimp nets provides positive proof that a site has been left "trawlable."

Over the past four years much has been learned about the trawling verification process and several questions concerning current regulations have been raised specifically relating to unburied pipelines, snags and debris encountered outside the MMS trawl limits, and non-produced caisson removal verification requirements.

These questions will be examined in greater detail later in this presentation.

REVIEW OF TRAWLING REQUIREMENTS

The NTL 92-02 "Minimum Requirements for Site Clearance (and Verification) of Abandoned Oil and Gas Structures in the Gulf of Mexico" was issued 28 May 1992.

The regulation requires all abandoned well and platform locations to be cleared of all obstructions present as a result of oil and gas activities.

For clearance purposes, the locations are defined as follows:

1. Exploratory or delineation wells drilled with MODU - 300-foot radius
2. Platforms - 1,320-foot radius
3. Single well caisson and well protectors - 600-foot radius

The first type of site does not require trawling to verify that the site is clear. The second and third sites do require trawling for verification.

Platform and caisson sites located in less than 300-feet of water must be trawled over 100 percent of their limits in two directions (N/S, E/W).

The trawling contractor shall possess a valid commercial trawling license from one of the Gulf Coast states for at least the past two consecutive years.

The trawling vessel must be equipped with a precision navigation system.

The trawling vessel must be outfitted with trawling nets that are representative of the accepted shrimping industry standard of up to No. 18 twine (ribbon strength) size net strength. No Turtle Excluder Devices are to be used. Trawl nets are to be picked up after a maximum drag time of 30 minutes and all shrimp in the trawl released.

There are specific trawling restrictions addressed in the NTL for areas where pipelines, shipwrecks, or hangs are known to exist:

- No restrictions for abandoned pipelines.
- No trawling within 300-feet of any shipwrecks.
- No restrictions for buried active pipelines for which no above ground obstructions exist.
- For unburied active pipelines that are eight inches in diameter or larger, and for unburied smaller diameter lines that have obstructions (e.g., valves) present, trawling shall be carried out no closer than 100 feet to either side and in the same direction as (parallel to) the line. Trawling shall not be carried out across the line.
- For unburied active pipelines that are smaller than eight inches in diameter and have no obstructions present, trawling is to be carried out in the direction of the line and trawling on top of the line is acceptable. Trawling shall not be carried out across the line.

Trawling grid patterns shall be as follows for the trawling equipment specified:

- 40-foot grid pattern for vessels trawling with two 50- to 65-foot nets or four 30-foot nets.
- 60-foot grid pattern for vessels trawling with two 66- to 80-foot nets or four 31- to 40-foot nets.
- 80-foot grid pattern for vessels trawling with two 81-foot or larger nets or four 41-foot or larger nets.

The trawling activity report will include the following:

- Summary of Trawling Activity.
- Listing, with description, of all debris recovered.
- Equipment Damage Report.
- Navigation Post Plot.
- Certification Statement that site is trawlable by Captain and Inspector.

EQUIPMENT USED BY K C OFFSHORE:

K C Offshore uses two 90-foot steel hulled commercial trawl vessels to perform site clearance verification work. The vessels are equipped with twin engines, hydraulic steering, auto-pilot, radio and cellular communications, and living accommodations for six men. The vessels are Coast Guard Safety Inspected.

Each vessel tows a trawl net spread of four 55-foot nets and maintains an inventory of 20+ nets on board. Special equipment that is available includes 80-foot "Gorilla" nets, anchor chain, heavy duty winches, and cutting torches.

The survey navigation equipment consist of a Differential GPS (DGPS) satellite positioning system interfaced to a Sentinel Navigation Computer system. The DGPS positioning system has 5+/- meter accuracy and twenty-four hour per day coverage.

The development of the 80-foot Gorilla nets was in response to the operators' requests for a more cost-efficient means of cleaning debris from the seafloor. The previous options were to use divers or underwater magnets. With greater water depths, the cost of diving operations increase and the divers' bottom time decreases. By using two 80-foot "Gorilla" nets, which are constructed with No. 96 twine four-inch mesh net material, the seafloor can be swept to pick up and recover debris prior to the verification trawling. The 80-foot nets cover a wide swath and can literally clean up to twenty acres of seafloor in an hour.

EXPERIENCE:

K C Offshore, in association with Milton Dufrene & Son, and ALD Trawlers, Inc., has completed 140 site clearance verification projects over the past four years - 99 caissons sites and 41 platform sites.

SPECIFIC PROJECT EXPERIENCE AND PROBLEMS ENCOUNTERED:

A. Ship Shoal Area - 40-foot water depth

- 10 Caisson Sites
- 2 Caissons - No Snags

- 8 Caissons - 23 Snags
  17 Snags within 300-feet of structure
  4 Snags beyond 300-feet of structure
  2 Snags outside grid
- Total Project duration - 21 days

B. Eugene Island Area - 28-foot water depth

- 1 Caisson Site
- 12 Snags Total
  5 Snags within 300-feet of structure
  5 Snags beyond 300-feet of structure
  2 Snags outside grid
- Total Project Duration - six days
- 3 Nets Destroyed

C. South Timbalier Area - 131-foot water depth

- 1 Platform Site
- 7 Snags total
- 2 Snags within 300-feet of structure
- 5 Snags beyond 300-feet of structure
- Total Project duration - 27 days
- three Nets Destroyed

D. South Marsh Island/Vermilion Area - 25-foot water depth

- 3 Caisson Sites
- 1 Caisson - No Snags
- 2 Caisson - six Snags
  5 Snags within 300-feet of structure
  1 Snag beyond 300-feet of structure
- Total Project Duration - 10 days
- 3 Nets Destroyed

RESULTS AND FINDINGS:

- The trawling method of site clearance verification is definitely the best method available today to perform this work.

- With the utilization of the "Gorilla Nets" trawling has evolved to become an integral part of the clean-up process and sometimes the primary tool to be used.

ITEMS FOR FURTHER CONSIDERATION:

- Questions have been raised about unburied active pipelines in less than 200-feet of water. In general, the MMS regulations call for all pipelines to be buried three feet below the seafloor in less than 200-foot water depth. However, occasionally unburied active pipelines have been discovered and the trawling restrictions concerning avoiding active pipelines invoked. This is in compliance with the NTL, but still does not address the problem of the unburied pipeline presenting an obstacle to trawling.

- Caissons that have been installed, but the well never produced, are granted "Exploratory or Delineation Well" drill-site status. This means that no trawling is required when the caisson is removed.

- Snags and debris are sometimes encountered outside the required trawl grid area. Normally these items are reported in the Trawling Report, but there is no requirement to remove these items.

- Natural seafloor features, such as reef outcrop or slabrock, can cause considerable net damage even with no industry-related debris present. Clearing every line on a site such as this can result in extensive net damage, which increases the operator's cost of verification significantly.

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Kinsella, Cook & Associates is a full-service offshore surveying company and is one of the leaders in developing the site clearance trawling activities in the Gulf of Mexico.

SESSION 4D

LATEX III: HYDROGRAPHY OF THE LATEX SLOPE REGION

Session: LATEX III: HYDROGRAPHY OF THE LATEX SLOPE REGION

Co-Chairs: Dr. Murray Brown and Dr. Tom Berger

Date: December 16, 1993

Presentation	Author/Affiliation
Introduction	Dr. Murray Brown Minerals Management Service Gulf of Mexico OCS Region
Loop Current Eddy Shedding Cycle	Dr. Thomas Berger Science Applications International Corporation Raleigh, North Carolina
Repeated Observations of an Anticyclonic Loop Current Eddy in 1992	Dr. Doug Biggs Department of Oceanography Texas A&M University Dr. Giulietta Fargion Department of Marine Biology Texas A&M University at Galveston Mr. Ron Kozak NOAA National Data Buoy Center Stennis Space Center, Mississippi Dr. Peter Hamilton Science Applications International Corporation Raleigh, North Carolina
Surveys of Eddies U, V, and W with Expendable Probes and Drifters	Dr. Peter Hamilton Science Applications International Corporation Raleigh, North Carolina Dr. Giulietta Fargion Department of Marine Biology Texas A&M University at Galveston Dr. Doug Biggs Department of Oceanography Texas A&M University
Dynamic Topography of Eddies U, V, and W in 1992-93 from GULFCET, Aircraft, and Ship-of-Opportunity Surveys	Dr. Giulietta Fargion Department of Marine Biology Texas A&M University at Galveston Dr. Peter Hamilton Science Applications International Corporation Raleigh, North Carolina Dr. Doug Biggs Department of Oceanography Texas A&M University
Topex/Posiedon and ERS-1 Altimeter Data Analysis in the Gulf of Mexico: Verification of a "Climatological" Altimetric Mean Reference Surface	Dr. Robert Leben Dr. George H. Born Colorado Center for Astrodynamics Research University of Colorado, Boulder

LOOP CURRENT EDDY SHEDDING CYCLE

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INTRODUCTION

Knowledge of the Loop Current eddy shedding cycle has important ramifications for the offshore industry and for basic scientific understanding of circulation in the Gulf of Mexico and of stability processes in western boundary currents. Currently, the MMS and other agencies are involved in efforts to develop and verify numerical models of Gulf of Mexico circulation processes. Verification of the models' capabilities to replicate the eddy shedding cycle depends on knowledge of actual cycle.

One of the objectives of the Eddy Circulation Study has been to "monitor and characterize ... the eddy-shedding process and the behavior of Loop Current eddies ...." Certainly a part of any effort to monitor and characterize a process is to provide a unique identifier for individual manifestations of the process so that different observers can compare their efforts. Over the years, a number of different designation schemes for Loop Current eddies have been used including those developed by NOAA, MMS, and Horizon Marine, Inc. This effort began as an attempt to rationalize the various eddy designations and grew to develop an historical list of eddies over the past 20 years. The results presented are preliminary.

RESULTS

Data used were the NOAA Oceanographic Monthly Summary and Auer's paper derived from he same data set (Auer 1987); MMS Technical Reports (SAIC 1989); descriptive listings provided by Horizon Marine, Inc. and the offshore industry (K. Schaudt personal communication); GEOSAT altimetric climatologies provided by Dr. Robert Leben of the University of Colorado (Leben and Born 1993); and published and unpublished data provided by Dr. Fred Vukovich (Vukovich 1988; Vukovich personal communication). Data from the period 1 January 1981 through the present were used to compare names assigned to Loop Current eddies. Earlier data from Vukovich were added to these later data to make a 20-year timeline of the eddy shedding process.

The primary data source for the NOAA Oceanographic Monthly Summary and the Vukovich data is satellite IR imagery. There are many times when the Gulf of Mexico sea surface is obscured by clouds or there is minimal sea surface temperature (SST) range due to seasonal warming (summer, roughly May through October); thus detecting and tracking eddies in the SST signal is often difficult. Different designators have been frequently applied to eddies in the Oceanographic Monthly Summaries if there were long periods that the eddy was not observed. The designators discussed here are those assigned at the time the eddy formed.

Table 4D.1 shows the months an eddy is believed to be in process of separating from the Loop Current from January 1981 through June 1993 and the names applied in various sources. Names applied to the eddies are source coded: Oceanographic Monthly Summary (OMS), Horizon Marine (HM), Auer (A87), Vukovich (Vn, where n=0 in 1972), MMS programs (MMS SOOP or letter), GEOSAT data (L93 name) and industry programs (CASE). Multiple names indicate a speculation that all are the same feature observed at different times before eddy shedding was complete. An asterisk indicates an eddy not reported in Vukovich (1988).

Figure 4D.1 shows the preliminary timeline of eddy separations, where the eddy translated into the central and western Gulf of Mexico, extracted from the various data sources with the addition of data from 1972-1980 from Vukovich (1988 and personal communication) and SAIC (1989). The periods shown as eddy separation events are, in some cases, distillations or combinations of periods shown in Table 1. HM Steady Eddy, for example, was reported to have been adsorbed by the Loop Current and never translated westward.

Table 4D.1. Eddy Separation Month and Name.

Feb-Jun 81	OMS c (Feb-May); V10(Mar); MMS SOOP and A87 C (Feb); CASE 81b (Jun)
Oct-Dec 81	OMS f (Nov); A87 F (Oct); MMS SOOP (Dec, possible)
Jan 82	A87 E, CASE 82a
May-Jun 82	OMS e,f (different feature from Nov 81 f); V11 (May); A87 1F and CASE 82b (Jun)
Dec 83	A87 G
Mar-Apr 83	V12 (Mar) and A87 1I (Apr), MMS SOOP(possible)
Jul-Aug 83	MMS SOOP (Jul) and CASE 83b "ARCO" (Aug)
Dec 83-Feb 84	OMS j and A87 J(Dec);OMS k and A87 K(Jan); V13 (Feb)
Jul 84	MMS A (SOOP)
Jan-Apr 85	OMS m,o; HM Elusive; CASE E8585; MMS B (Apr)
Apr-Jul 85	V14 (Jul); HM Fast; V14 and L93 Fast (Jul)
Nov 85-Feb 86	OMS q,s; HM Hot (Nov); MMS C (Dec); V15 (Jan); L93 Hot (Feb)
Aug-Dec 86	OMS t; HM Instant and MMS D (Aug); V16 (Oct); L93 Krazy (Dec)
Apr-Aug 87	OMS u; HM Jupiter; MMS E
Oct 87-Jan 88	OMS v; V17 (Nov); HM Kathleen and L93 Lazy (Jan)
Mar-Jun 88	OMS x; HM L, Murphy (Apr); MMS F (Jun); V18 (May)
Aug 88	L93 Murphy
Feb-Mar 89	OMS y; HM Nelson, CASE Oggie
May-Jun 89	V19 (May), HM Oggie (Jun)
Aug-Sep 89	CASE Nelson (Aug); L93 Nelson (Sep)
Jan&Mar 90	OMS z
Jun-Sep 90	OMS a; CASE Quiet, HM Quiet (Jul); V20
Nov 90-Apr 91	OMS b (Jan); HM Steady
May-Sep 91	CASE Triton (May); HM Triton (Jul); V21 (Sep)
Mar-Jul 92	OMS e,f; HM Unchained and MMS U (May); V22 (Jul)
May-Jun 93	OMS h; HM and CASE Whopper and MMS W (Jun)
Sep-Oct 93	OMS i; HM Xtra (Sep); MMS X and CASE Xtra (Oct)

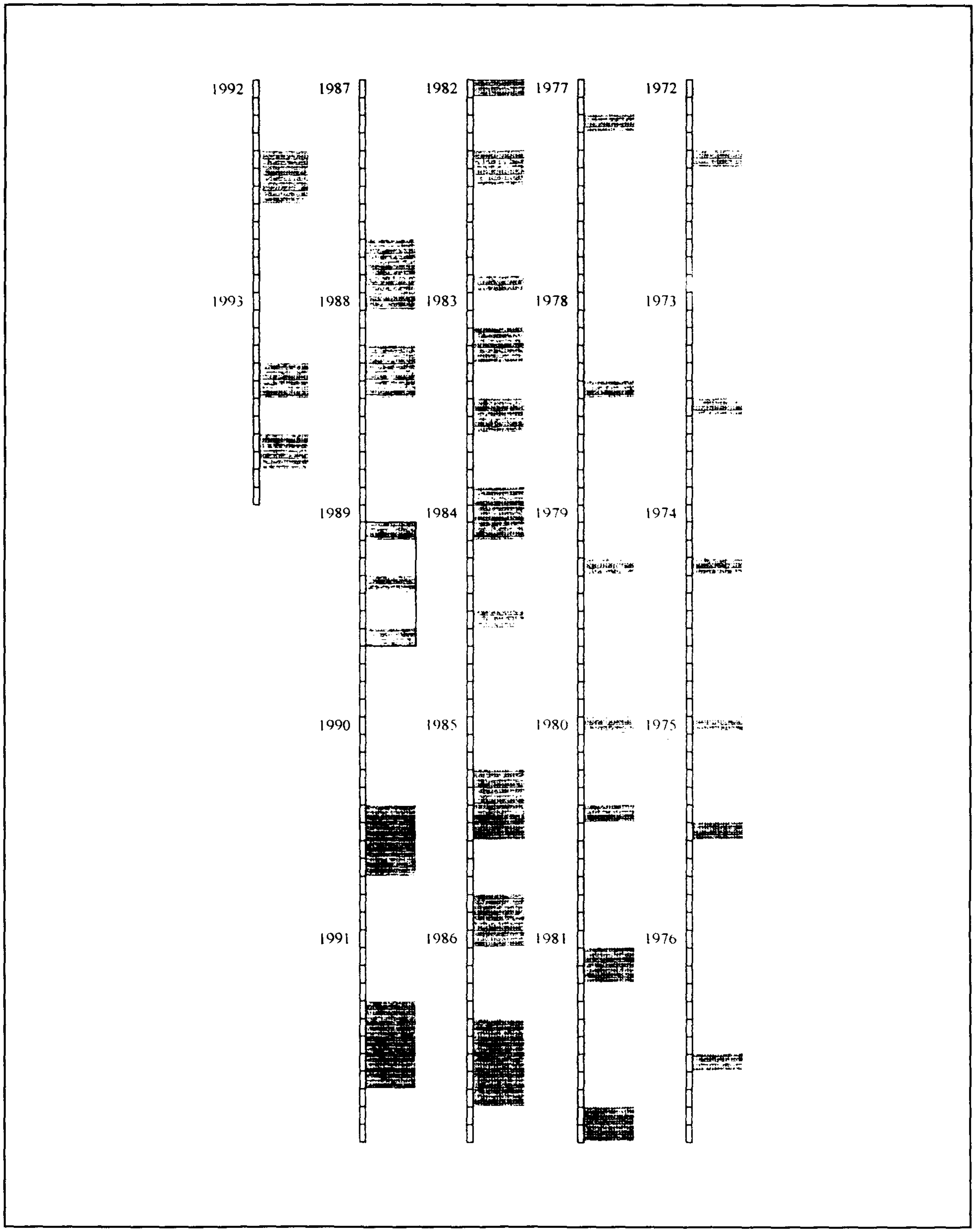

Figure 4D.1. Eddy shedding cycle 1972-1993. Shaded blocks indicate mouth of eddy separation from the Loop Current.

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Dr. Thomas Berger has been with SAIC in Raleigh, NC, since 1987. He is currently Program Manager of two MMS funded field programs. His research interests are in remote sensing of mesoscale processes. Dr. Berger received his B.A. in zoology from Catholic University in 1959, M.S. in physical oceanography from Naval Postgraduate School in 1970, and Ph.D. in physical oceanography from Old Dominion University in 1987.

REPEATED OBSERVATIONS OF AN ANTICYCLONIC LOOP CURRENT EDDY IN 1992

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SUMMARY

Eddy Triton, an anticyclonic eddy shed by the Loop Current in late June 1991, drifted WSW to collide in April-May 1992 with the continental margin of the western Gulf of Mexico. Because this collision took place concurrently with the start of GULFCET and LATEX. Eddy field programs, closely spaced CTD, XBT, and AXBT data allow a detailed look at the impact of this collision on the hydrography of the continental slope of the NW Gulf of Mexico.

After separating from the Loop Current in June 1991, Eddy Triton apparently re-connected and then detached again in summer-autumn 1991. In mid- and late summer 1991, when strong anticyclonic flow along the northern perimeter of this 250 x 150 km eddy encroached upon the upper continental slope off the Mississippi River delta, the offshore operations of a number of oil companies were adversely affected. As a result, this large, persistent Loop Current eddy was surveyed by a dozen industry-sponsored cruises from July to October 1991 (G.Z. Forristall communication).

After Eddy Triton's pull back from and subsequent drift WSW away from the Louisiana continental margin, industry surveys of this warm-core ring were suspended. However, a ship-of-opportunity transit across Eddy Triton in January 1992 shows that water

of Caribbean origin in the upper 250 m of this warm-core ring was mixing with adjacent Gulf water (Figure 4D.2), and combined ship, aircraft, and satellite data allow us to describe the subsequent westward progress of this eddy and its collision with the continental margin of the western Gulf of Mexico.

JANUARY-FEBRUARY-MARCH 1992

In late January 1992 and 7 months after Triton had formed, a Straits of Yucatan to Galveston ship of opportunity CTD + XBT transit made closely-spaced CTD + XBT stations in the eastern part of this warm-core ring from 25-27°N, 90-93°W. The 15°C isotherm of the main thermocline and the 8°C isotherm of the lower thermocline were both downwarped more than 100 m from the periphery to the interior of the ring. At this time, the eddy exhibited a geopotential difference of +25 to +30 dyn cm between interior and periphery relative to a reference level of 800 db, corresponding to a baroclinic mass transport of 9.6 Sv in the Loop Current remnant surrounding the interior. AVHRR imagery and Argos buoy trajectory data from February 92 show Triton was still a large-size elliptical eddy, measuring about 200 km N-S x 300 km W-E. Argos buoy #7493, which was deployed in Triton in late January 1992 by the National Data Buoy Center, described 5 anticyclonic loops within the ring in February and March, while the eddy was located in the central Gulf between 92°W and 94°W.

APRIL-MAY-JUNE 1992

In April 1992, the leading edge of Triton apparently contacted the continental margin of the western Gulf of Mexico. Argos buoy #7493, which was entrained near ring center, continued to make anticyclonic circles of ever decreasing diameter as it drifted slowly WSW. The first GULFCET CTD + XBT survey of the NW Gulf 15-21 April, an AXBT survey 6-7 May, and a ship of opportunity XBT survey 17 May - 4 June (Figure 4D.3) found that eddy shape deformed dramatically during this period of collision: the W-E (initially the principal) axis compressed to less than 150 km, while the N-S axis elongated to more than 400 km. Although the center-to-periphery difference in dynamic height remained +25 to +30 dyn cm and geostrophic transport about ring periphery remained about 10 Sv, during this interaction with the Mexican continental margin the eddy seems to have exchanged substantial mass and volume with the slope water (Figure 4D.2B, 4D.2C) and shed vorticity as cyclonic eddies.

JULY-AUGUST-SEPTEMBER 1992

The trajectory of Argos drifter #7493 from mid-July through mid-August indicates that after Triton collided with the continental margin of the western Gulf, what was left of this warm-core ring apparently "rebounded" to the north and east. The drifter continued to move anticyclonically, but the ellipses it described were now larger in size. Moreover, the ellipses measured greater in WE dimension (200-250 km) than in NS dimension (100-150 km). AXBT overflights of the LATEX slope 7-11 August, followed by GULFCET cruise 2 from 10-25 August, crossed into the northern part of the remnants of Eddy Triton near 26.2°N along 95.1°W. CTD casts here confirmed that Triton could still be distinguished by the signature of its Caribbean Water subsurface salinity maximum (36.54-36.56 PSU; Figure 4D.2D). The ship and aircraft also surveyed a cyclone 150 x 100 km in size that was located NE of Triton over the LATEX slope between 26.5°N and 27.5°N, 92.5°W to 94.5°W. It appears that an additional cyclone was located WNW of Triton, for the surface flow convergence which would be set up by a cyclone-Triton pair with such geometry apparently created an offshelf "squirt" of cool coastal water that persists for about two weeks in AVHRR imagery 2-18 July. Further interpretation from AVHRR imagery is problematic, though, because surface waters of the western Gulf were nearly isothermal for the rest of July and August 1992. Moreover, with the passage of Hurricane Albert through the western Gulf 25-27 August, Argos drifter #7493 detrained from Eddy Triton. The buoy was subsequently captured by the cyclonic circulation to the NE of Triton, in which it moved counterclockwise and north to reach 27.5°N, 93.0°W before it ceased transmitting in mid September.

OCTOBER-NOVEMBER-DECEMBER 1992

By the time that the NW corner of the Gulf was next surveyed, the remnants of Eddy Triton had either dissipated over the NW slope, or they merged with or were squeezed into the SW Gulf by incoming Eddies U and V. GULFCET cruise three, which surveyed the LATEX slope from 8-22 November 1992, found that one of these two incoming Loop Current eddies (Eddy V) had taken up position in the NW corner of

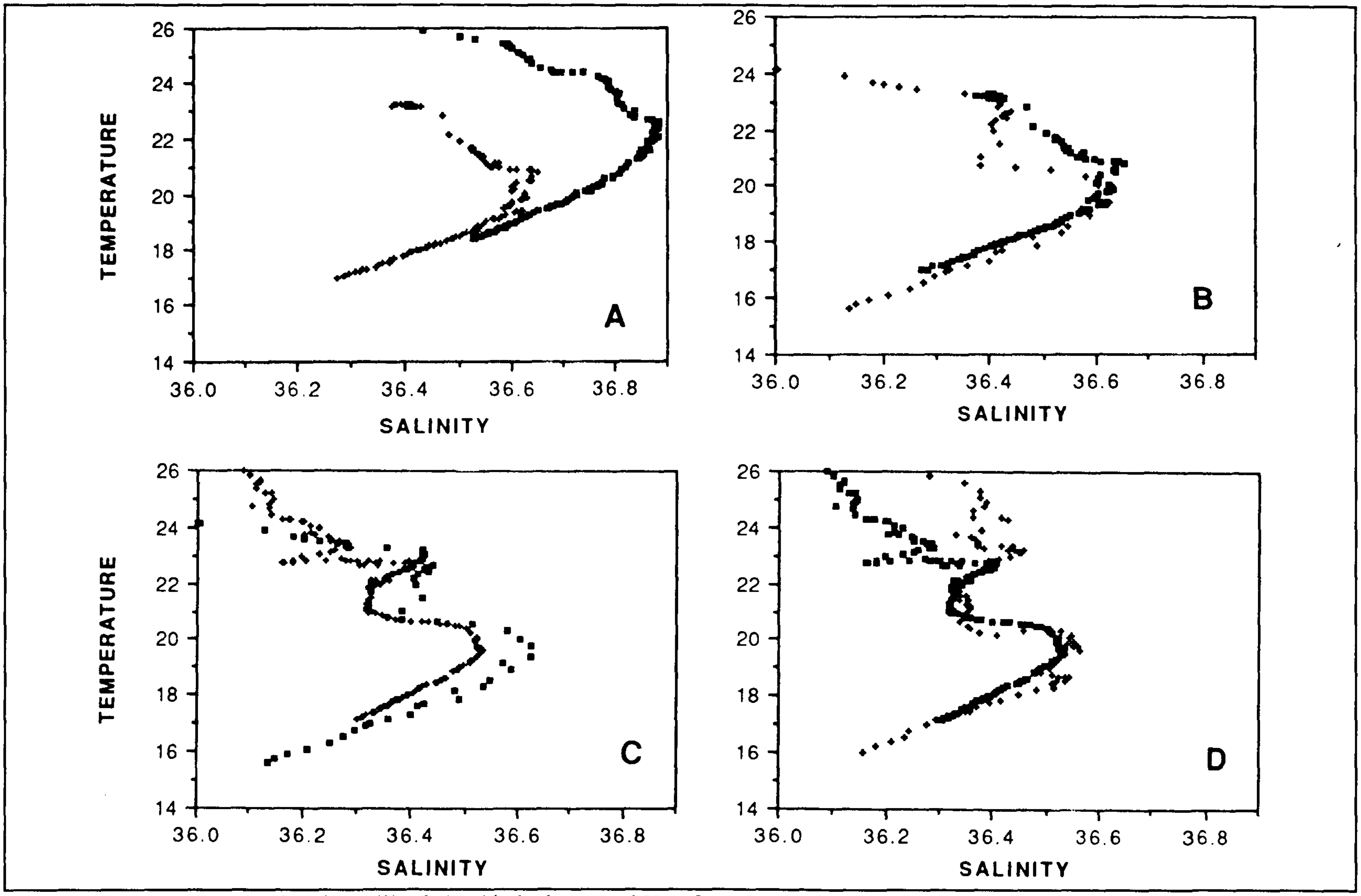

Figure 4D.2. Temperature-Salinity (T/S) relationship in the upper 250 m from Conductivity-Temperature-Depth (CTD) casts of opportunity in Eddy Triton: A) In late January 1992, 7 months after this warm-core ring separated from the Loop Current (+), compared to the Caribbean source water for the Loop Current in the Straits of Yucatan (squares); B) In mid-April 1992, at age 11.5 months (+), versus age 7 months (squares); C) In late June 1992, at age 13 months (+), versus age 11.5 months (squares); D) In late August, at age 15 months (+), versus age 13 months (squares).

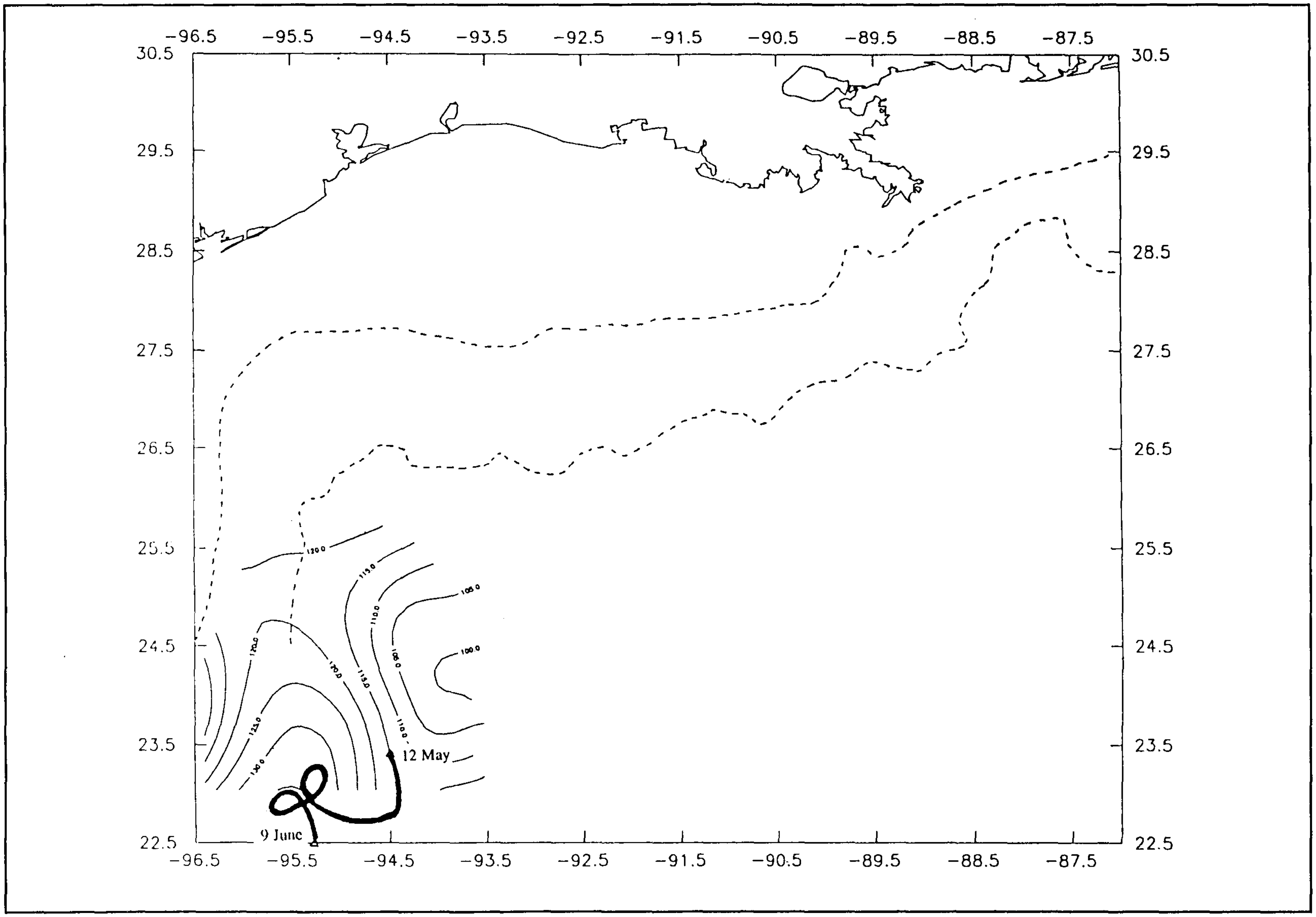

Figure 4D.3. Dynamic topography (relative to 800 db) from ship-of-opportunity XBT survey 17 May to 4 June 1992, during collision of Eddy Triton with the continental margin of the western Gulf of Mexico. The 500 m and 2000 m depth contours are shown by dashed lines; the trajectory of Argos drifter 7493 for 12 May - 9 June (JD 133-161) is shown by the heavy solid line.

the Gulf. Called "Eddy Vazquez", this new warm-core ring was characterized by salinity >36.8 PSU in the subsurface salinity maximum. The rotation, translation, and dynamic height and geostrophic transport associated with these new Loop Current eddies is described in the two papers which follow (Hamilton *et al.* ITM'93); Fargion *et al.* ITM'93).

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Hamilton, P., G.S. Fargion, and D.C. Biggs. 1993. Surveys of Eddies U, V, and W with expendable probes and drifters. Proceedings MMS-ITM'93.

Dr. Douglas C. Biggs, an Associate Professor in the Department of Oceanography at TAMU, served as Program Manager for the MMS-TAMU Ship-Of-Opportunity Program 1989-1993. He received his Ph.D. in 1976 from the MIT-WHOI Joint Program in Oceanography.

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Dr. Peter Hamilton is a Senior Oceanographer at Science Applications International Corporation, Raleigh, North Carolina. Over the last 10 years, Dr. Hamilton has been studying circulation processes over the continental slopes and rises of the Gulf of Mexico and the Middle and South Atlantic Bights. Dr. Hamilton has a Ph.D. in physical oceanography from the University of Liverpool.

SURVEYS OF EDDIES U, V, AND W WITH EXPENDABLE PROBES AND RIFTERS

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INTRODUCTION

Between August 1992 and August 1993, three Loop Current anticyclonic eddies were surveyed by air deployed XBTs and XCPs and tracked using deployments of ARGOS lagrangian drifters. These LATEX C surveys were largely event driven; however, additional hydrographic data was obtained from seasonal surveys of the Louisiana Texas continental slope (the Gulfcet program - Fargion *et al.* 1993) and a number of ship-of-opportunity (SOOP) transects (Biggs *et al.* 1993) across the slope and deep basin.

RESULTS

Eddy U was initially a large (~ 300 km diameter) vigorous Loop Current eddy probably formed in the early summer of 1992. In Figure 4D.4, drifter 02447 made one circuit of the eddy in late August 1992 and then was entrained in a smaller anticyclonic eddy situated over the base of the slope at about 92.5°W. This smaller anticyclone was named eddy V and its formation is uncertain. The northern edge of eddy V (or possibly the combined eddies U and V) was observed in the Gulfcet 02 cruise in the middle of August 1992 about one degree east of the position indicated by drifter 02447 in Figure 4D.4. The separation (at Station 11; Figure 4D.4) between eddies U and V was confirmed by an AXBT transect on 11 October 1992 and a SOOP transect about a month later. Eddy U was seeded at the beginning of November with drifter 02449. Thus, between August and November 1992, eddy U had remained in much

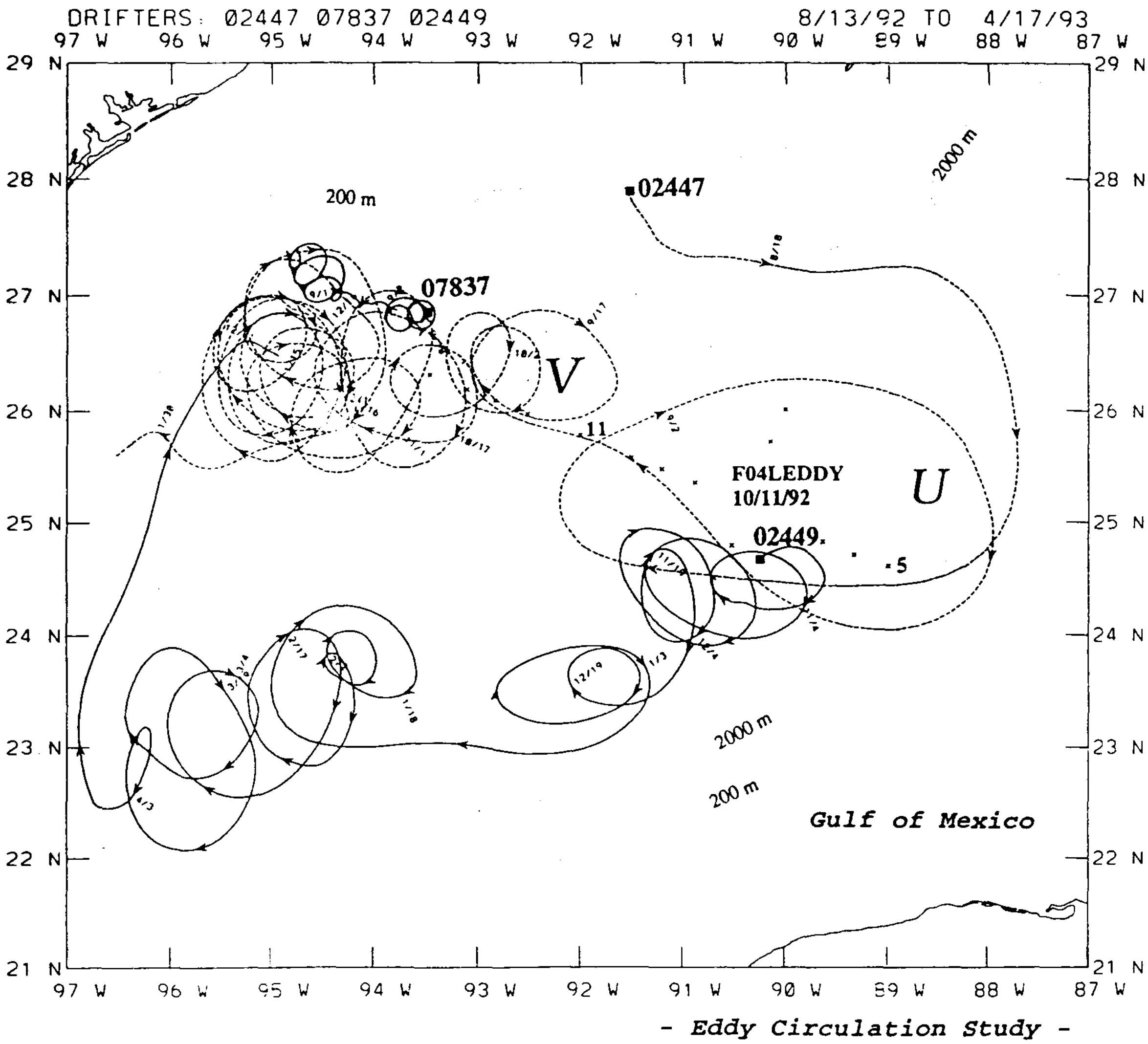

Figure 4D.4. Smoothed tracks for the indicated drifters. Arrow heads are positioned every five days and alternative arrows are marked with month and day (00 hours GMT). The station positions for the F04LEDDY AXBT survey of eddies U and V are indicated with small crosses.

the same position at about 91°W (Figure 4D.4). Eddy U subsequently moved to the southwest as tracked by drifter 02449.

During this September-to-December 1992 time period, eddy V moved westward along the base of the slope. At the same time a cold cyclonic eddy that was observed on the middle to lower slope at about 93.5°W in the Gulfcet 02 cruise and an AXBT survey in August 1992 was seeded with drifter 07837 (Figure 4D.4). This cyclone moved to the west preceding the advance of eddy V. After its arrival in the northwestern corner at about 95°W, eddy V was surveyed a number of times between mid-November 1992 and May 1993. In the latter half of December 1992, eddy V moved abruptly from the base of the slope (2,000 m isobath) northward onto the lower slope. The depth of the 15°C isotherm remained at ~350 m in the center of the eddy with maximum swirl speeds of about 65 cm/s and an eddy diameter ~100 km. However, the rotational period increased from ~7 to ~10 days during December 1992. Figure 4D.5 shows the depth of 15°C isotherm at the beginning of January 1993 and Figure 4D.6, the eddy velocities derived from smoothed drifter tracks and XCPs. The XCP velocities are averaged vertically from the surface to the depth of 15°C isotherm and from the 15°C isotherm to the bottom in order to remove effects of small scale fluctuations in the instantaneous velocity profile caused by internal waves. Above the thermocline, the averaged XCP velocities are reasonably consistent with the velocities derived from drifter tracks. Below the thermocline, the flows are about 20 cm/s, directed across the isobaths towards the deepwater, and extend to the bottom in more than 1,000 m water depth. This indicates a substantial flow below the eddy, which also implies that downwelling may occur at the shelf edge. Similar deep offshore flows were observed below eddy V from XCP velocity profiles measured in May 1993, indicating that these flows could be important to the dynamics of eddies over slope topography. In May 1993, eddy V was similarly situated to Figure 4D.5, but the 15°C isotherm depth had decreased to about 280 m. Swirl speeds were still about 60 cm/s. There are indications from Gulfcet cruise 04 in February and a short drifter track in March 1993 that eddy V may have undergone a southwards excursion to the lower slope between the January and May 1993 AXBT surveys. During May and June 1993, drifter 06938 (Figure 4D.7) shows that eddy V drifted further west to about 96°W. Further surveys from the summer and fall of 1993 should give further information on the history of eddy V and will be analyzed in the future. However, the robust and long-lived nature of the eddy circulation in the northwest corner of the Gulf slope is a noteworthy feature of this data.

Eddy W was formed from the Loop Current in June 1993. Drifter 02448 (Figure 4D.7) shows the eddy moved westward along the base of the slope to about 92°W. At this point, the eddy and the surrounding slope were surveyed with AXBTs at the beginning of August 1993. The survey shows a relatively small elongated eddy very similar to eddy V in September of 1992 (Figure 4D.4). The depth of the 8°C isotherm (Figure 4D.8) shows the anticyclone interacting with a cyclonic cold eddy on the lower slope at about 93°W. Drifter 06938 make an anticlockwise circuit of this cold eddy at this time (Figure 4D.7). The interaction causes the deeper sections of eddy W to be forced up onto the middle slope (Figure 4D.8). Immediately after this interaction, eddy W moves rapidly away from the slope in a SSW direction. This is a completely different track to that of the similar eddy V which remained close to the northern slope in its journey across the Gulf (compare Figures 4D.4 and 4D.7).

SUMMARY

Three Loop Current anticyclonic eddies were surveyed with air-deployed expendable probes (AXBTs and AXCPs) and ARGOS drifters. These measurements were complemented by ship-based hydrographic surveys from the Gulfcet and Ship of Opportunity programs. Eddies U and V were first surveyed in the Central Gulf in August and September of 1992. Eddy U moved to the southwest towards the Mexican slope, but Eddy V moved westward along the base of the Louisiana and Texas slope. Eddy V moved abruptly into the NW corner of the Gulf in December 1992 and remained in this region until at least the summer of 1993 with only a slow decrease in the depth of the 15° and 8°C isotherms at its center. Eddy W, formed in June 1993, was similar in size and characteristics and position to Eddy V. It apparently interacted with a cold cyclonic eddy on the lower northern slope at about 93°W and subsequently moved rapidly towards the SSW into the western deep basin of the Gulf.

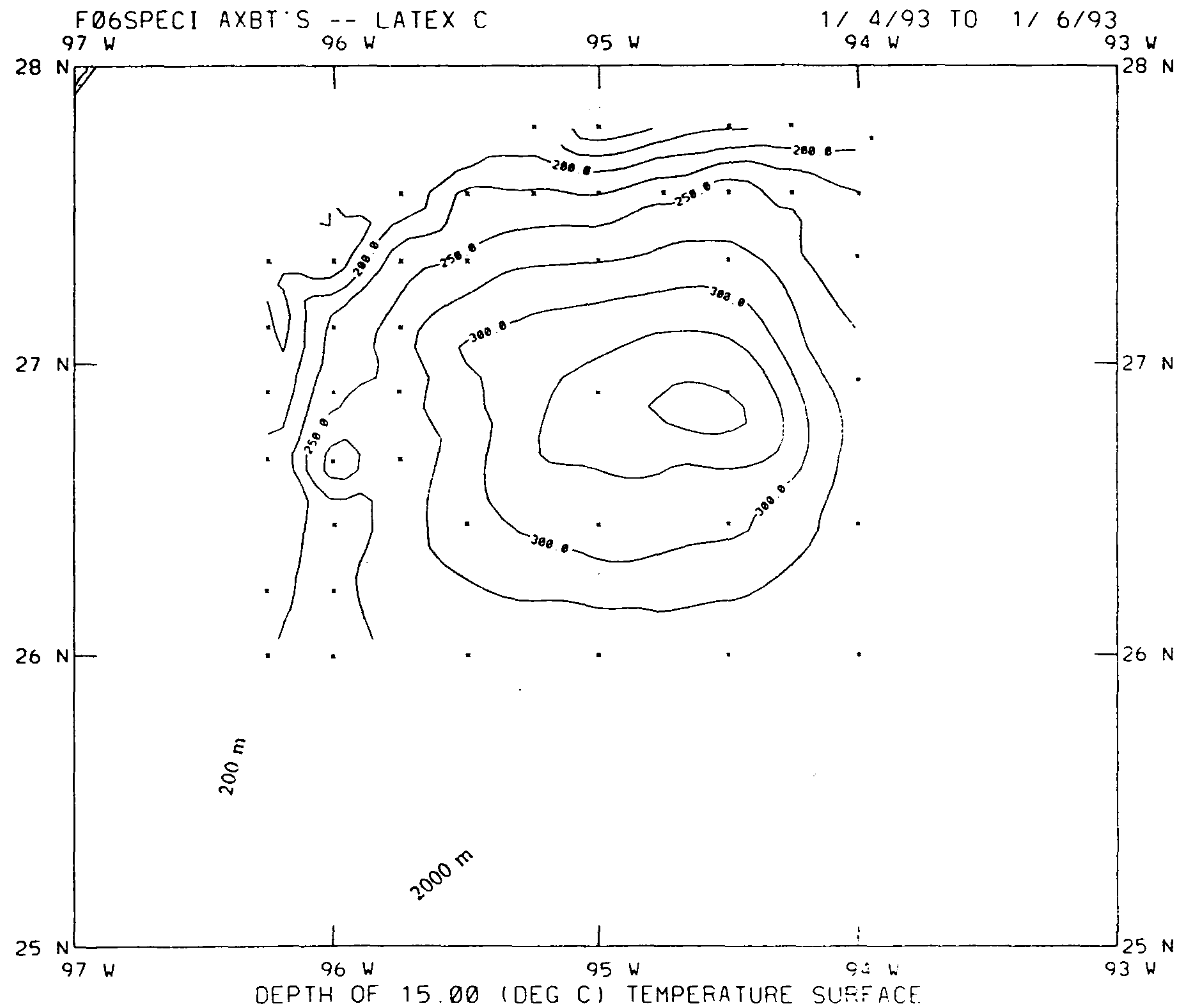

Figure 4D.5. The depth of the 15°C isotherm from F06SPECI AXBT survey of eddy V.

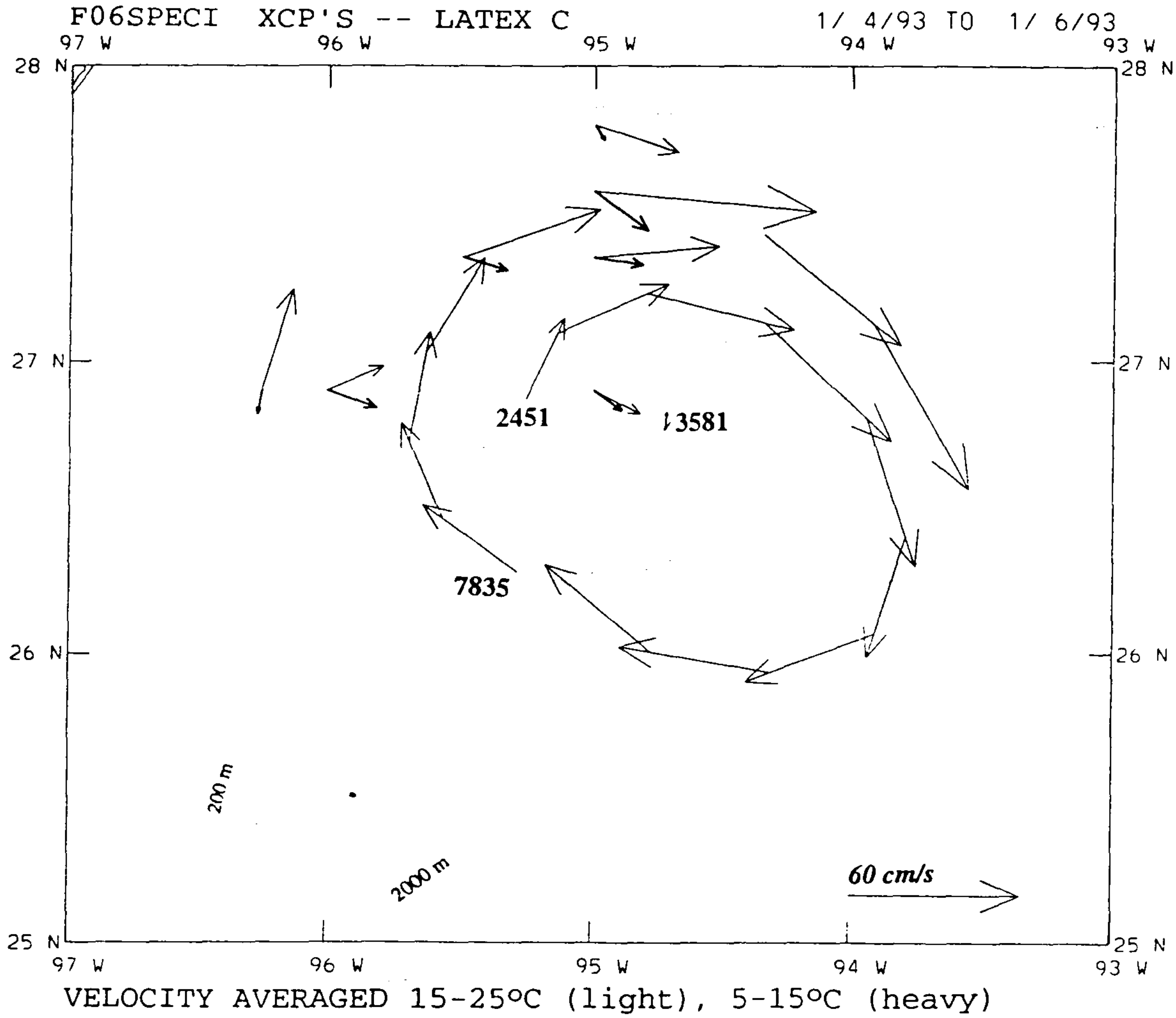

Figure 4D.6. Velocity vectors at daily intervals derived from the indicated smoothed ARGOS drifter tracks in eddy V. Positions with thick and thin arrows are depth averaged velocities derived from AXCP profiles.

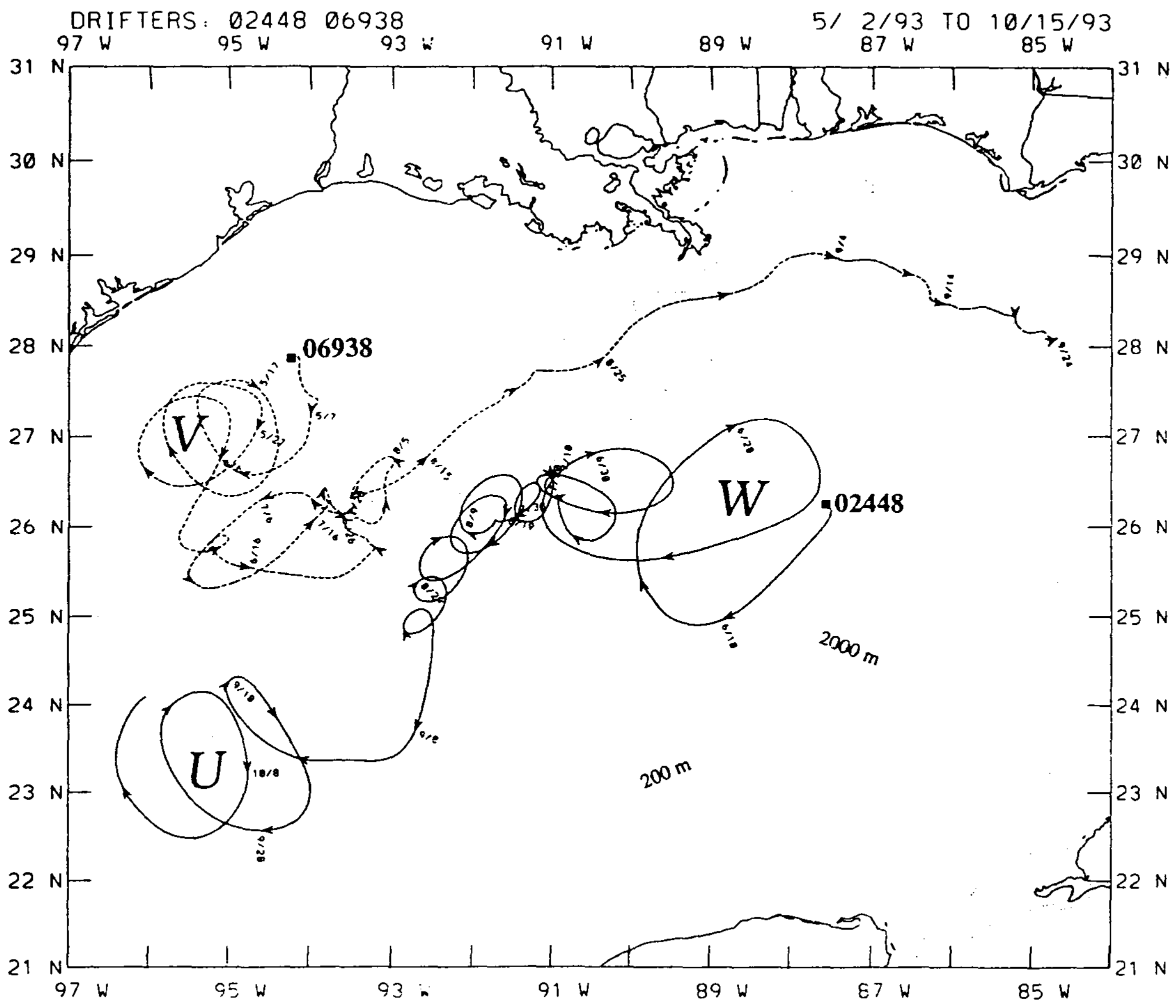

Figure 4D.7. Smoothed tracks for the indicated drifters. Drifter 02448 was deployed in eddy W and 06938 is initially in eddy V.

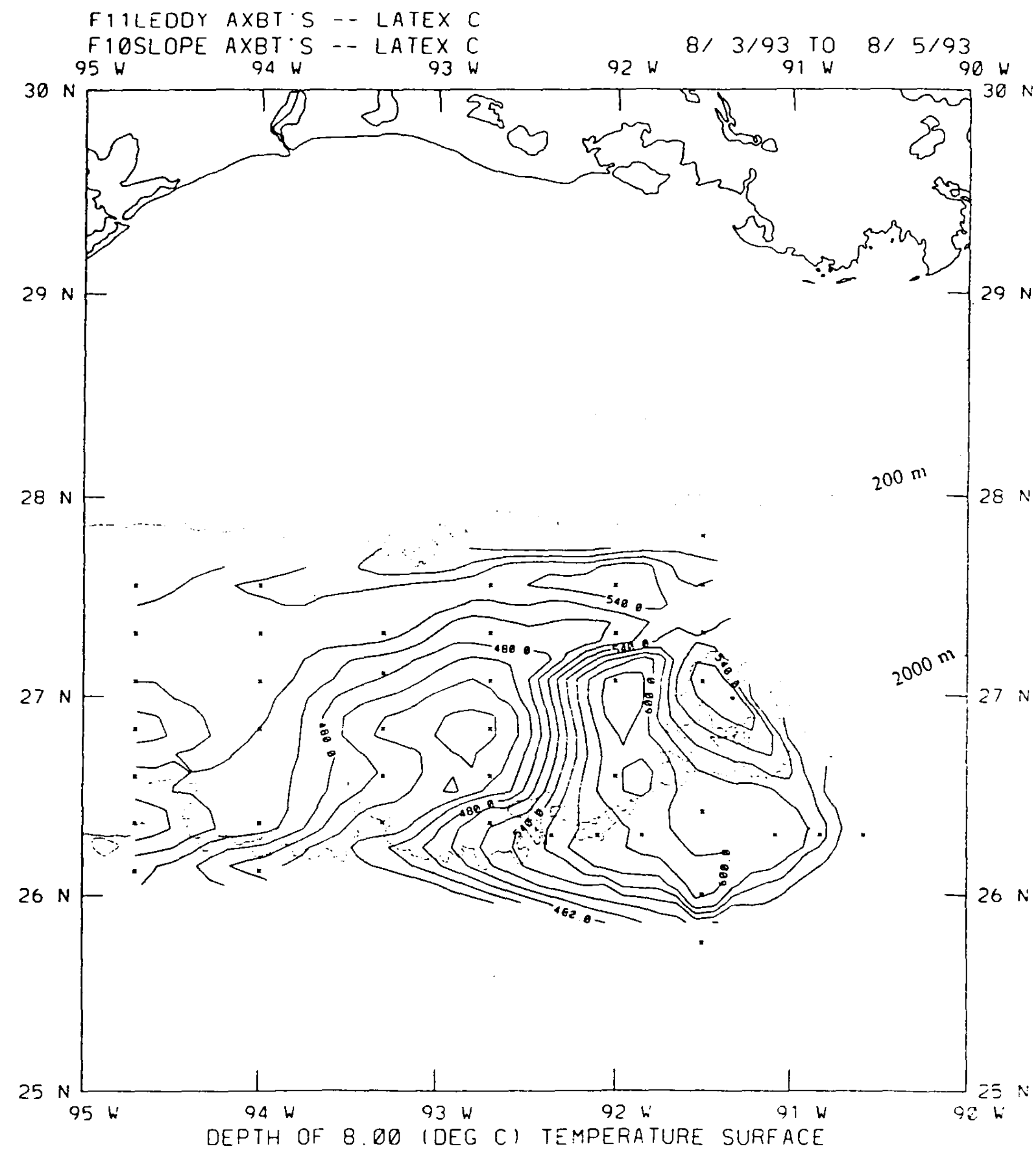

Figure 4D.8. The depth of 8°C isotherm from F10 and F11 AXBT surveys of the slope cyclone and eddy W.

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DYNAMIC TOPOGRAPHY OF EDDIES U, V, AND W IN 1992-93 FROM GULFCET, AIRCRAFT, AND SHIP-OF-OPPORTUNITY SURVEYS

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SUMMARY

Six GulfCet plus three ship-of-opportunity shipboard surveys were combined with eleven LATEX-C aerial surveys in 1992-1993 to allow a detailed look at the time evolution of Loop Current anticyclonic eddies: eddies Unchained ("U"), Vazquez ("V") and Whopper ("W").

INTRODUCTION

Dynamic height of the three anticyclonic eddies shed by the Loop Current in 1992-1993 has been computed by merging six seasonal ship surveys (GULFCET) and three ship-of-opportunity (SOOP) with 11 aerial surveys (Latex-C). The size, location, translation and depth of eight, 15 and 20° isotherms associated with eddies "U", "V" and "W" have been described by previous speakers and will not be examined here (Hamilton *et al.* ITM'93; Berger ITM'93). Instead, this report will focus on summarizing the geopotential anomaly (Dynamic height and Sverdrup transport) of the three rings. The GULFCET hydrographic program was designed to resolve meso-to-large scale circulation features in support of the only study of the distribution and abundance of marine mammals in the north-central Gulf of Mexico. While the Latex-C aerial survey and the ship-of-opportunity survey were designed to sample slope eddies in northwest corner of the Gulf of Mexico, the GULFCET area of study extends from the Florida-Alabama border to the Texas-Mexico border between the 100 and 2,000 meter isobaths.

METHODS

GULFCET raw XBT data were processed with an in-house conversion program using Sparton's drop rates. XBT drop rate was corrected using the method of Singer (1990), by empirically calculating the CTD-XBT Depth Difference (m) as a function of T-7 Isotherm Depth for the stations where both CTD and XBT data were obtained. The first order empirical fit was $y = 0.047x - 2.9$, so a depth adjustment of $x = (1.047x) - 3$ m was done on the all XBT data (GULFCET XBTs and AXBTs).

All XBT temperature data (GULFCET XBT stations and AXBTs) reflect this depth correction before the eight, 15 and 20°C were plotted. LATEX-C slope surveys were grouped by month (i.e., F02 with F03) and the resulting isotherms were compared with those of GULFCET cruises nearest in time. If the two data sets, GULFCET and LATEX-C, were consistent in space we proceeded to compute geostrophic circulation fields for LATEX-C data using GULFCET CTD data.

XBT data were combined with the CTD data to compute local geostrophic circulation fields. A micro VAX 3,600 computer was used for the calculations of dynamic height and mass transport/geostrophic velocity between station pairs, as described by Biggs *et al.* (1990). All of our geopotential computations for LATEX-C and GULFCET cruises 01-04, and 06 are referenced to the 800 dbar surface. Hofmannn and Worley (1986) have shown empirically that the choice of an 800 to 850 dbar reference level should allow baroclinic transport calculations to be in the mass balance throughout the western GOM. Their model is supported by transport calculations for anticyclone eddies (Biggs 1992).

PRELIMINARY RESULTS

Twenty surveys were analyzed in the Gulf of Mexico from August 1992 to 5 September 1993 (Table 4D.2). Table 4D.2 summarizes the survey dates, the depth of the 8°C isotherm and the dynamic height computed at 800 dbar reference level. During the GULFCET cruise 02, new eddy "U" as well as old eddy Triton were present in the central area and west corner of the Gulf. Eddy Triton had a dynamic height of 125 cm while that of moving eddy "U" was greater than 140 dyn cm. Figure 4D.9 is a composite for August 1992, to illustrate GULFCET 02 dynamic heights with LATEX A drifter track number 2447. Eddies "U" and "V" were seen in October by the eddy survey 04 and by the Gyre (for values see Table 4D.2). In November 1992 eddy "V" had a dynamic height greater than 140 dyn cm (Figure 4D.10); in January 1993, a dynamic height greater than 135 dyn cm Figure 4D.11; and in February 1993, a dynamic height around 125 dyn cm (Figure 4D.12). A complex temperature topography was seen in the spring cruises, eddy "V" was present in the slope survey 08 and eddy 09 survey, but on the following survey, GULFCET 05 eddy "V" moved on the Texas-Louisiana shelf. In early August 1993, the NW side of eddy "W" was detected with a dynamic height around 135 dyn cm (Figure 4D.13). Later on GULFCET cruise 06, the north side of eddy "W" had a dynamic height around 120 dyn cm. Also in the same cruise, eddy "X" was detected with a dynamic height higher than 145 dyn cm (Figure 4D.14).

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Table 4D.2. Summary table of the GulfCet and ship-of-opportunity shipboard and LATEX-C aerial surveys.

Cruise ID	Date	Comments	8°C isotherm depth (m)	Dyn. Height at 800 dbar
F02 Slope F03 Eddy SAIC	8/7/1992 8/9/1992	Eddy "U"	550 m	115 cm
GulfCet 02 TAMUG	8/10-24/1992	NW corner of Eddy (U)	600 m	> 135 cm
F04 Eddy SAIC	10/11/1992	Eddy "U" & Eddy "V"	both > 675 m	
Gyre 92G-13 SOOP	10/28-31/1992	Eddy "U" & Eddy "V"	718 m 656 m	157 cm 142 cm
GulfCet 03 TAMUG	11/8-22/1992	Eddy "V"	650 m	140 cm
F05 Eddy SAIC	12/19/1992	Eddy "V"	650 m	
F06 Speci F07 Slope SAIC	1/4/1993 1/6/1993	Eddy "V"	> 650 m	135 cm
Gyre 93G-01	1/9-12/1993	Eddy "V"	678 m	133 cm
GulfCet 04 TAMUG	2/12-27/1993	Eddy "V" & "no name" Eddy	625 m 600 m	125 cm 110 cm
F08 Slope F09 Eddy SAIC	5/12/1993 5/16/1993	Eddy "V" moving inshore	600 m	
GulfCet 05 TAMUG	5/23 - 6/5/1993	Eddy "V" moved inshore		
Gyre 93G-07 SOOP	6/1-4/1993	Eddy "W"	788 m	170 cm
F010 Slope F011 Eddy SAIC	8/3/1993 8/4/1993	Eddy "W"	625 m	135 cm
GulfCet 06 TAMUG	8/28 - 9/5/1993	North side Eddy " W " & Eddy "X"	575 m > 675 m	125 cm > 145 cm

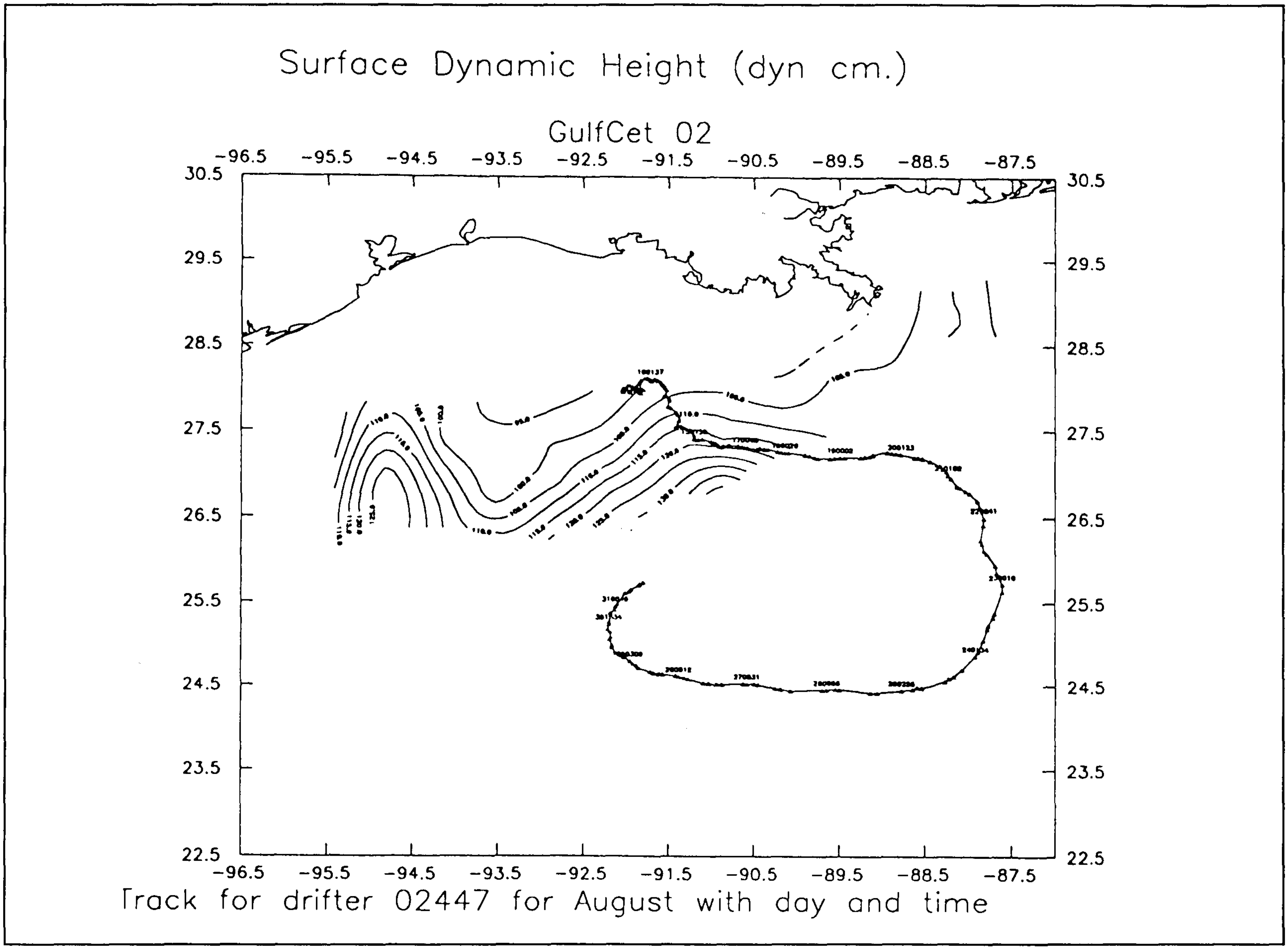

Figure 4D.9. August 1992: GulfCet 02 surface dynamic topography (cm) with respect to 800 dbar with LATEX A drifter track number 2447.

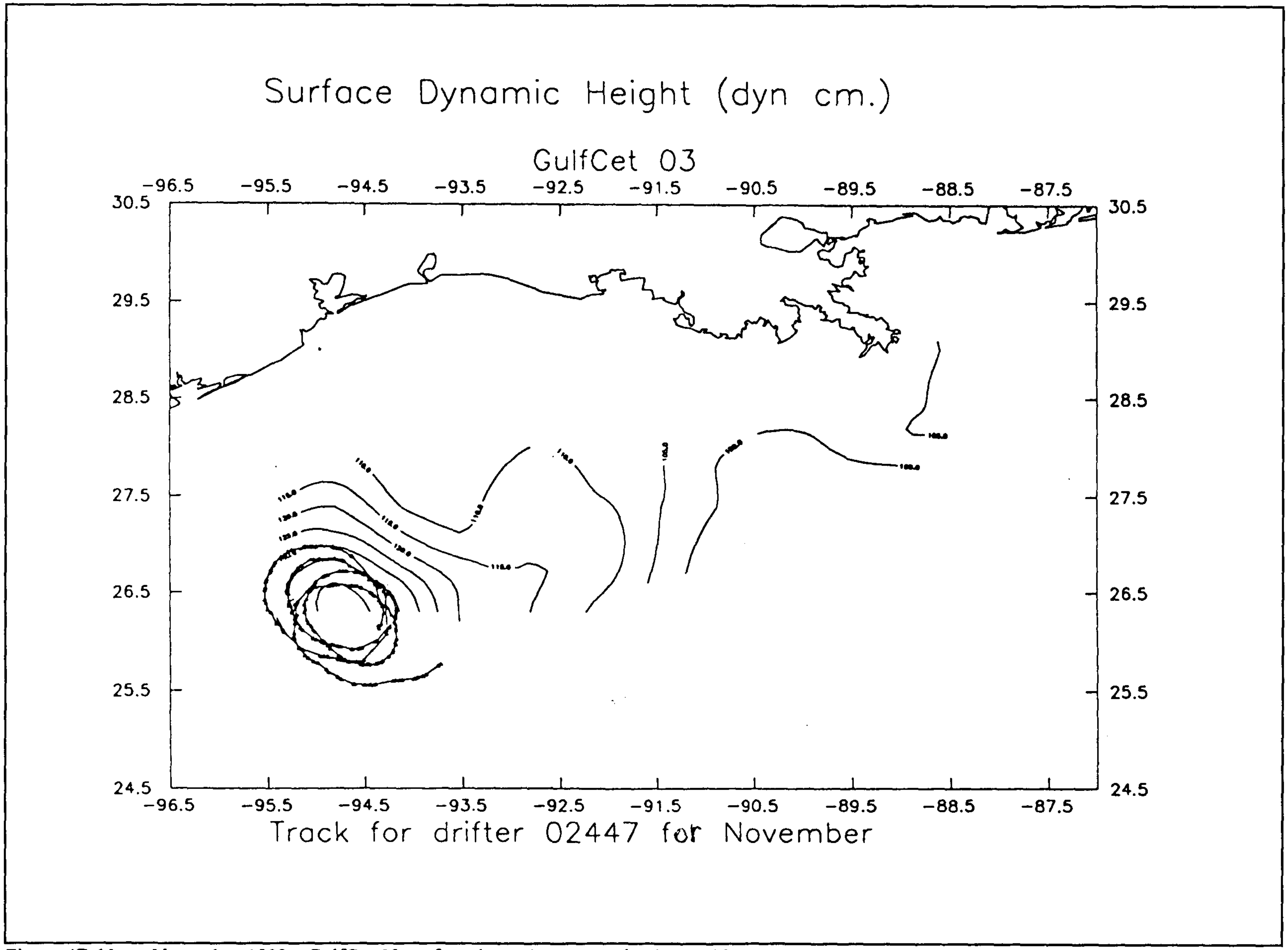

Figure 4D.10. November 1992: GulfCet 03 surface dynamic topography (cm) with respect to 800 dbar with LATEX A drifter track number 2447.

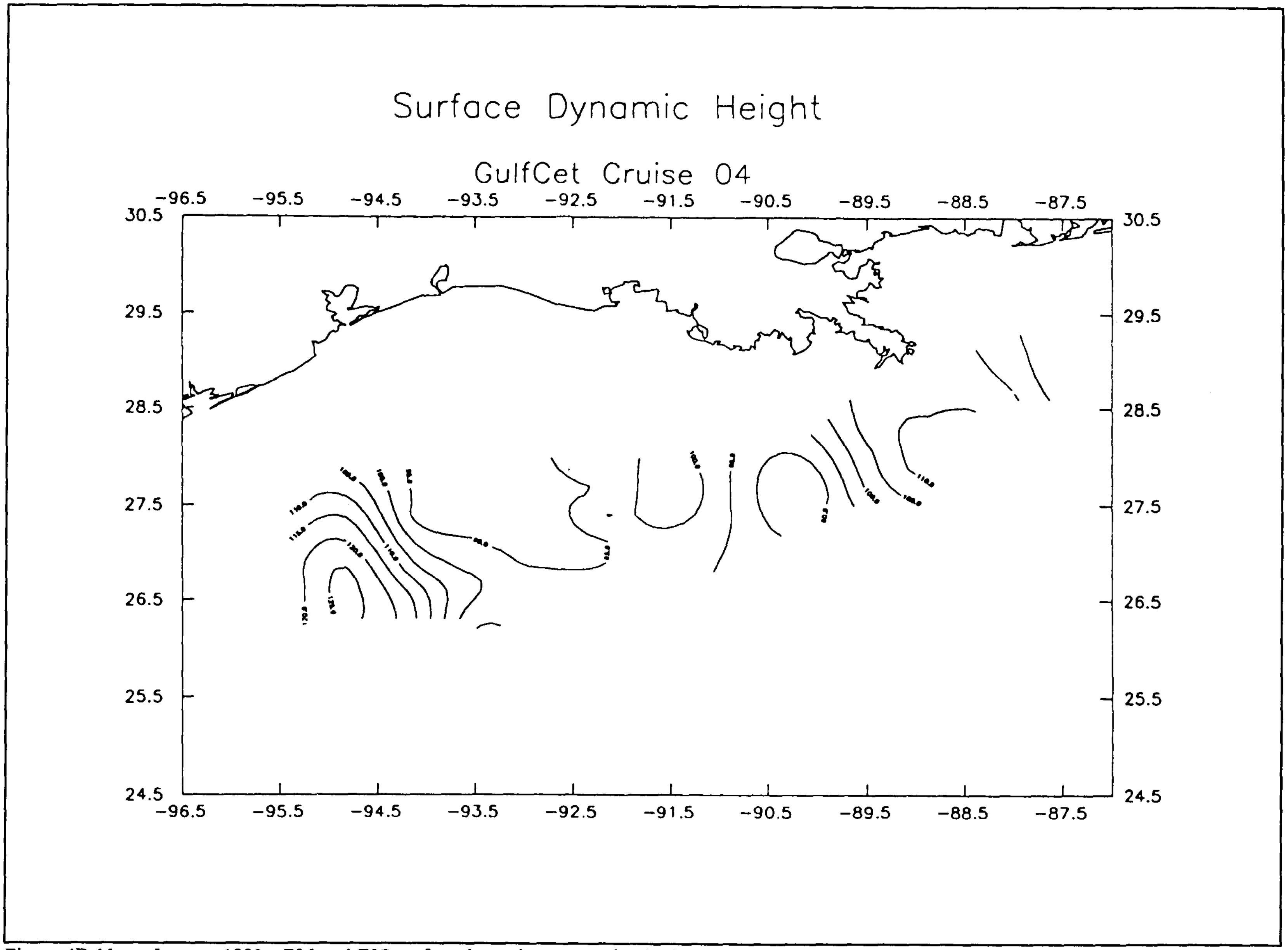

Figure 4D.11. January 1993: F06 and F07 surface dynamic topography (cm) with respect to 800 dbar using GulfCet 04 CTD.

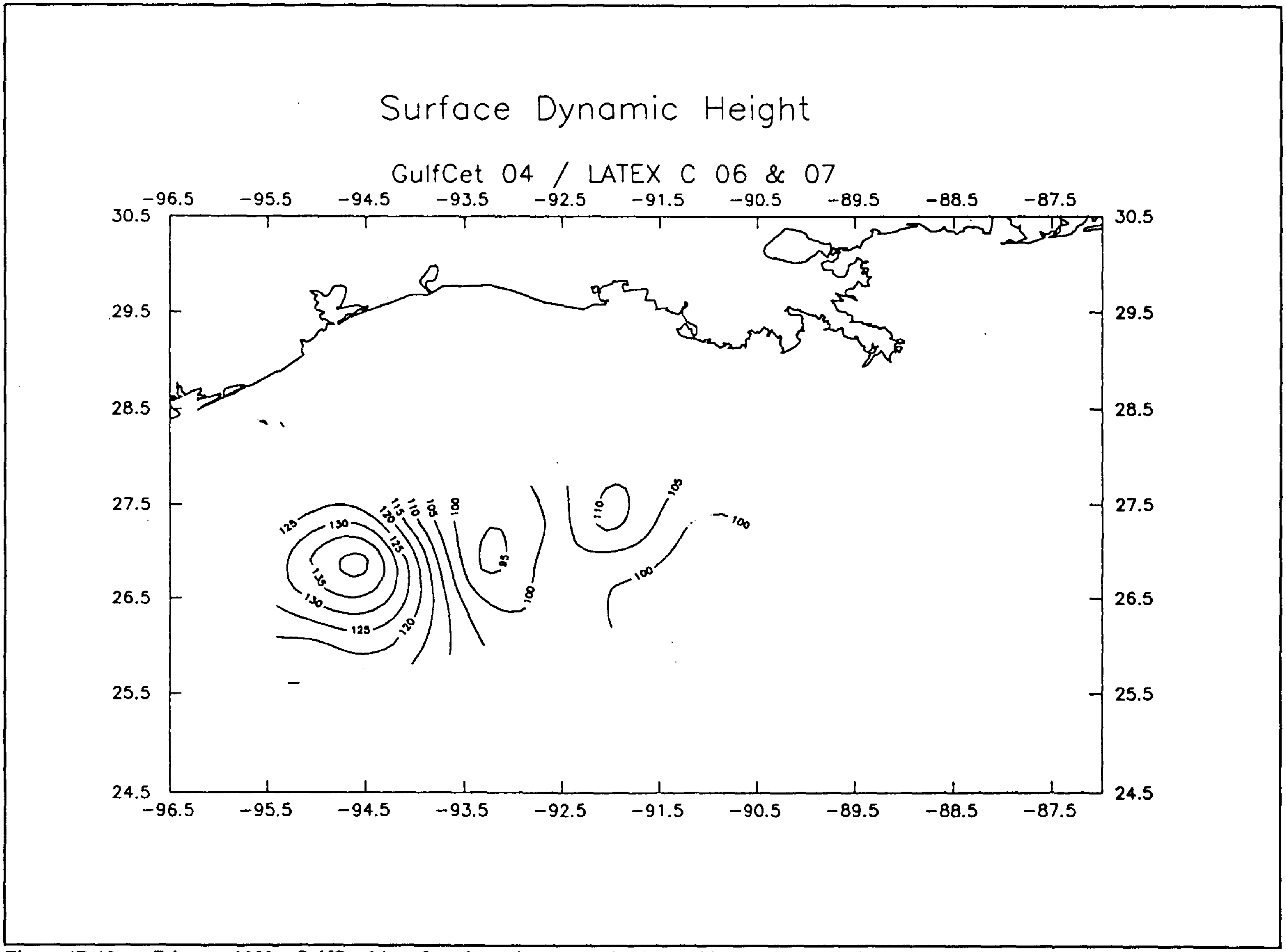

Figure 4D.12. February 1993: GulfCet 04 surface dynamic topography (cm) with respect to 800 dbar.

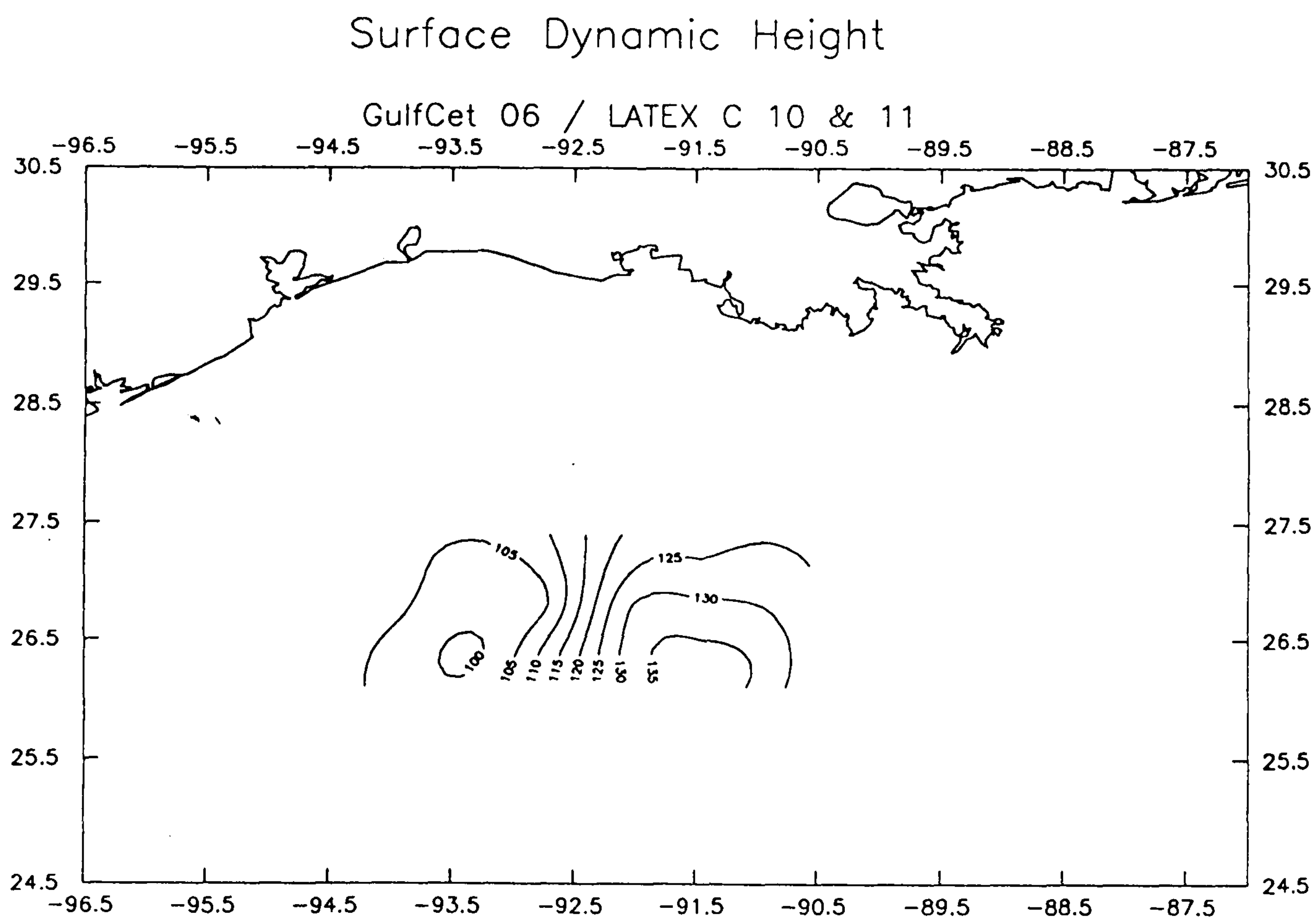

Figure 4D.13. August 1993: F010 and F011 surface dynamic topography (cm) with respect to 800 dbar using GulfCet 06 CTD.

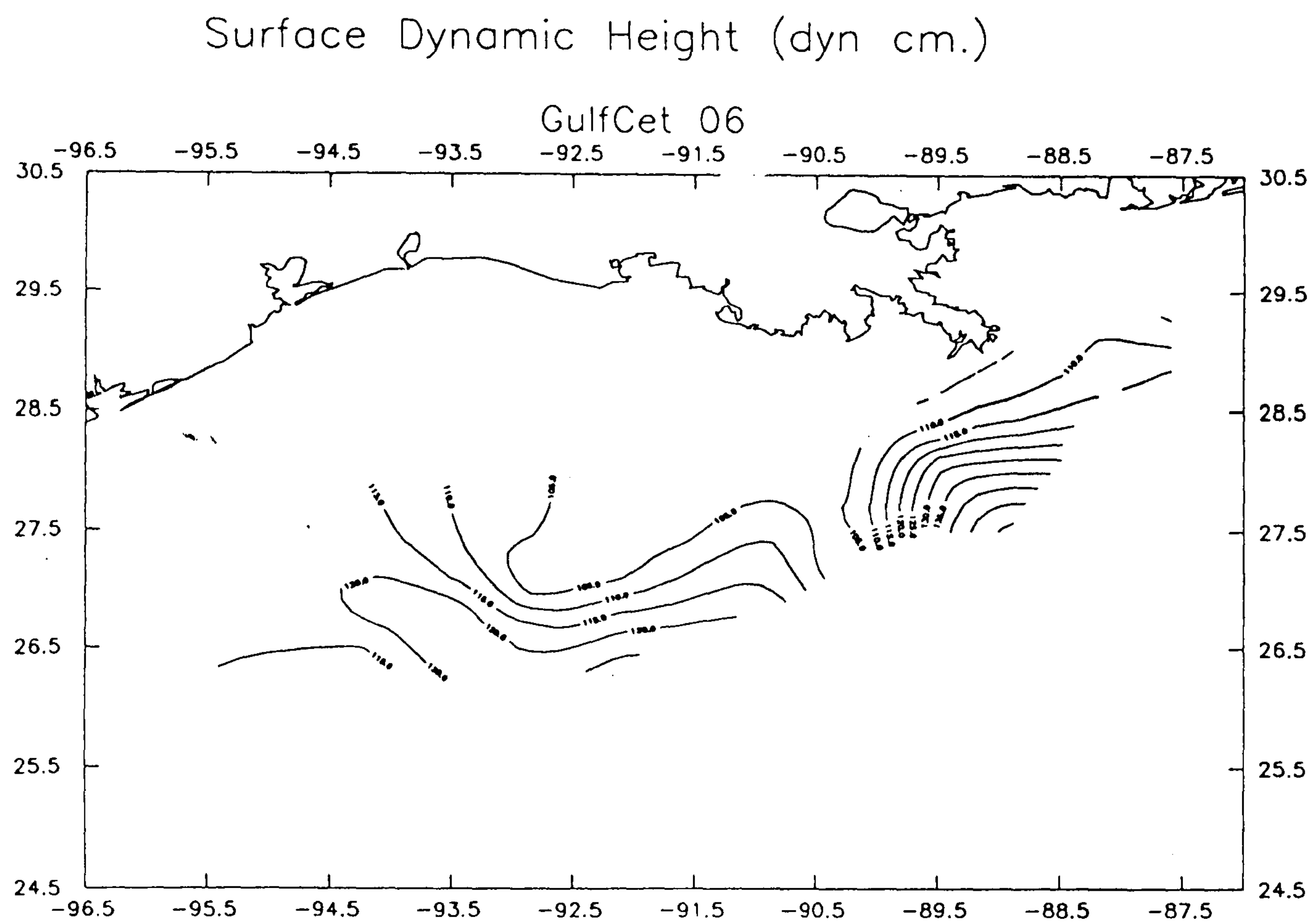

Figure 4D.14. August 1993: GulfCet 06 surface dynamic topography (cm) with respect to 800 dbar.

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Dr. Giulietta S. Fargion, an Associate Research Specialist in the Department of Marine Biology at TAMUG, serves as Data Manager and PI for the MMS-TAMUG GulfCet Program 1991-1994. She received her Ph.D. in Oceanography in 1989 from Scripps Institution of Oceanography, La Jolla.

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TOPEX/POSIEDON AND ERS-1 ALTIMETER DATA ANALYSIS IN THE GULF OF MEXICO: VERIFICATION OF A "CLIMATOLOGICAL" ALTIMETRIC MEAN REFERENCE SURFACE

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INTRODUCTION

Over four year of altimeter data were collected from the combined GEOSAT Geodetic and Exact Repeat Missions, spanning the time period from April 1985 through August 1989, during which six major and at least two minor Loop Current eddies were directly observed (Leben and Born 1993). In 1991 and 1992, respectively, the European Space Agency (ESA) ERS-1 and the U.S/French NASA/CNES TOPEX/POSEIDON altimeter satellites were launched. For the first time, altimetry data from two satellites could be used in concert to map circulation variability with unprecedented spatial and temporal sampling, giving the most complete picture to date of Loop Current eddy shedding in the Gulf of Mexico.

Intermission comparisons of the current altimeter observations of Loop Current eddies in the Gulf of Mexico with those during the GEOSAT time period require a consistent mean sea surface to which all data can be referenced. A method has been developed for correcting existing altimetric mean sea surfaces for short wavelength geoid errors, allowing accurate referencing of the current repeat track altimeter data. Validation of the technique using TOPEX and ERS-1 data over the Gulf of Mexico has been performed by comparisons with hydrographic surveys. It is now possible to accurately reference all past, present and future altimetric observations over the Gulf of Mexico the same mean surface, allowing consistent comparisons and estimates of Loop Current eddy center paths, translation speeds and dynamic height anomalies.

METHODS AND RESULTS

Real-time Loop Current eddy detection in the Gulf of Mexico using satellite altimetry was first attempted in 1988 during the GEOSAT Exact Repeat Mission (ERM) (Forristall *et al.* 1990). Near real-time (within 48 hours) GEOSAT ERM data were used for operational detection of eddies, to aid in the selection of locations for in situ measurements at sea. The altimeter sea surface height (SSH) anomalies showed mesoscale circulation that was subsequently validated by coincident buoy and expendable bathythermograph (XBT) data. The computation of the SSH anomalies relied on along-track mean reference surfaces determined from exact repeat cycles three-22. Thus, real-time eddy detection was only attempted well into the GEOSAT ERM after relatively accurate real-time orbits became available and a suitable along-track mean surface could be computed.

Ideally, operational detection of mesoscale oceanic variability with respect to existing mean surfaces using repeat track (collinear) analysis could begin as soon as an altimeter is in orbit. However, success of such an enterprise is dependent upon the availability of sufficiently accurate along-track mean sea surfaces to permit computation of sea surface height variability. This is the primary motivation behind the so-called "follow on" missions which will place satellites in orbits flown by previous altimeter missions. Unfortunately, when a satellite is placed in a new orbit, as was done with ERS-1 and TOPEX/POSEIDON, the oceanographic signal is often masked by the along-track geoid signal not present in the mean reference surface. Fortunately, this scenario may not be as limiting as it appears upon first inspection.

In the absence of an along-track mean reference surface computed with repeat cycle data along an altimeter satellite exact repeat ground track, along-track means may be determined by interpolation relative to existing mean surfaces or geoids. Unfortunately, the inaccuracy of the marine geoid at length scales of several hundred kilometers prevent its use as a reference surface for detection of mesoscale eddies. Instead, altimetric mean surfaces must be used. We have selected a gridded mean surface (Basic and Rapp 1992) which we will refer to as the Rapp mean. This mean surface is based on a combination of three and a half years of GEOS three, three months of Seasat and 22 cycles (approximately one year) of GEOSAT ERM altimeter data and bathymetric data, and is a global 1/8 degree gridded data set. The mean surface estimate over the Gulf of Mexico is one of the most accurate because of the high spatial resolution of the GEOS-three data and the use of bathymetric data to improve accuracy at short length scales.

Initial attempts to provide near-real time operational monitoring of Loop current eddies (Johnson 1993) employed collinear differencing with respect to the Rapp mean surface. This surface was used for detrending of residual orbit error and calculation of the SSH anomalies from both the TOPEX/POSEIDON and ERS-1 satellites. Unfortunately, the analysis showed significant contamination of the SSH anomaly by short wavelength along-track geoid signals not present in the mean surface. Loop Current eddies, however, could still be detected.

Subsequently, a technique was developed to correct the along-track Rapp mean surface for these short wavelength geoid errors. In summary, the technique is as follows:

1. Along-track data interpolated from each cycle is high pass filtered by local linear detrending of the SSH anomaly with respect to the Rapp mean sea surface. This filter retains the major component of the previously unsampled geoid signals at short wavelengths (< 100 km) which are not present in the Rapp mean surface.

2. The local linear detrended along-track repeat cycle data are averaged to obtain short wavelength mean corrections to the Rapp surface along both the TOPEX and ERS-1 ground tracks. The averaging minimizes the contribution of the time-dependent mesoscale signal and short wavelength noise still present in the high pass filtered along-track data without affecting the time-invariant geoid signal.

3. Standard detrending of the orbit error can then be performed relative to the corrected along-track mean surface.

The advantages of using an along-track mean correction are threefold. First, data from concurrent exact repeat altimeter missions can be referenced to the same mean surface by standard collinear techniques. This is a significant advantage over crossover differencing between mission data sets because of the increased temporal and spatial sampling afforded by collinear analysis. This is further enhanced when data from multiple altimeters in repeat track orbits are exploited in concert for oceanographic studies. Second, the correction converges in as few as six repeat cycles when an existing mean reference surface is used. This allows accurate referencing of current altimeter missions relative to a "climatological" mean, long before suitable intramission means surfaces become available which are uncontaminated by seasonal, annual or interannual variability. Finally, both historical and current altimeter data streams can be referenced to the same mean surface to allow a consistent extension of historical time series

Altimeter-derived dynamic height anomalies with respect to a corrected along-track mean surface show agreement with hydrographic estimates to better than five cm root-mean-square (rms) in the western gulf. A survey nearly coincident with a satellite overfight was conducted in March 1993 by the R/V Gyre along a TOPEX/POSEIDON ground track in the western gulf. Along-track dynamic height differences were better than two cm rms, which is within the generally accepted error bound for the altimeter measurements. Poorer agreement was found in the eastern gulf where the mean circulation from the Loop Current dominates. The mean circulation has been removed by differencing of the altimetry relative to the mean sea surface, hence, dynamic height computed using altimetry will not reflect the total Loop Current signal.

As part of an extensive, multi-year field and modeling study of the Gulf of Mexico, sponsored by the Minerals Management Service (MMS), near-real-time altimetry is being posted at weekly intervals by electronic mail on a science bulletin board. The objective of this posting has been to examine the utility of altimetry in an operational setting for design of ongoing field studies as well as to aid industries engaged in offshore activities (Johnson 1993). Very early on in the TOPEX/POSEIDON mission, cooperation with other components of the program created an opportunity to assess the accuracy of near-real-time altimetric analysis by comparisons with the hydrographic surveys.

To compare directly with the dynamic heights estimated from the XBTs dropped along extended survey transects of the gulf, the optimally interpolated sea surface height anomaly fields from the 10-day repeat TOPEX/POSEIDON cycle at the half cycle time nearest the survey, including the ERS-1 35-day repeat centered on the midpoint of the TOPEX data were interpolated to the station location using bilinear interpolation. To remove the ambiguity of the reference surface from both the hydrography and altimetry estimates, the mean of the altimetric sea surface height anomalies was set equal to the mean dynamic height computed from all stations with depths greater than 800 meters along the survey transect.

The optimally interpolated altimeter data coincident with the 28-31 October 1992 R/V Gyre Cruise 92G-13 are shown in Figure 4D.15. Station locations are shown as filled circles along the cruise transect. The two warm-core rings that were transected by the survey line are clearly seen in the altimetry. As it has been the custom since 1985 to name the Loop Current eddies, eddies #21 and #22 were called Eddy U and Eddy V. In Figure 4D.15, the centers of Eddies U and V are located near 90W, 24N and 94W, 26N, respectively. The comparison with hydrography is shown in Figure 4D.16, with agreement to 6.5 cm rms at all stations along the survey line. Differences at stations (16-32) west of 90W, from near the center of Eddy U through Eddy V, had a rms of only 3.1 cm. The excellent agreement west of 90W supports the hypothesis that the mean circulation is quite weak in the deep western gulf and has been well approximated by the Rapp mean surface and correction.

CONCLUSION

This work represents an important milestone in the preparation of an altimeter climatology for the Gulf of Mexico. It is now possible to reference GEOSAT, TOPEX/POSEIDON and ERS-1 altimeter data relative to a validated ''climatological'' mean sea surface, allowing consistent analysis and comparison of the sea surface height variability in the Gulf over the time periods, 1985-1989 and 1991 to the present.

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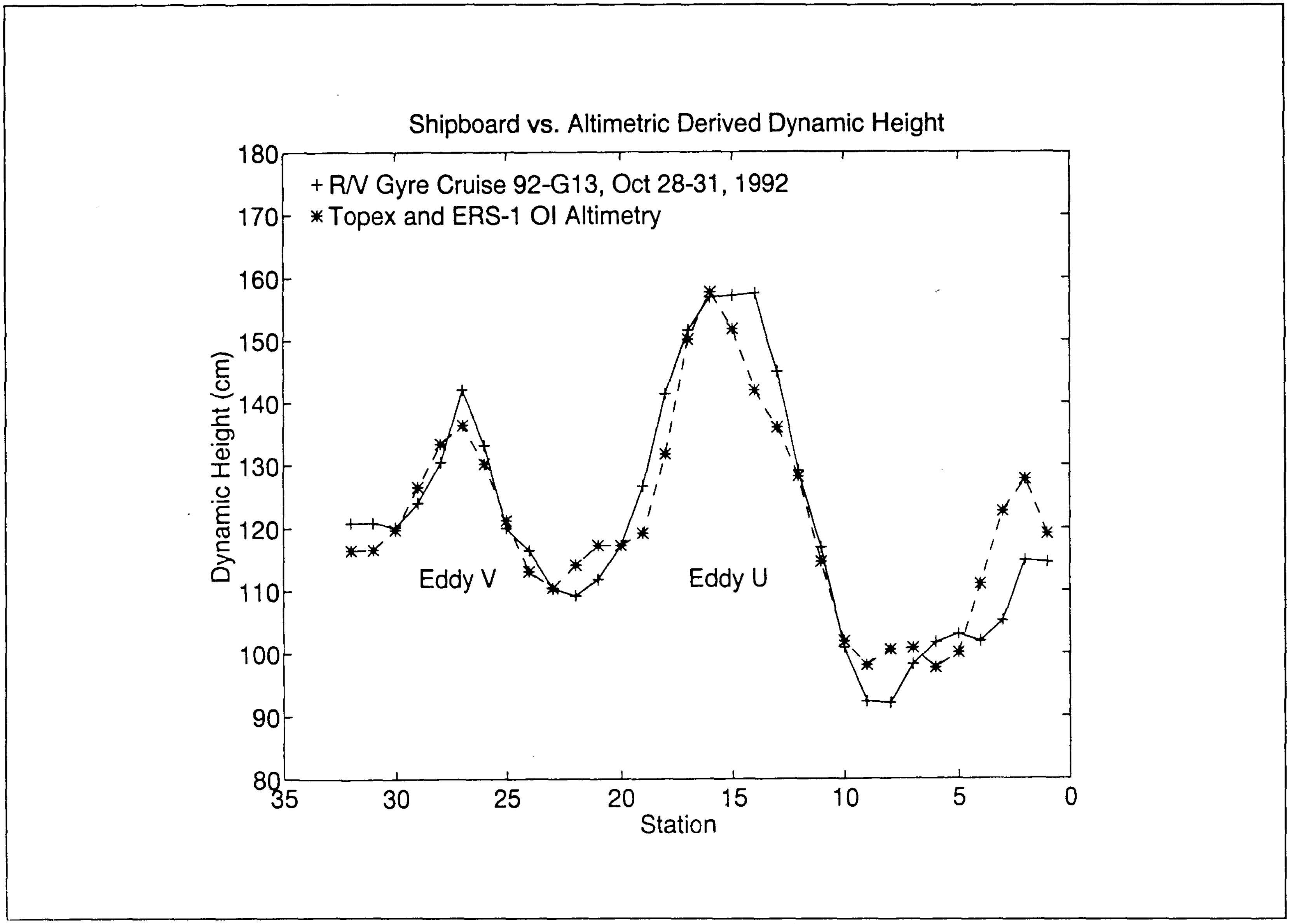

Figure 4D.15. Optimally interpolated TOPEX/POSEIDON and ERS-1 altimeter data coincident with the October 28-31, 1992 R/V Gyre Cruise 92G-13. Station locations are shown as filled circles along the cruise transect.

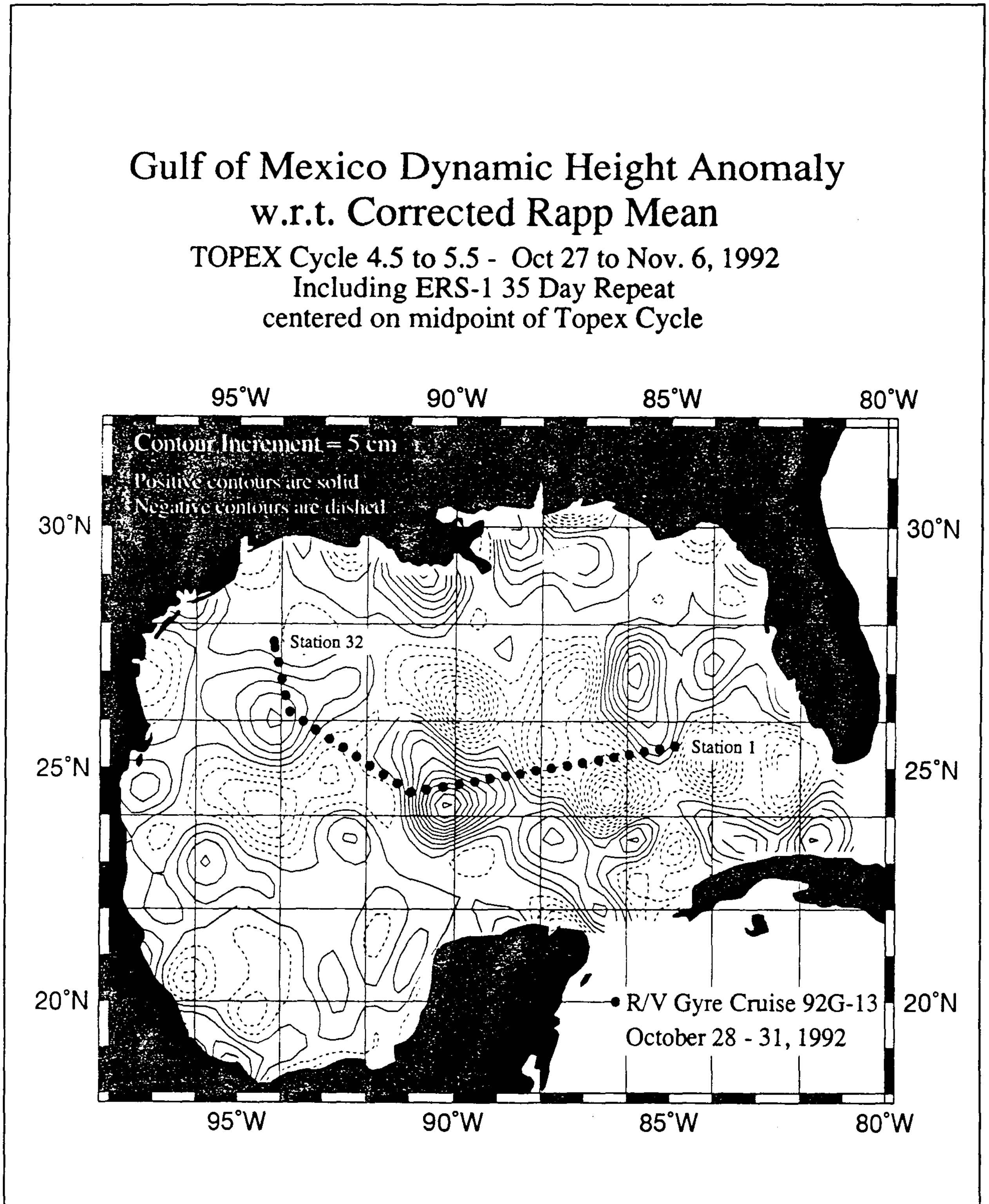

Figure 4D.16. Comparison of altimeter and XBT derived dynamic heights along Gyre Cruise 92G-13 transect, with agreement to 6.5 cm rms at all stations along survey line. Differences at stations (16-32) west of 90W, from near the center of Eddy U through Eddy V, were 3.1 cm rms.

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SESSION 5A

CURRENT AND PENDING GULF OF MEXICO BONDING REQUIREMENTS AND PROCEDURES

Session: CURRENT AND PENDING GULF OF MEXICO

Co-chairs: Mr. John L. Rodi and Mr. Carrol S. Williams

Date: December 16, 1993

Presentation	Author/Affiliation
Introduction	Mr. John L. Rodi Mr. Carrol S. Williams Minerals Management Service Gulf of Mexico OCS Region
Discussion on Current Policy on General Bonding and Supplemental Bonding	Mr. John L. Rodi Minerals Management Service Gulf of Mexico OCS Region
Document not submitted	Mr. Harold L. Cargol, Jr. Texaco Exploration and Production, Inc.
Current and Pending Gulf of Mexico Bonding Requirements and Procedures	Mr. Carrol S. Williams Mr. John L. Rodi Minerals Management Service Gulf of Mexico OCS Region
Document not submitted	Mr. Harold L. Cargol, Jr. Texaco Exploration and Production, Inc.

DISCUSSION ON CURRENT POLICY ON GENERAL BONDING AND SUPPLEMENTAL BONDING

Mr. John L. Rodi
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The new three-tier approach, effective on 26 November 1993, applies to submissions to MMS of lease assignments or operational activity plans on or after that effective date. Specifically, the approach will be triggered by the filing of any one of the following: an initial Exploration Plan (EP); an initial Development and Production Plan (DPP); an initial Development Operations Coordination Document (DOCD); a significant revision (i.e., a supplemental plan) to an approved EP, DPP, or DOCD; or a request for assignment of a lease with an approved EP, DPP, or DOCD.

The three tiers specifically prescribed by the final rule are as follows:

1. A $50,000 lease or $300,000 areawide bond for leases with no MMS-approved operational activity plan or leases under an MMS-approved operational activity plan but with no submittal to MMS of assignment or operational activity plans on or after 26 November 1993. A lessee need not provide this bond if an applicable lease or areawide bond is in place in accordance with one of the following higher requirements.

2. A $200,000 lease or $1,000,000 areawide bond for leases with submittal on or after 26 November 1993, of a proposed EP, or a significant revision to an approved EP, or a proposed assignment of a lease with an approved EP. A lessee need not provide this bond if an applicable lease or areawide bond is in place in accordance with one of the following higher requirements.

3. A $500,000 lease or $3,000,000 areawide bond for leases with submittal on or after 26 November 1993, of a proposed DPP, or DOCD, or a significant revision to an approved DPP or DOCD, or a proposed assignment of a lease with an approved DPP or DOCD.

The final rule allows for a lessee to submit a bond in an amount less than the just-mentioned prescribed amounts when the authorized MMS officer agrees with the lessee's evidence that well abandonment, platform removal, and site clearance costs for the lease will be less than the amount of the lease bond coverage prescribed in the final rule.

The authorized MMS officer, for good cause, may permit the lessee to provide the required bond after submission of an assignment or operational activity plan but prior to the approval of operational activity under the relevant plan.

A bond in the same amount may be substituted by an operator at any time for the required equivalent lessee bond under the final rule. The substitution of an operator's bond does not relieve the lessee of its obligation to comply with the terms and conditions of the lease.

In satisfaction of the MMS bond requirement, the final rule prescribes acceptance of bonds issued by a surety certified by the U.S. Department of the Treasury or U.S. Treasury securities which are negotiable at the time of submission for an amount of cash equal to the value of the required bond. The authorized MMS officer may approve alternatives to surety bonds and U.S. Treasury securities in response to supplemental bond requirements if the interests of the U.S. government are protected to the same extent as such historically-accepted financial instruments.

The final rule retains the provision under which the authorized MMS officer may require additional security in the form of a supplemental bond or bonds on a case-by-case basis to ensure present and future compliance with all lease obligations. Factors to be examined by the authorized MMS officer in determining the need for supplemental security include, but are not limited to, a lessee's financial ability, record of meeting obligations, and projected financial strength.

The final rule holds the assignee responsible for all obligations associated with a lease subsequent to the effective date of an assignment, including associated surety bond requirements.

MMS Gulf of Mexico OCS Region Procedures

In addition to disseminating the enclosed final rule to all concerned parties, this LTL provides the following related procedural information and guidance applicable to the MMS Gulf of Mexico (GOM) OCS Region. The authorized MMS officer for all decisions under these procedures shall be the GOM OCS Regional Director, or his designee.

30 CFR 256.58

A $50,000 lease or $300,000 areawide bond will be required for all leases with no MMS-approved operational activity plan, or leases under an MMS-approved operational activity plan but with no submittal to the GOM OCS Region of assignment or operational activity plans on or after 26 November 1993. The GOM OCS Region policy is that a supplemental plan will be required in all cases where the drilling of a well or the installation of a platform was proposed in an approved EP, DPP, or DOCD and more than three years have elapsed since the planned commencement date without the proposed activities being conducted. The acceptability of operational activity plans will be determined on a case-by-case basis in those instances where less than three years have elapsed since the approved commencement date of a proposed activity without the activity being conducted.

There is no change under the subject final rule regarding the MMS GOM OCS Region's acceptance of alternate security instruments. This office presently accepts surety bonds from U.S. Treasury-certified sureties, and U.S. Department of Treasury securities which have a cash value at the time of purchase equal to the MMS bond requirement. Alternative instruments which provide the same degree of security as these currently accepted will be considered on a case-by-case basis. For informational perspective, such alternatives as letters of credit or production escrow accounts have historically been deemed unacceptable.

There is no change under the subject final rule regarding the MMS GOM OCS Region's policy that an operator may substitute its bond for the required equivalent lessee bond. Furthermore, each operator in the MMS GOM OCS Region must still post a $50,000 lease or $300,000 areawide bond, at a minimum, regardless of any such substitution.

30 CFR 256.59

For information regarding the appropriate bond forms to be used under the subject amendment, contact the MMS GOM OCS Region Adjudication Unit at (504) 736-2612.

30 CFR 256.61

The higher bond requirements prescribed in the final rule will be triggered by any of the following submissions to the GOM OCS Region on or after 26 November 1993: an EP; a DPP; a DOCD; a significant revision to an approved EP, DPP, or DOCD; or a request for assignment of a lease for which an EP, DPP, or DOCD has been approved or submitted for approval.

The submission date used in the MMS GOM OCS Region under this rule will be the date a filing for approval is actually made with the appropriate office.

In the case of assignments, incomplete filings will be returned to the applicant for correction, in which case the resubmittal date will be applicable. Furthermore, any bonds prescribed in the final rule must be provided at the time of assignment submission unless alternatively approved by the authorized MMS officer prior to filing of the assignment. Such an alternative arrangement, which may relate to a change in the amount and/or submission date for the required bond, must be clearly documented in the correspondence accompanying the assignment. Omission of the bond without such approval and documentation will result in return of the assignment for resubmittal. For more information on MMS assignment application requirements, contact the MMS GOM OCS Region Adjudication Unit at (504) 736-2612.

In the case of operational activity plans, i.e., EP or DPP or DOCD, a filing will generally not be returned for resubmission provided it contains one of the following:

1. A statement that the appropriate lease bond as prescribed in the final rule has been furnished concurrently to the GOM OCS Region Office of Leasing Environment.

2. A statement, including proof that the wells and/or platforms proposed in the subject EP, DPP, or DOCD can be removed and their sites

cleared for less than the amount of the final rule's prescribed lease bond coverage, and that a lease bond in the appropriate amount less than the prescribed amount has been furnished concurrently to the GOM OCS Region Office of Leasing and Environment.

3. A request, including justification, to delay furnishing the appropriate lease bond until after filing of the subject EP, DPP, or DOCD but before receiving MMS approval of drilling permits or platform applications under that EP, DPP, or DOCD.

4. A statement that the activities proposed in the subject EP, DPP, or DOCD are covered by an appropriate areawide bond.

Supplemental bonds, which represent security deemed necessary over and above the bond requirements prescribed in the subject rule, will continue to be applicable. The MMS GOM OCS Region will require such supplemental bonds at such time as a lessee's OCS liability related to facility abandonment and site clearance exceeds the sum of that company's lessee bonds on file with that office on a lease-specific or areawide basis, whichever is relevant. Based on current MMS GOM OCS Region procedures, a waiver of this supplemental bond requirement on a specific lease will be granted by the authorized MMS officer if at least one lessee meets the following criteria:

1. The MMS-estimated cumulative potential lease abandonment liability for the lessee is less than or equal to 25 percent of the most recently available and independently audited calculation of that lessee's net worth. Assumed herein is that each co-lessee is separately liable for 100 percent of abandonment costs.

In addition to the above waiver requirement, a lessee must satisfy at least one of the following criteria:

2. Total employment of 500 people or more as evidenced by publicly available and independently accepted information sources.

3. A minimum net worth of $35,000,000 in the most recent available year as certified by an independent Certified Public Accountant.

4. Minimum gross annual oil and gas sales of $45,000,000 in the most recent available year as certified by an independent Certified Public Accountant.

5. Lessee is restricted from joint bidding on OCS leases based on the most recent semiannual U.S. Department of Justice review and determination.

The first four of the previously stated supplemental bond waiver criteria relate directly to the subject final rule's allowance for such waiver on the basis that a lessee's financial capacity exceeds existing and anticipated lease obligations. The fifth criterion relates to the final rule's allowance for such waiver on the basis that projected financial strength is evidenced by existing OCS production in excess of existing and future obligations.

The MMS GOM OCS Region reserves the right to require supplemental bonds from lessees regardless of the previously stated waiver criteria if MMS review of independently certified information indicates recent or future events questionably affect financial capability.

Pursuant to 30 CFR 256.61(d), the MMS GOM OCS Region also considers numerous factors other than those stated above in determining a payment schedule for those cases where a supplemental bond is required.

Finally, supplemental bond procedures and related determinations, including waiver, may be reviewed by MMS at any time, and MMS reserves the right to make appropriate redeterminations upon completion of such reviews.

For a copy of the current detailed supplemental bond procedures used in the MMS GOM OCS Region, contact the MMS GOM OCS Region Adjudication Unit at (504) 736-2612.

30 CFR 256.62

The MMS has recently issued a Notice to Lessees and Operators (NTL) which clearly defines the issues of assignor and assignee lease abandonment responsibility. For a copy of that NTL, contact the MMS GOM OCS Region Public Information Unit at (504) 736-2519.

Mr. John L. Rodi is a supervisor in the Sales and Support Unit within the Minerals Management Service (MMS) Gulf of Mexico OCS Region's Office of Leasing and Environment. Prior to this position, he served as a staff economist within both MMS and the U. S. Army Corps of Engineers. He holds both a B.A. and M.A. in Economics.

CURRENT AND PENDING GULF OF MEXICO BONDING REQUIREMENTS AND PROCEDURES

Mr. Carrol S. Williams
Mr. John L.Rodi
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INTRODUCTION

The bonding program was developed to protect the United States' government from incurring costs involved with oil and gas facilities abandonment and site clearance on the Outer Continental Shelf (OCS). Although, a general bond is required for activities on the OCS, a supplemental bond is required when a lessee's liability, related to facility abandonment and site clearance, exceeds the sum of the company's relevant lease-specific or area-wide general bonds on file with Minerals Management Service (MMS).

Utilizing historical data, MMS developed a minimum general bonding and supplemental bonding level to insure the coverage of cost incurred in removing these facilities. This information is calculated according to the number of platforms, water depths and number of wells. It covers plugging and abandonment of wells, removal of platforms, and site clearances. When the data demonstrates that the cost will exceed the general bonding level, a supplemental bond is required.

The amount of the supplemental bond is determined by MMS in conjunction with the submission of assignment of record title interest, Plan of Exploration (POE) or Development Operations and Coordination Document (DOCD). It must be submitted prior to the approval of ownership transfer or operational activity.

A lessee's supplemental bond must be secured before MMS will allow additional activities on a lease. The supplemental bond can be met by a surety bond issued by a company certified by the U.S. Department of Treasury, or U.S. Treasury securities which are negotiable at the time of submission for an amount of cash equal to the value of the required bond.

A lessee can request a waiver from supplemental bond, if through MMS data and the company's audited financial statements, it can meet MMS requirements for financial strength. During the past year, a financial review was performed and a change in the financial waiver criteria was recommended, which is currently under review. It is anticipated these requirements will be issued with the Phase II bonding requirements. It is currently projected that the 1,410 companies operating in the GOM Region have a cumulative liability of \$ 8,501,950,000 in plugging, abandonment, and site clearance cost.

During the past three years, 10 companies with OCS leases have filed for bankruptcies. Due to the implementation of the bonding and supplemental bonding programs, the United States' government has not directly incurred any facilities abandonment or site clearance costs.

Carrol S. Williams is employed by the Department of Interior, Minerals Management Service (MMS), and has served as a program and financial Analyst, for the Office of Leasing and Environment, in the Gulf of Mexico OCS Region for the past several years. During the past year he has completed a statistical review of the financial position of companies doing business in the Gulf of Mexico upon which new proposed polices are being formulated.

Mr. John L. Rodi is a supervisor in the Sales and Support Unit within the Minerals Management Service (MMS) Gulf of Mexico OCS Region's Office of Leasing and Environment. Prior to this position, he served as a staff economist within both MMS and the U. S. Army Corps of Engineers. He holds both a B.A. and M.A. in Economics.

PROPOSED REVISIONS TO MMS GOM REGION SUPPLEMENTAL BOND EXEMPTION CRITERIA

Individual Company	Proposed Rules	3rd Party Guarantor
	Requirement A.1: Production > OR = to X X = __________BOE/DAY	
AND **Requirement A.2:**		
"x" = _____	Cumulative MMS Liability divided by Tangible Net Worth < or = to "x" (3rd Party Guarantor MMS Liability includes **Guaranteed** cumulative MMS liability)	"x" = _____
OR **Requirement B.1**		
"x" = _____	Current Ratio > or = to"x" (Current Ratio equals Current Assets divided by Current Liabilities)	"x" = _____
OR		
"x" = _____	Quick Ratio > or = to "x" (Quick Ratio equals Cash and Account Receivables divided by Current Liabilities)	"x" = _____
AND **Requirement B.2:**		
"x" = ______	Debt Equity Ratio < or = to "x" (Debt Equity Ratio equals Total Liabilities divided by Tangible Net Worth)	"x" = _____
AND **Requirement B.3:**		
"x" = _____	X Continuous years as OCS-qualified WITH PRODUCTION in oil, gas or sulphur.	"Not Applicable to Guarantor"
AND **Requirement B.4:**		
"x" = _____	Cumulative MMS Liability divided by Tangible Net Worth < or = to "x" 3rd Party Guarantor MMS Liability includes **Guaranteed** cumulative MMS liability)	"x" = _____
OR **Requirement C:**	Approved for Self Insurance under OPA 90.	

SESSION 5B

CHEMOSYNTHETIC COMMUNITIES II

Session: CHEMOSYNTHETIC COMMUNITIES II

Co-Chairs: Dr. Robert Avent and Dr. James Brooks

Date: December 16, 1993

Presentation	Author/Affiliation
Recurrent Regional and Small-Scale Patterns in the Distribution of Hydrocarbon Seep Fauna	Dr. Ian R. MacDonald Geochemical and Environmental Research Group Texas A&M University
Document not submitted	Dr. Robert Carney Louisiana State University
Paleontology of Seep Bivalve Communities	Mr. Kenneth A. Warren Dr. Eric N. Powell Department of Oceanography Texas A&M University
A Descriptive Synthesis of Gulf of Mexico Hydrocarbon Seeps	Dr. William W. Schroeder Dauphin Island Sea Lab Marine Science Program University of Alabama Dr. Ian R. MacDonald Geochemical and Environmental Research Group Texas A&M University

RECURRENT REGIONAL AND SMALL-SCALE PATTERNS IN THE DISTRIBUTION OF HYDROCARBON SEEP FAUNA

Dr. Ian R. MacDonald
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Texas A&M University

INTRODUCTION

The vestimentiferan tube worms, mussels (seep mytilids), and the vesicomyid and lucinid clams that colonize natural hydrocarbon seeps are variously able to exploit the chemical enrichment that occurs in localized zones when oil and gas arrive at the interface between sediments and sea water. Previous sections have considered the geological and chemical features associated with this interface (Sager, this volume; Kennicutt, this volume) and the physiological adaptations of chemosynthetic megafauna (Fisher, this volume). Here, we shall examine how these characteristics combine to produce predictable distribution patterns within these faunal groups.

REGIONAL OCCURRENCE

Regionally, a map of the known seep communities indicates a broad belt of occurrence across the upper to mid-continental slope (Figure 5B.1). The landward limits of seep communities appear to be real and increasingly to restrict occurrence of seep fauna in water depths less than about 500 m-although physiological and ecological causes of this restriction are very poorly understood. The seaward and east-west extents of this distribution are artificially constrained by the limits of exploration. The presence of perennial oil slicks, which form over many seeps and which can be detected by satellite remote sensing, indicates that seeps are general across the full depth cross-section of the slope. Collection of oil-laden surface sediments by piston coring also indicates the general prevalence of seepage on the slope. One deep water (2,200 m) seep has been explored in Alaminos Canyon, and the thriving chemosynthetic community found in that site (Brooks *et al.* 1990) supports the idea that lower slope seeps are colonized. To the east, the Mississippi Fan and Canyon region does appear to limit seepage; this is confirmed by general lack of surface slicks and reduction in sediment hydrocarbon levels. There are seep communities off Mobile Bay in Viosca Knoll region. The steepness of the Florida Escarpment (and coincident lack of hydrocarbon reservoirs) also limits the eastward occurrence of seep communities at slope depths; however, the first documented finding of tube worms and mytilids was at the base of the Florida Escarpment, at a depth of 3,600 m (Paull *et al.* 1984). The Escarpment communities have been linked not to thermogenic hydrocarbons, but to connate fluid seepage from the highly porous Florida Platform. Noting the oil reserves of the Mexican slope, and the similarities between the Yucatan and Florida Escarpments, it is clear that seep communities have a known distribution that indicates their presence across the full extent of the continental slope in the U.S. Gulf of Mexico and a potential distribution that is circumambient of the entire Gulf.

This broad regional distribution, however, belies the local occurrence of chemosynthetic communities. Because the fauna depend upon geological processes, they are freed from the restrictions that increasing water depth imposes upon the photosynthetic food chain; thus they often form very dense aggregations in the otherwise food-poor deep sea. However, because their food supply is so specific, seep communities are sharply limited by the spatial and temporal conditions of seepage; thus seep communities tend to be dense but small in area.

On the northern slope, movement of the Louann Salt produces both the maturity traps and the migration conduits that lead to hydrocarbon seepage. Seep communities are thus clearly linked to the underlying salt structures, but the dependence is variable on a relatively small scale. For example, a bathymetric chart of the Green Canyon regions where many of the best-studied seeps are found was produced from a data set arrayed in a 250-m grid (NOAA 1992), and clearly shows several salt structures and slump zones produced by salt movement. However, at this scale, no unambiguous preference for topographic features can be distinguished. This is because the seepage zones on the seafloor, although characterized by distinctive geological features, typically occupy areas a few tens to a few hundreds of meters in width.

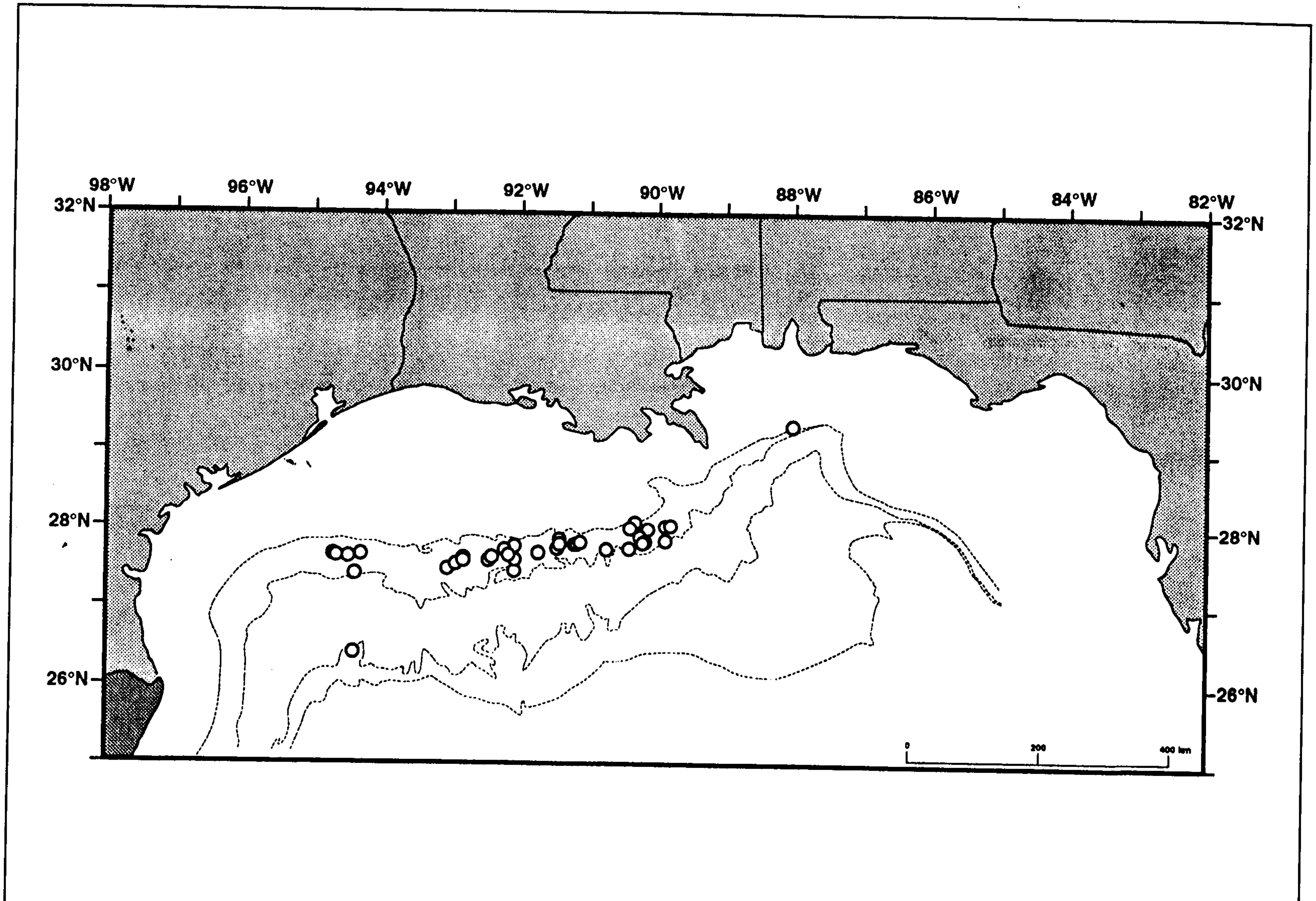

Figure 5B.1. Map of the northern Gulf of Mexico showing the locations of known chemosynthetic communities. The range of probable occurrence extends to the base of the slope and along the entire slope margin. Depth contours show the 500, 1,000, 2,000, and 3,000 m isobaths.

FINE-SCALE PATTERNS

When bathymetric data are available at a finer scale (<10 m grid) clearer preferences emerge. Spatially, seep mussels are the most restricted and typically occur as one to five m wide ovoid or linear patches, often on slope terraces or mound crests. Tube worms form in bush-like clusters that colonize surface sediments along fault zones. The widths of these colonies are typically 10 to 100 m, while the lengths often extend the entire active length of the faults. Vesicomyids and lucinids are spatially the least restricted. There is much difficulty in distinguishing living vesicomyids from accumulations of dead shells, and the infaunal lucinids are collected by coring. Generally, however, the bivalve beds occupy large flat regions up to 1,000 m in width. These distribution patterns are the result of the adaptations that each faunal group has made to colonize and exploit seepage and will be briefly outlined in the following.

SEEP MYTILIDS

Methane availability limits the habitat suitable to seep mussels. Gaseous hydrocarbons, migrating from depth, is relatively less restricted by sediment pore structure than is liquid oil (Verweij 1993). Bubbling gas vents are therefore relatively more localized than the oily sediment in seep zones. Secondary processes such as hydrate formation and dissociation, carbonate precipitation, and indeed the tightly bound mat of mussels, will channelize and retard gas seepage; overall though, the cross-section is relatively small. A somewhat less restrictive case occurs where mussels are able to exploit methane dissolved in seeping brine. Here, the greater density of brine tends to maintain it as a distinct fluid in pools of flow channels on the seafloor. The major restriction here is substrate stability, because the anoxic brine becomes toxic to mussels unable to extend their siphons into the overlying sea water. In both cases, gas vents and brine seeps, the habitable gradient is steep and the actual habitat areas is restricted. At brine seeps, mussels dominate, with occasional solitary tube worms able to exploit sediment anoxia. At gas vents in oil seeps, the mussels usually occur surrounded by more extensive tube worm bushes.

TUBE WORMS

Tube worms have two requirements that, in combination, limit their habitat. Their symbionts utilize H_2S, which is probably derived from sulfate reduction in a sediment column made anoxic by the bacterial degradation of the massive carbon input provided by oil seepage. No measurable concentrations of H_2S have been detected at the off-bottom heights where the tube worms' gas exchange plumes are commonly found (MacDonald *et al.* 1989). The implication is that H_2S is supplied by diffusion across the tube wall in that portion of the tube that is usually buried in the anoxic sediments. The tube worms themselves require a hard attachment substrate for larval sediment, although this requirement may be relaxed somewhat where larvae can settle on adults. The combination of these two requirements is met along the active portions of faults where carbonates are exposed and sufficient sedimentation or mud expulsion has occurred to provide a sediment drape. Tube worms do occur in lithified crevices, but the extent of such colonies is sharply limited, and the development of the individual worms is generally stunted.

BIVALVES (VESICOMYIDAE AND LUCINACEA)

Seep clams also exploit sediment anoxia: the vesicomyids by extending their vascularized foot below the surface oxidized layer while their siphon takes in oxygenated sea water; the lucinids by constructing a Y-shaped burrow within which they can control oxygen levels through siphon pumping or shifting their position (Reid and Brand 1986; Cary *et al.* 1989). Lucinids have a very wide distribution in the Gulf of Mexico, including shallow estaurine areas where sediment anoxia is clearly not related to oil seepage. Of the two groups therefore, the spatial extent of lucinids around seeps should be the greater. There is difficulty in confirming this, however, because the animals' infaunal habits tend to hide them from view. Vesicomyids require the shallow anoxia typical of a mud flow flats and have been confirmed to colonize areas >one km wide (Rosman *et al.* 1987). All three groups, mussels, tube worms, and vesicomyids, have been sighted together under the exceptional circumstances where all of the conditions of brine seepage, sediment anoxia, and attachment substrate co-occur.

TEMPORAL STABILITY

Life-spans of the Gulf chemosynthetic fauna, where they can be determined by growth experiments, are long: on the order of tens to possibly hundreds of years. Short-term change in their communities should, therefore, result from variation in fluid flow or other seep-related processes. Successful settlement events should be relatively rare and the effects of predation relatively limited. Comparison of seep communities photographed at intervals of up to three years reveals little direct evidence for change in either community composition or density. This is in marked contrast with the chemosynthetic communities at the Galapagos hydrothermal vent, where entire aggregations of tube worms were replaced with mussels over a period of less than five years (Hessler *et al.* 1988). Indirect evidence, on the other hand, points to change and various rates. Most rapid change will undoubtedly result from catastrophic events such as blow-outs. Upended carbonate slabs and sharp sided pockmarks are clear indicators that such blowouts do occur. Over a circa-annual time scale, variation in water temperature can destabilize near-surface hydrates and greatly increase local seepage. (MacDonald *et al.* 1993). Finally, rechannelization of fluid flow may choke off fluid flow in a highly localized area; evidence for this can be seen in the defunct mussel beds that are commonly found in the vicinity of living beds. In general, however, the incidence of short-term change seems to be low enough that likelihood of detecting it in the short term is reduced.

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Dr. Ian R. MacDonald has been working with questions concerning marine ecology in the Gulf of Mexico for the past 10 years. He has been involved in the study of chemosynthetic communities at oil seeps since the first discoveries in 1985 and has published numerous peer-reviewed papers on related topics.

PALEONTOLOGY OF SEEP BIVALVE COMMUNITIES

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Chemoautotrophic benthic assemblages have been discovered on the continental slope of Louisiana in the Gulf of Mexico. These communities are associated with petroleum seepage, and resemble those assemblages found at hydrothermal vents (Kennicutt *et al.* 1985 and Brooks *et al.* 1987). Callender and Powell (1992) describe the prominent features of petroleum seep assemblages as high density, high abundance of large organisms, dominance by a single taxon, and low diversity. Six distinct biofacies have been recognized from petroleum seep assemblages; dominated respectively by mytilid mussels, vesicomyid clams, *Lucinoma* clams, thyasirid clams, vestimentiferan tubeworms, and the normal slope fauna. The long-term history of these seep assemblages is not well known. This study was designed to examine the long-term record of seep assemblages by comparing guild and tier structure, paleoenergetics, and changes in community composition of the six biofacies at a number of petroleum seep sites.

Seep assemblages from five sites, GC-184, GC-234, GC-272, GB-386, and GB-425, were sampled by submersible grabs and surface vessel box cores and piston cores. The grab and boxcore samples were used for guild and tier structure and paleoenergetics analysis. The piston core samples were sectioned at five centimeter intervals and are being used to investigate changes in community composition over thousands of years of accumulation, in addition to paleoenergetics and guild and tier structure analyses.

Autochthonous seep assemblages are characterized by a unique tier and guild structure, size-frequency composition, and animal density that together identify the paleoenergetics structure of these communities and distinguish them from other autochthonous assemblages of the shelf and slope. All seep assemblages were dominated by primary consumers, whereas the non-seep assemblage was dominated by carnivores. Carnivore dominance seems to be typical of shelf (or euhaline) death assemblages. Seep assemblages, in contrast, retain the theoretically-expected rarity of predaceous forms in fossil assemblages. The infaunal tier was well represented in most petroleum seep assemblages because a large fraction of the shelled biota were infauna or semi-infauna. Dominance by shelled infauna is unusual. Local enrichment of food resources and the dominance of shelled primary consumers explain the guild and tier structure of seep assemblages. Nearby autochthonous and parautochthonous assemblages relying on planktonic production are substantially different in each of these criteria. The non-seep autochthonous assemblages were dominated by epifauna and semi-infauna as is typical for continental shelf and slope assemblages.

A hindcasting paleoenergetics model was used to estimate the energy demand of both seep and non-seep assemblages. The basic paleoenergetics equation is as follows:

$$A_{Lt} = P_{gLt} + P_{rLt} + R_{Lt}$$

where A_{Lt} is the energy assimilated over the individual's life span, P_{gLt} is the portion of net production devoted to somatic growth, P_{rLt} is the portion of net production devoted to reproduction, and R_{Lt} is the amount of energy respired over the organism's life span. The two important products of the hindcasting model are paleoproduction and paleoingestion. Paleoproduction is equal to the individual's biomass-at-death, while paleoingestion is the amount of energy consumed by the organism over its life span, which is the assimilated energy divided by the assimilation efficiency,

$$I_{Lt} = A_{Lt} \ (A/I)^{-1}.$$

Hindcasting of energy demand based on the observed biomass as preserved and an estimate of sedimentation rate shows that energy demand by the community exceeds the supply from plantkonic rain in seep communities, a crucial verification of the adequacy of the hindcasting model.

Bathymodiolus sp., *Lucinoma atlantis*, and *Thyasira oleophila* shells were radiocarbon dated from the seep sites at GC-234, GC-184, and GB-425, respectively. A calibration curve of amino acid dating was used to increase the number of lucinids and thyasirids that could be aged. Piston cores from the "Mussel Beach" area of GC-234 recovered two buried mussel beds. The first bed, centered at about 95 centimeters depth, contained shells estimated to be between 2,000 and 3,000 years old. Mussels from the deeper bed, at about 195 centimeters, were estimated to be between 3,000 and 4,000 years old. Thus, the two mussel beds were approximately 1,000 years apart in age. Both of these beds contained individuals in life position, and some of the mussels still had byssal thread attachments, indicating the importance of catastophic burial in the preservation of mussel beds. The lucinids from GC-184, at 68 centimeters depth, were calculated to be over 3,500 years old, while the GB-425 thyasirids at 40 centimeters depth were 500 to 1,000 years old. The lucinids from a depth of 10 centimeters at GC-272 were found to be modern in age, and no deeper individuals were encountered.

Change in community composition rarely occurred over the length of the cores (about 200 centimeters) taken from the mussel, lucinid, and thyasirid beds. Even at GC-234, an alternative seep fauna did not occupy the site between the times of mussel bed burial. In the other cases (thyasirid and lucinid biofacies), sites were occupied more or less continuously, but with varying infaunal densities. Thus individual seep communities are unique, persistent and resilient over long time scales. A transition from non-seep to seep biofacies was never evident in any of the cores; accordingly, the ages previously mentioned represent minimal ages of the seep sites studied.

Finally, we developed a computer program designed to reconstruct the original abundance and size-frequency distribution from a collection of bivalve fragments. The need for this shell reconstruction program comes from the fact that many seep bivalves are obtained in fragmented condition due to taphonomic processes. A primary attribute of the program design was the use of simple readily measured characters (shell length, width, thickness, weight) allowing rapid analysis of shell fragments. The program was tested using a mussel, two lucinids, and an arc shell. In each case, the whole shells were measured and then broken into a minimum of three to four pieces, and then remeasured. Numerical abundance was slightly overestimated and size-frequency skewed slightly towards smaller size classes. In terms of paleoproduction and paleoingestion, these errors proved of little consequence. Accordingly, this modeling approach shows promise as a way to reconstruct the original size-frequency and abundance of shells from their fragments permitting their use in this type of paleoecological analysis.

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Mr. Kenneth A. Warren is a graduate research assistant in the Department of Oceanography at Texas A&M University. His current research is concerned with the paleoecology of hydrocarbon seep communities. Mr. Warren received his B.S. in Marine Science from the University of South Carolina.

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A DESCRIPTIVE SYNTHESIS OF GULF OF MEXICO HYDROCARBON SEEPS

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INTRODUCTION

Ecological theory proposes that every species occupies a niche uniquely defined by the organism's adaptation to a restrictive combination of geological space, physical and chemical tolerances, nutritional requirements, predators, feeding adaptations, prey, mobility, reproductive needs, etc. (Hutchinson 1953). By extension, an aggregate of niches forms an interdependent community of organisms; classes of communities, generally united by some more or less arbitrary theme form an ecosystem (the lake in Hutchinson's example). This study has the formal title: "The Chemosynthetic Ecosystem Study"; it is appropriate to consider the fauna of deep-sea hydrocarbon seeps in these terms.

In practice, species are described by their morphology rather than their ecological niche; and communities and ecosystems are often defined as convenient catchalls for organisms that seem to cluster together. We simply know too little about too many species to explain adequately why they are where we find them. For example, the fauna of the deep sea is characterized by a great abundance (numerical, not biomass) of highly diverse animals that burrow or crawl on the seafloor. Deep-sea biologists are generally unable to explain why groups are found together, to predict what their geographic range will be, or how they will persist in the face of disturbance. In this context, the chemosynthetic communities found at cold seeps and hot vents offer the distinct opportunity for rigorous ecological definition. As Fisher (this volume) has shown, these animals depend, directly or indirectly, upon chemoautotrophic productivity of bacteria and their metazoan hosts; the bacteria have well-defined chemical requirements that are met by a very narrow range of geological circumstances. We argue that chemosynthetic communities at hydrocarbon seeps form a distinct subset of these communities; a subset which, to date, is known only from the northern Gulf of Mexico.

This presentation is an attempt to identify reductively the factors that make the Gulf seep communities unique. The exercise progresses in steps from the regional to the local and from the general to the specific. At each level, we attempt to list key characteristics that distinguish a specific component of Gulf of Mexico seep ecosystem from its broader context.

The Gulf of Mexico Hydrocarbon System

1. The northern Gulf of Mexico is one of the most productive petroleum basins in the world and is characterized by multiple hydrocarbon source rocks and appropriated reservoirs.
2. Large amounts of liquid hydrocarbons have been preserved instead of being cracked to gas because of the timing of subsidence and Cenozoic salt tectonics.
3. The influence of natural seepage on hydrocarbon levels in slope sediments is widespread.

Salt Structures and Faults

1. Movement of the Louann Salt body is the agent responsible for complex bathymetry and extensive faulting on the northern Gulf Slope.
2. Locally active salt movement produces both the capping structures for hydrocarbon accumulation and the conduits for vertical migration.
3. Hypersaline fluids derive from dissolution of the salt stock.

Seep Zones

1. Seeps are sub-sets of the fault systems, generally << 1 km in extent.
2. Seeps form at kinks in faults or at the intersection of several faults.
3. Fluid discharge is active and continuous and may form perennial slicks on the sea surface.
4. Poorly consolidated sediments in seeps are radically transformed by fluid flow, producing such features as pockmarks, constructional mud mounds, hydrate mounds, and massive carbonates.

The Seep Hydrocarbon System

1. Freshly arriving oil is rapidly degraded by microbial activity in the near sea floor sediments.
2. Gaseous hydrocarbons dynamically vent or form hydrates that trap additional gas and oil at the surface.
3. Hydrates may dissociate with slight increases in bottom water temperature, releasing pulses of oil and gas.
4. Degradation of oil establishes a shallow (<5 cm) oxic/anoxic interface and maintains high H_2S concentration through reduction of seawater sulfate.

Seep Chemoautotrophs

1. Seep vestimentiferans: slow growing (probable life-span is 100+ years), slender, low $d^{13}C$ values, and often rooted in soft sediment.
2. Seep mytilids: slow growing (probable life-span is 50+ years), methanotrophic, variable $d^{13}C$ values (-60 to -30‰), and speciose.
3. Seep clams: mobile, slow growing (??), infaunal (lucinids), and epifaunal (vesicomyids).

Seep Heterotrophs

1. Reduced endemism among megafauna.
2. Depauperate infauna.

Temporal Change

1. Marked long-term stability of community composition (bivalves).
2. Punctuated short-term stability.

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Dr. William W. Schroeder has been involved in oceanographic investigation for over 27 years. He has conducted research throughout the Gulf of Mexico as well as in the Caribbean Sea, the Bahaman Islands, the Gulf of Papua (northern Great Barrier Reef), Antarctica, and Southern Africa. His principal research interest is interdisciplinary oceanography with emphasis placed on the relationships of the geological and physical environments to the biological environment. Specific areas of research include: characterization of the continental margin environments/habitats (e.g. hard bottom and hydrocarbon seep/chemosynthetic communities); coupling of land, estaurine systems and the continental margins; and Quaternary climate variability and paleoceanography.

Dr. Ian R. MacDonald has been working with questions concerning marine ecology in the Gulf of Mexico for the past 10 years. He has been involved in the study of chemosynthetic communities at oil seeps since the first discoveries in 1985 and has published numerous peer-reviewed papers on related topics.

SESSION 5C

COASTAL ZONE MANAGEMENT: RECENT GULF OF MEXICO OCS CONSISTENCY ISSUES

Session: COASTAL ZONE MANAGEMENT: RECENT GULF OF MEXICO OCS CONSISTENCY ISSUES

Co-Chairs: Ms. Lore Hantske O'Hanlon and Ms. Bonnie LaBorde Johnson

Date: December 16, 1993

Presentation	Author/Affiliation
Summary—Coastal Zone Management Session	Ms. Lore Hantske O'Hanlon Texas General Land Office Ms. Bonnie LaBorde Johnson Minerals Management Service Gulf of Mexico OCS Region
Document printed as Addendum (page 497)	Mr. Bill O'Beirne NOAA Office of Ocean and Coastal Resources Management
The Florida Coastal Management Program	Ms. Lynn Griffin Florida Department of Environmental Protection
Alabama's CZM Review Process for OCS Activities	Ms. Kelly Williams Alabama Department of Environmental Protection
Document not submitted	Ms. Rachel Wilson Department of Natural Resources Coastal Management Division
Mississippi Coastal Program Overview	Mr. Gary Cuevas Mississippi Department of Wildlife Fisheries and Parks Bureau of Marine Resources
The Texas Coastal Management Program and Oil and Gas Activities	Ms. Diana Aguilar Ramirez Texas General Land Office

SUMMARY—COASTAL ZONE MANAGEMENT SESSION

Ms. Lore Hantske O'Hanlon
Texas General Land Office

Ms. Bonnie LaBorde Johnson
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Gulf of Mexico OCS Region

The Coastal Zone Management (CZM) session provided an information exchange among the Gulf States on CZM consistency issues. The MMS was particularly interested in assisting the State of Texas in obtaining ideas for their current CZM program development.

Mr. Bill O'Beirne, of NOAA's Office of Ocean and Coastal Resources Management (OCRM), presented an overview of current CZM guidance and policy in light of the CZMA Reauthorization Amendments of 1990 and a discussion of major problems encountered by states developing their programs.

Coastal Zone Consistency Coordinators from three gulf offices, Mr. Gary Cuevas, Biloxi, Mississippi; Ms. Kelly Williams, Mobile, Alabama; and Ms. Lynn Griffin, Tallahassee, Florida, served on the panel. In addition, Ms. Lore Hantske O'Hanlon, who led the panelists, and Ms. Diana Aguilar Ramirez served on the panel and represented the State of Texas Coastal Management Division of the General Land Office.

Each of the states provided an overview of their CZM Program, focusing on organization and structure to implement the program; a description of the federal and state consistency review processes and time frames; the policies regarding oil and gas development; examples of consistency issues regarding oil and gas development and related activities for both state waters and on the Outer Continental Shelf (OCS); and specific types of OCS and other energy-related activity problem areas.

THE FLORIDA COASTAL MANAGEMENT PROGRAM

Ms. Lynn Griffin
Florida Department of Environmental Protection

Florida began its involvement in reviewing offshore oil and gas lease sales and exploration plans in the late 1970s. Florida's Coastal Management Program (FCMP) was approved by NOAA in 1981. The FCMP was administered by the Florida Department of Environmental Regulation (recently renamed the Department of Environmental Protection) until 1992 when it was transferred to another department. The DEP is the primary state agency with statutory interest in offshore oil and gas development and, therefore, its evaluation and recommendations form the basis of the state's consistency positions on proposed activities.

Several prominent issues have marked the state's position on how oil and gas activities should proceed offshore of Florida. From the outset, the state took the position that the size, distribution and pace of lease sales should be primarily determined by the presence of, and the need to protect, marine and estuarine resources in the eastern Gulf of Mexico and the south Atlantic. In the 1970s and 1980s, the state's position was that drilling in some areas would probably be acceptable with sufficient environmental safeguards, while other areas should be removed from the leasing schedule altogether because they are too vulnerable to tolerate such activities. Although some buffer zones were granted, in general, DOI's area-wide leasing strategy used throughout the 1980s did not mesh with this approach. The result was several lease sale confrontations with the state. Today's leasing process is more rational in its approach, but still is not as sensitive to the state's issues as we would like it to be.

Florida also asserted that an inextricable link exists between the planning and execution of a lease sale and the later stages of exploration and development. We believe this linkage entitles the state to consider potential development and production impacts as a consequence of an earlier decision to lease or explore.

Another major issue for the state has been the adequacy of information on which DOI's decisions, at all stages, are based. Over the years, we have raised objections based on such issues as the level of information available on the character and distribution of offshore habitats; the adequacy of physical oceanographic information; the adequacy of the MMS model used to predict oil spill trajectories; and the sufficiency of socioeconomic impact evaluations. Some information gaps have been filled in by studies conducted under the MMS' Environmental Studies Program and special task forces. By using the federal consistency process, the state has required operators to provide oil spill trajectory analyses to document worst case circumstances and, in specific instances, to monitor the effects of exploration on local natural resources.

Florida's concerns apply throughout the eastern Gulf and south Atlantic areas, but are most widely recognized in the southern part of the state, in the offshore areas south of 26° N latitude. Common to this region are rich assemblages of hard and soft bottom communities, including spectacular coral reefs. An abundance of tropical and sub-tropical fish, shellfish, and other wildlife associates with these areas as well as adjacent coastal marsh, mangrove and intertidal areas. The Everglades, Florida Bay and the southwest Florida shelf are a unique, vast coastal ecosystem of national significance. The introduction of major industrial development into this area, which would inflict both mechanical and chemical changes to the system, has always been a paramount concern to the state. In addition, the state believed that prevailing ocean currents in this region made the threat of an oil spill even more acute because it could be delivered onshore fairly rapidly. Landfalls were predicted in the most vulnerable areas (e.g., mangrove marshes, shallow bays and inlets, mud flats) as well as sandy beaches fronting some of the state's most important tourist destinations.

Despite repeated insistence by the state that no leases should be offered south of 26°N, DOI proceeded to do so in 1984 and 1985. Two companies, Mobil and Unocal, filed plans of exploration on several blocks in the Pulley Ridge area. The companies expected to discover oil at these locations. In 1988, the state objected to these plans based on inconsistencies with specific provisions of its coastal management program. In 1993, following four years of deliberation through the U.S. Department of Commerce appeals process, the state's consistency objections were upheld. Commerce supported the state's position under both grounds for appeal provided in 15 CFR 930, subpart H. This was a significant result, since it is unusual for a state to be supported on the first ground which considers the adverse environmental effects of the activity.

The biological resources of the northern Gulf, while different from the south, are also characterized by abundant marine and estuarine fisheries, significant recreational resources, and a strong tourist-based economy. Since 1991, the state has argued that the panhandle of Florida should be protected by a 100-mile buffer zone in which there will be no oil and gas activity. The need for this buffer is based, in part, on the lack of sufficient scientific information to make sound management decisions, particularly with regard to biological, physical oceanographic, social and economic impacts. DOI has not agreed to support such a buffer zone.

In 1991, the state objected to two plans of exploration for blocks off of Pensacola in the Destin Dome and Pensacola planning areas which were filed by Chevron and Mobil, respectively. Based on the results of previous explorations, economically recoverable quantities of natural gas are known to exist in this area of the Gulf. The Chevron well is the last exploratory well in a group of blocks for which the company is developing a plan of development and production. The cumulative and secondary impacts of development and production were assessed as a part of the state's review of both the Chevron and Mobil plans. In addition, the state based its objection on the lack of resource and socioeconomic information for the affected region.

In 1993, the U.S. Department of Commerce overrode the state's consistency objection by supporting the first ground of Chevron's appeal. Commerce has not yet handed down its decision on the Mobil exploration plan for the Pensacola area. Chevron is now in the process of applying for an air quality permit from the Environmental Protection Agency and expects to proceed with exploration if the permit is issued.

Air quality regulation is a new area of involvement for the state. The recent Clean Air Act amendments reassigned the responsibility for issuance of air quality permits for oil and gas activities in the eastern Gulf from MMS to EPA. The state may seek delegation of this program in the future. For the recent Chevron exploration plan, DEP air quality staff worked closely with the EPA in reviewing the permit application. This relationship would be expected to continue whether the program is delegated or not.

In the future, Florida expects to be facing its first development plan at the Chevron Destin Dome blocks. In earlier stages of preparation of the plan, Chevron coordinated with the Governor's Office and state agencies to determine the appropriate resource information necessary for the state to conduct its consistency review. Since this is the first development plan in the eastern Gulf, an environmental impact statement will be required. One issue which has yet to be clarified is how the timing of the EIS and the consistency review of the plan will be coordinated. When the plan of development is filed, it will trigger the consistency review as well as the preparation of the EIS. However, the information in the EIS will be necessary for the state to make its consistency decision. Since an EIS cannot be completed and reviewed within the consistency time period, a consistency objection to the plan may be inevitable.

When the CZMA was reauthorized in 1990, Congress amended the Act to reverse the Supreme Court's 1984 decision in *California v. Watt* which had made lease sales ineligible for federal consistency review. Now that this coordination mechanism applies to the leasing process once again, Florida is hopeful that future lease sales will be more in line with its resource management goals.

Lynn Griffin served as the Federal consistency coordinator for the Florida Coastal Management Program from 1981-1992 in Tallahassee, Florida. Since 1992, she has been coordinating Federal consistency procedures for the Florida Department of Environmental Protection. Since 1979, Ms. Griffin has been responsible for conducting the DEP's review of OCS plans. Ms. Griffin received B.S. and M.S. degrees in biology from Florida State University. Her master's studies were part of the Department of Interior's MAFLA baseline surveys of the Gulf of Mexico.

ALABAMA'S CZM REVIEW PROCESS FOR OCS ACTIVITIES

Ms. Kelly Williams
Alabama Department of Environmental Protection

The Alabama Coastal Area Act, authorizing the development of a coastal area program, was adopted by the state legislature in 1976. In 1979, the development of the Alabama Coastal Area Management Program (ACAMP) was completed, and in 1982, the responsibility for the management of the program was divided between the Alabama Department of Economic and Community Affairs (ADECA), and the Alabama Department of Environmental Management (ADEM). ADECA is responsible for all non permit-related activities, such as planning, research, and policy development, while ADEM is responsible for all permit, enforcement, regulatory, and monitoring activities.

The stated philosophy of Alabama's Coastal Area Management Program is to encourage growth while maintaining environmental quality. The management program identifies two types of policies: policies for coastal resource uses and policies for natural resource protection. Coastal resource uses include coastal development and mineral resources, commercial fishing, recreation, and transportation. These uses are consistent with the ACAMP to the extent that the activity is carried out in a manner consistent with the ACAMP policies for natural resources. Natural resources identified in the ACAMP include biological productivity, water quality, water resources, air quality, wetlands and submersed grassbeds, beaches and dunes, wildlife and fisheries habitat, endangered species, and cultural resources.

The regulatory definition of Alabama's coastal area is coastal waters and the adjacent shorelands strongly influenced by each and in proximity to the shorelines of Alabama, and includes transitional and intertidal areas, salt marshes, wetlands, and beaches. The inland boundary is defined by the continuous ten-foot contour line. The seaward boundary is the outer limit of the territorial sea and runs parallel to the Alabama coast three miles southward from the land-sea interface. Since Alabama has only 55 to 60 miles of Gulf frontage, many OCS projects that are reviewed through the coastal zone management program are much closer to the Louisiana coast than to the Alabama coast. For instance, a well location which may be submitted for review in the Viosca Knoll area may be 30 miles from Louisiana's boundary, but 80 miles from Alabama, or a well in the Mississippi Canyon area may be 40 miles from Louisiana but over 100 miles from Alabama's coast.

Alabama's review process for activities on the Outer Continental Shelf is coordinated by ADEM's Coastal Program which is based in the Mobile Branch Office under the Field Operations Division. The review process includes a 30-day public notice period as well as a $200 fee associated with each surface location. ADEM coordinates its review with the local U. S. Fish and Wildlife Service in Daphne, the Geological Survey of Alabama, ADEM's Water Division, and ADEM's Air Division in its review of each project. The Fish and Wildlife Service provides comments on potential impacts to endangered or threatened species, and the Geological Survey provides comments regarding potential impacts to oil and gas reserves located beneath state lands and on potential impacts to unusual geological structures. ADEM's Water Division provides comments on potential impacts to Alabama's water quality, and ADEM's Air Division evaluates potential impacts to Alabama's air quality.

ADEM's Coastal Program regulations state that activities related to the extraction of oil and gas are considered to be of significant national interest. However, sitting, construction, and operation of energy facilities that degrade the coastal area are not permissible. To date, ADEM has not denied certification of any production, development, or exploration plan on the Outer Continental Shelf. That is not to say that the state has not objected to certain aspects of proposed activities. However, in those cases where objections have arisen, ADEM has encouraged consultation between the lessee and concerned agencies, consistency letters have been conditioned to address protection of coastal resources, and issues of concern have ultimately been resolved.

OCS issues of particular concern to ADEM in the past have included control of marine debris, protection of state gas reserves, preservation of water quality, and conservation of unique geologic structures and biological communities.

With the advent of the annual beach clean-up, marine debris has become an area of particular concern. Debris associated with the oil and gas industry has been recovered on beaches gulf-wide. Although operators are required by federal regulations to provide for the collection of trash for proper disposal, occasionally development plans are deficient in addressing this issue. We have commented on this issue in the past to raise awareness of this problem.

The most controversial projects are those located immediately outside state waters where problems arise concerning potential impacts to state resources. A problem that all Gulf states have probably experienced is the potential drainage of oil or gas from beneath state lands. The Geological Survey of Alabama reviews each proposal at ADEM's request and advises the coastal program whether a well is to be drilled on a structure common to both state and federal waters. If the Survey determines that extraction of state resources could occur, then the CZM program initiates discussion between the applicant and the Survey. This is primarily an economic issue; for this reason, the coastal program has elected to allow the State Oil and Gas Board to resolve this matter with the lessee. However, in cases where this controversy has risen, ADEM has conditioned its certification of the project to require that the lessee come to an agreement with the Oil and Gas Board prior to initiating operations.

If a discharge is proposed adjacent to the state boundary, ADEM's Water Division considers impacts to state water quality. Each activity is reviewed on a case by case basis. Impacts to areas of biological concern are considered, such as shellfish harvesting areas, submersed grassbeds, and beaches. Standard requirements of ADEM certification have been that discharge monitoring reports, noncompliance reports, and Spill Contingency Plans be submitted to ADEM. ADEM is concerned about potential impacts to fisheries habitat, recreational beaches, wetlands, and submersed grassbeds which could result from a major oil spill in the Gulf of Mexico; therefore, submittal of a Spill Contingency Plan is routinely requested by ADEM.

Another area of concern has been the pinnacle trend area located off the coasts of Alabama and Mississippi. These pinnacles contain sensitive seagrass communities which attach to naturally occurring hard or rocky formations. They occur in water depths of 73 to 100 meters approximately 70 to 80 miles offshore. Although Alabama has not denied certification in these areas, the Geological Survey has commented on proposed activities in these areas and ADEM forwards copies of these comments to the lessee. The MMS live bottom stipulation requires lessees to conduct a bathymetric survey prior to beginning operations in the pinnacle trend area, and if it is determined that live bottoms might be adversely impacted, measures will be required to protect those areas. ADEM has not attempted to condition activities in these areas beyond what MMS currently requires.

Ms. Kelly Williams has been with the Alabama Department of Environmental Management since 1985 and currently works as an Environmental Scientist in the Department's Coastal Program in Mobile, Alabama. She coordinates Alabama's CZM review of oil and gas exploration and production activities in the Outer Continental Shelf. Ms. Williams received a B.S. in biology from the University of Alabama and did graduate work at Louisiana State University.

MISSISSIPPI COASTAL PROGRAM OVERVIEW

Mr. Gary J. Cuevas
Mississippi Department of
Wildlife, Fisheries and Parks
Bureau of Marine Resources

The Mississippi Coastal Program is built around 10 goals which guide decisions affecting the management of Mississippi's coastal resources. These goals set clear objectives for the State when making management decisions that attempt to balance economic considerations of coastal resource development and environmental protection. The Mississippi Coastal program goals generally provide for the following:

1. Reasonable industrial expansion and efficient waterfront utilization;
2. Conservation and protection of coastal wetlands and ecosystems;
3. Conservation and protection of the state's seafood and aquatic life;
4. Conservation of air and water quality;
5. Beneficial use of water resources;
6. Preservation and enhancement of cultural and historic resources;
7. Encourage the preservation of natural scenic qualities;
8. Consideration of the national interest;
9. Provide assistance to local governments for public facilities; and
10. Coordinate implementation of public policy in the coastal area.

The legislative basis for these goals can be found in the state's Coastal Wetlands Protection Law, various seafood statutes, the Air and Water Pollution Act and the surface and ground water withdrawal statutes.

The Bureau of Marine Resources of the Mississippi Department of Wildlife, Fisheries and Parks is the lead agency for the administration of the Mississippi Coastal Program. In this administrative capacity the Bureau exercises regulatory responsibilities in the coastal area through the policy coordination procedures with the other coastal program agencies. Other coastal program agencies are the Mississippi Department of Archives and History, the Mississippi Department of Environmental Quality, Offices of Pollution Control and Land and Water Resources. Each agency has both direct regulatory and commenting responsibility for matters under their control.

The Bureau of Marine Resources regulates projects and activities affecting the coastal wetlands and administers the seafood ordinances. The Bureau also certifies consistency determinations for federal projects.

Other non-regulatory functions of the Bureau include; special management area and waterfront planning, shorefront access construction, fisheries and wetlands research, coastal habitat acquisition and public information/education.

The most current issue confronting the Bureau is dockside casino gaming. Ten casinos have opened on the Mississippi Coast and all have required authorization from the Bureau for relatively minor construction including pier and mooring piles to realignments of shorelines and channels. Present casinos have located in already commercialized areas and no impacts to tidal marshes have occurred. Many more casinos are planned for the Coast.

Present policies are encouraging casinos to locate in commercial waterfronts and to avoid important marshes, bays and recreational waters. Future anticipated issues in the coastal are expected to be stormwater management and other non-point source pollution.

The Bureau and the Mississippi Coastal Program is at a crossroad. Decisions made now will determine the direction of coastal development more so than at any other time in coastal history, with perhaps the exception of settlement of the Coast by D'Iberville in 1699.

Mr. Gary J. Cuevas has served as the Program Manager for the Department of Wildlife, Fisheries, and Parks/Bureau of Marine Resources, Biloxi, Mississippi, since 1975. He is responsible for implementing provisions of Mississippi's Coastal Zone Management Plan. Mr. Cuevas received his B.S. in Architectural Technology from the University of Southern Mississippi.

THE TEXAS COASTAL MANAGEMENT PROGRAM AND OIL AND GAS ACTIVITIES

Ms. Diana Aguilar Ramirez
Texas General Land Office

INTRODUCTION

In 1991, the Texas Legislature passed Senate Bill 1053, which mandated the Texas General Land Office (GLO) to coordinate and develop the Texas Coastal Management Program (CMP) in cooperation with the other state resource management agencies. Governor Richards signed the bill into law and sent a letter to Commerce Secretary Robert Mosbacher informing him of the state's intent to submit a state program for approval under the federal Coastal Zone Management Program (CZM). Under the state's development schedule, the CMP will be submitted to the U.S. Department of Commerce in June 1994.

The purpose of this session is twofold. First, the GLO, as the state lead for developing the CMP, wants to inform all potentially affected parties of the direction in which the CMP is moving. Second, GLO wants to learn from states already in the CZM and from the regulated community (1) what common pitfalls the state programs face, (2) how Texas can avoid these pitfalls, and (3) what types of mechanisms might accomplish the coastal natural resource protection and governmental efficiency and effectiveness goals of the CMP. This discussion will focus on the issues most relevant to oil and gas activities both in state waters and on the Outer Continental Shelf (OCS).

THE TEXAS COASTAL MANAGEMENT PROGRAM

The CMP is being developed as a "networked" program--one which links the existing regulations, programs, and expertise of the multiple state, federal, and local entities that now manage various aspects of coastal resource use. The state agencies and subdivisions that comprise the current regulatory and management structure will be required to exercise their respective authorities in conformance with the goals and policies of the CMP.

To oversee development and implementation of the CMP, and compliance with its goals and policies, amendments to the state's Coastal Coordination Act in Senate Bill 1053 established the Coastal Coordination Council. The council is composed of the commissioner of the General Land Office, who serves as chair; the attorney general; the chair of the Parks and Wildlife Commission; the chair of the Texas Natural Resource Conservation Commission; a member of the Railroad Commission of Texas; and two gubernatorial appointees who serve two-year terms--a local elected official from the coastal area and a coastal resident.

The council is charged with "adopting the goals and policies" of the CMP and with reviewing "all actions taken or authorized by state agencies and subdivisions that may adversely affect coastal natural resource areas." In addition, the council is authorized to review federal actions (including federally licensed and permitted activities and OCS activities) for consistency with the CMP.

The chief unifying element of the Texas Coastal Management Program is the body of enforceable goals and policies adopted as rules by the Coastal Coordination Council combined with the council's power of consistency review. The goals and policies provide uniform guidance for decision-making by all entities regulating natural resource use within the Texas coastal area.

The council has broad discretion because the Coastal Coordination Act does not dictate the form of the CMP goals and policies. However, the council must operate within parameters set by the legislature. For the council, these parameters are found in statutes other than the Coastal Coordination Act. Because the CMP relies on various agencies' and subdivisions' authorities to regulate or otherwise manage activities and resources, the council cannot adopt goals and policies that are contrary to express restrictions or limitations contained in these agencies' or subdivisions' respective statutory delegations of authority.

The goals and policies of the CMP are written to ensure that adverse effects on coastal natural resource areas (CNRAs) are avoided. The Coastal Coordination Act defines coastal natural resource areas as coastal land and water features requiring special management. CNRAs are areas that have significant biological, geological, physical, historical, cultural, or recreational characteristics which are important to the ecological health, public safety, enjoyment, and economic viability of the coastal area. CNRAs form an integrated but fragile ecosystem within the coastal area, with each resource having unique functions and values that are vital to the health of the overall coastal ecosystem.

Fourteen CNRAs have been designated in the CMP preliminary draft document. They are waters under tidal influence; waters of the open Gulf of Mexico; coastal public submerged land; coastal wetlands; submerged aquatic vegetation; tidal sand and mud flats; oyster reefs; coastal shore areas; gulf beaches; critical dune areas; coastal hazard areas; coastal barriers; coastal historic areas; and coastal parks, wildlife management areas, and preserves. The first seven CNRAs are of particular significance to oil and gas activities occurring in state or federal waters.

Policies applicable to oil and gas and related activities include a sitting policy which requires agencies and subdivisions to permit activities to be located only at the site that will avoid adverse effects on CNRAs. If avoidance is impossible, the policy requires the activity to be located at a site that will result in the least adverse effects on CNRAs.

Because the sitting of oil and gas exploration and production facilities depends on subsurface geology, sitting alternatives are much more limited than for other types of development. The CMP goals and policies will establish sitting requirements for oil and gas exploration and production focusing on the most sensitive CNRAs--coastal wetlands, submerged aquatic vegetation, tidal sand and mud flats, oyster reefs, and coastal public submerged lands.

Additionally, the CMP currently contains policies covering the construction, operation, and maintenance of energy facilities and related activities; construction and operation of solid waste treatment, storage, and disposal facilities (including oil and gas exploration and production solid waste facilities); oil and hazardous substance spill prevention, response, and remediation; discharge of wastewater to coastal waters (i.e., waters under tidal influence and waters of the open Gulf of Mexico); nonpoint-source water pollution; development in critical areas (i.e., coastal wetlands, submerged aquatic vegetation, tidal sand and mud flats, and oyster reefs); construction of waterfront facilities and other structures on coastal public submerged lands; dredging and dredged material disposal; emission of air pollutants; and state certification of point-source discharge of pollutants to waters of the United States.

The vast majority of CMP policies are based on current statutory authorities of the implementing agencies. In only a few select cases will changes have to be made in the existing state rules.

STATE AND FEDERAL CONSISTENCY REVIEW

The Coastal Coordination Council will enforce the consistent implementation of the CMP goals and policies by exercising its right to review state and federal actions for consistency with the CMP. For state consistency review, the council will exercise this authority through two means. First, the council will review agency and subdivision rules implementing the CMP goals and policies to ensure their consistency with the CMP goals and policies.

Second, the council reserves the right to review individual actions that fall above a substantive threshold set by the CCC in consultation with the implementing agency. The second mechanism is effective upon council certification of an agency's or subdivision's rules. If an agency or subdivision does not submit its rules for the council's consistency review, all individual actions under the relevant rules are subject to individual council review.

The state consistency review process for individual actions begins after the state agency or subdivision has issued a permit or has otherwise given its approval for an activity to commence. The council has 30 days to decide whether an eligible action will receive individual council review. If it will, the council has 90 days to review and determine whether the action is consistent with the CMP goals and policies. If the council judges an action to be inconsistent with the CMP, it may remand the action to the agency or subdivision with the request that it be made consistent. If, after being remanded, the action is still found to be inconsistent with the CMP goals and policies, the council will reverse the action, making the agency's decision to authorize the action void. The Attorney General's Office is authorized to enforce the council's ruling by filing suit to stop the action.

Under federal consistency review, the council reviews those federally licensed and permitted activities that are listed in the CMP document for consistency with the CMP goals and policies. The preliminary draft CMP document includes activities that require an individual §404 permit under the Clean Water Act or a §9 or §10 permit under the Rivers and Harbors Act of 1899; construction and operation of deepwater ports; sitting, design, construction, and operation of natural gas pipelines, transportation, and storage facilities; OCS activities described in detail in OCS plans, including pipeline placement within the western Gulf of Mexico; and OCS lease-sale activities.

The federal consistency review process for listed federally licensed and permitted activities, including OCS activities, begins upon council receipt of an administratively complete application for the federal license or permit. The council has six months to review the application and the applicant's consistency certification and either concur with or object to the applicant's consistency certification. If the council concurs, the federal agency moves forward with its permitting process. If the council objects, the federal agency may not issue the permit or authorization. The Secretary of Commerce may review a federal license or permit activity, including those described in detail in an OCS plan, that have been found inconsistent with the CMP goals and policies if the activity furthers one or more of the national objectives contained in §§302 and 303 of the CZMA, if the activity's furtherance of the national interest outweighs its adverse effects on CNRAs, if the activity will not violate any requirements of the Clean Air Act or Clean Water Act, and if there is no reasonable alternative available that would allow the activity to be undertaken in a manner consistent with the CMP goals and policies.

SUMMARY

The CMP is a comprehensive program that will affect the way many activities are undertaken within the CMP boundary. The CMP will also affect some activities that occur outside the CMP boundary that adversely affect CNRAs. To achieve the goals of the CMP, which include improving governmental efficiency and effectiveness, the state must ensure that the federal consistency review process is shortened to the minimum time necessary for the council to make informed decisions and includes mechanisms for coordination that have been proven to work.

Diana Aguilar Ramirez is a policy specialist with the Coastal Management Division of the Texas General Land Office. Ms. Ramirez is the staff lead for developing the federal consistency review process of the Texas Coastal Management Program. Ms. Ramirez has a Bachelor of Arts degree from the University of Texas at Austin and a Master in Public Affairs degree in domestic policy from the Woodrow Wilson School of Public and International Affairs, Princeton University.

SESSION 5D

BATHYMETRY AND COASTLINE DATA FOR THE GULF OF MEXICO

Session: BATHYMETRY AND COASTLINE DATA FOR THE GULF OF MEXICO

Chair: Dr. Murray Brown

Date: December 16, 1993

Presentation	Author/Affiliation
Introduction	Dr. Murray Brown Minerals Management Service Gulf of Mexico OCS Region
National Geophysical Data Center Bathymetric Data Holdings for the Gulf of Mexico and Progress on Compilation of New Bathymetry	Ms. Lisa A. Taylor Dr. Troy L. Holcombe Marine Geology and Geophysics Division National Geophysical Data Center
Document not submitted	Dr. Bill Bryant Texas A&M University
Preparation of a Gridded Bathymetry for the Gulf of Mexico	Dr. H. James Herring Dynalysis of Princeton
Document not submitted	Ms. Maura Lohrenz Naval Research Laboratory
National Developments in Bathymetric Mapping	Mr. Millington Lockwood Joint NOAA/USGS Office for Mapping and Research

NATIONAL GEOPHYSICAL DATA CENTER BATHYMETRIC DATA HOLDINGS FOR THE GULF OF MEXICO AND PROGRESS ON COMPILATION OF NEW BATHYMETRY

Ms. Lisa A. Taylor
Dr. Troy L. Holcombe
Marine Geology and Geophysics Division
National Geophysical Data Center

INTRODUCTION

The National Geophysical Data Center (NGDC), collocated with the World Data Center A for Marine Geology and Geophysics and the International Hydrographic Data Center for Digital Bathymetry in Boulder Colorado, maintains several large data bases that include bathymetry from the Gulf of Mexico. These are the National Ocean Service/Coast and Geodetic Survey Hydrographic Data Base for the U.S. Exclusive Economic Zone, the Global Trackline Marine Geophysical Data (GEODAS), and gridded and full resolution multibeam data bases from the world ocean. In addition, NGDC distributes the Global Relief CD-ROM containing several global topographic/bathymetric data sets and world-wide digital coastlines, as well as the U.S. Geological Survey GLORIA II long range sidescan sonar imagery for the Gulf of Mexico on CD-ROM.

As a participant in the Intergovernmental Oceanographic Commission sponsored International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico (IBCCA) project, NGDC is recompiling bathymetry from all the best data sources for the northern Gulf of Mexico. New bathymetry has already been completed for (1) the northeastern Caribbean region around Puerto Rico, and (2) the western Atlantic region east of the Blake Plateau and the northern Bahamas. The IBCCA project is an international effort that will result in published bathymetry and a digital bathymetric contour data base for the Caribbean Sea and the Gulf of Mexico.

BATHYMETRIC DATA

The National Ocean Service/Coast and Geodetic Survey Hydrographic data base contains in excess of six million data records, mostly depth soundings, from the U.S. Exclusive Economic Zone (EEZ) of the northern Gulf of Mexico. Three types of data records including soundings, non-sounding features (i.e., rocks, wrecks, lights), and bottom characteristics are included in the data base. Data collected prior to 1965 were digitized from hydrographic smooth sheets while data collected after 1965 were collected on digital media in the field. The Hydrographic data base is searchable by one degree square areas; NGDC also maintains a 15-second gridded version of this data set.

The Global Marine Geophysical Data Base (GEODAS) contains trackline bathymetry, magnetics, gravity and shot point navigation for the northern Gulf of Mexico. The data base contains 422 thousand kilometers of trackline bathymetry totaling 745 thousand data records for the Gulf of Mexico. The complete GEODAS data set is available on CD-ROM and is updated annually. The CD-ROM includes menu driven search and retrieval software that allows the user easy access to the data. The custom designed software enables the user to bring up header information on any cruise detailing survey specifics such as instrumentation used for collection and navigation and the types of data corrections applied. Searches for both analog and digital data can be conducted by institution, survey vessel, survey number, area, type of data and dates of survey. Screen plots displaying color coded tracklines within a search area can be generated easily as well as postscript plotting files.

The Multibeam Bathymetric Data Base maintained by NGDC contains six gigabytes of survey and trackline data from the National Ocean Service/Coast and Geodetic Survey, academic institutions, and foreign countries. National Ocean Service/Coast and Geodetic Survey multibeam surveys provide coverage from several areas of the Outer Continental Shelf area of the western Gulf of Mexico, totaling 1.5 gigabytes of data. The surveys are inventoried in GEODAS. In addition to the full beam-point data from the NOS/C&GS multibeam surveys, two gridded subsets of these data are available from NGDC. One data set is gridded by selecting data points every 250 meters using a Universal Transverse Mercator grid, and the other is a 15 second grid generated from the 250 meter grid. The high density and high quality of the multibeam gridded data lends itself to construction of base maps and generation of three dimensional images.

Surface-towed side-scan sonar imagery (GLORIA-II) together with digitized National Ocean Service/Coast and Geodetic Survey contours are available on a CD-ROM produced by the U.S. Geological Survey in cooperation with the NOAA/USGS Joint Office for Mapping and Research in the EEZ. The CD-ROM contains approximately 350 files of raster image data, grouped into three levels of detail, covering mostly the upper Continental Slope and deeper water portions of the northern Gulf of Mexico. With supporting software a full range of browse and zoom capability is provided with the CD-ROM.

The Global Relief CD-ROM contains a combination of several gridded data bases of global topography and bathymetry at various scales including the NOS/C&GS 15-second gridded hydrographic data set. It also contains the World Vector Shoreline, 20 topographic relief images, undersea feature gazetteers, and gridded gravitational-effect-of-topography data derived from SEASAT radar altimetry.

Future developments will include a redesigned NOS/C&GS Hydrographic Data Base to add greater flexibility in searching and retrieving the data. Bathymetric inventories will be combined so that comprehensive bathymetric information will be more easily accessed. NGDC is working toward providing the entirety of its digital data holdings on CD-ROM and also providing on-line inventories for all these data.

NEW BATHYMETRY

New bathymetry of the northern Gulf of Mexico is in the final stages of compilation as part of NGDC's contribution to the International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico project. The project is a joint effort among Colombia, Costa Rica, Cuba, France, Mexico, Venezuela and the United States, with each country assigned to one or more of the 17 areas of responsibility. NGDC is responsible for bathymetry for five areas, three of which cover the northern Gulf of Mexico. The first map in the series, covering the northeastern Caribbean around Puerto Rico, has been published; the second map, covering a portion of the western Atlantic east of the Blake Plateau and the northern Bahamas, is complete and near publication. The published maps are at a scale of 1:1,000,000 at 15 degrees north and are in Mercator projection. The generic contour interval is 200 meters, with intermediate contours added in most areas. As bathymetry for each area is completed, the contours will be scanned digitally to vector files and will eventually be made available as vector and raster data sets.

In synthesizing the new bathymetry we have normally used only data and contours for which specific track control information is available. In some areas where bathymetric contours were derived from sounding data of known high quality and track spacing, but for which track control was not available, the bathymetric contours were included without track control but with a reference to the data source. In some areas where high quality contours already exist, no recompilation was needed and the contours were included intact. In the remaining areas, original contours were drawn using principally digital data, with the source data ranging from tightly controlled surveys to random track data. GLORIA II side scan sonar imagery as well as seismic sections were used for interpretation of the bottom morphology in areas of less-dense track spacing.

Two bathymetric sheets depicting the topography of the western Gulf of Mexico have been completed. A contour interval of 100 meters is used with dashed lines for odd numbered contours. Near shore, dashed ten meter contours are added for detail. Both sheets clearly show the Sigsbee Escarpment landward of the 3,000 meter contour with a vertical relief of 500 to 600 meters. Two major canyons indent the Sigsbee Escarpment. The western side of the Mississippi Fan dominates the eastern most part of the compilation area. Landward of the Sigsbee Escarpment the salt deformation province of the upper Continental Slope, consisting of many isolated domes and basins, shows up clearly.

Ms. Lisa A. Taylor has worked as a geophysicist in the Marine Geology and Geophysics Division of the NOAA National Geophysical Data Center for eight years, where she oversees a large ongoing project to digitize bathymetric data from paper plotting sheets. Prior to her current position, she worked for the Naval Oceanographic Office, where she gained experience in hydrographic and oceanographic surveying. She received her B.A. degree in Geology

from the University of Colorado at Boulder and has worked extensively on bathymetry of the Caribbean, Bahamas, Gulf of Mexico and the Great Lakes.

Dr. Troy L. Holcombe has worked as Senior Scientist of the Marine Geology and Geophysics Division of the NOAA National Geophysical Data Center in Boulder, Colorado for 10 years. Previously Dr. Holcombe was associated with Naval Oceanography for 16 years, holding the post of Head of the Geology Branch at the Naval Ocean Research and Development Activity from 1976 to 1984, and working as an Oceanographer at the Naval Oceanographic Office from 1968 to 1975. Dr. Holcombe received his Ph.D. degree in marine geology from Columbia University. He has worked extensively and maintains interest in general geology, acoustic stratigraphy/structure, and geomorphology of oceanic regions, with an area concentration on the Gulf of Mexico and Caribbean region.

PREPARATION OF A GRIDDED BATHYMETRY FOR THE GULF OF MEXICO

Dr. H. James Herring
Dynalysis of Princeton

The primary objective of the study described here is to derive an accurate representation of the bathymetry of the Gulf of Mexico for use as input to an eddy-resolving general circulation model. As the program continued it became evident that the interest in a high quality bathymetric description of the Gulf was of more general interest. Accordingly, the following discussion will document the considerations, methodology and consequences of the data analysis.

Bathymetric data have been collected, analyzed and displayed for a wide variety of purposes. First of all, these data are of great practical value. Among the practical applications are navigation, environmental planning and monitoring, offshore oil drilling and mining, oceanographic research and, finally the original purpose here, ocean circulation modelling. The study of bathymetry also has significant theoretical value. The development of a uniform and usable description of the bathymetric distribution is a paradigm for a general two dimensional optimal analysis which could be extended to treat more complex fields containing additional dimensional variability such as water temperature or salinity. Therefore, bathymetric analysis represents a valuable learning, teaching and demonstration vehicle for optimal analysis in general. Finally, it is particularly ironic that the comprehensive description of the bathymetry in United States coastal waters is always assumed to be a solved problem until it is tested, as in the discovery of Queen Elizabeth II Rock in Vineyard Sound.

Due to the range of scales involved and the difficulty of making accurate measurements, it is axiomatic that there is never enough geophysical data, in general, and this is certainly true of bathymetric data. Therefore, it is essential to extract the maximum information from each element of data and combine as many complementary data sets as are available in order to produce the optimum product. The analysis and combination process is inevitably performed numerically on a computer so that for the assimilation of the data it must ultimately be converted, as required, from graphical and tabular form into machine readable digital form.

Bathymetric data has been measured for a wide range of purposes and is available from a number of sources in a variety of forms. Each source bathymetric data has a unique emphasis which affects the acquisition, archiving and presentation of the data. The earliest and most common form of bathymetric data is a plot of the zero bathymetric contour usually referred to as the coastline. The modern representation of the coastline is usually in the form of a digitized record from an aerial or satellite photograph. Other important primary sources of bathymetric data are archives of soundings made first with a lead line and later with single beam sonar, both of which are most practical in water depths of less than 200 meters. More recently, multibeam sonar has produced high resolution maps by scanning a swath on either side of the research vessel. Multibeam sonar complements conventional sounding since it works in depths greater than 200 meters.

Frequently it is necessary for consumers of bathymetric data to appeal to secondary sources of data as well. The most common secondary sources are nautical charts which have the coastline and show the depth in the form of bathymetric contours or numerical values and frequently both. Apparently in the case of the NOAA National Ocean Service (NOS), the distinction between primary and secondary sources of bathymetric data is not always clear since the original sounding data was often entered directly on the working charts referred to as smooth sheets, which became the draft for the final printed chart. Therefore, some of the raw data effectively only exists in the graphical form of the nautical charts. Other secondary sources of bathymetric data are digital fields that have been objectively analyzed previously. These data may be represented as values on some regular grid, referred to as gridded data, or the data may be in the form of digital coordinates of contours of selected depths.

The methodology of producing a gridded bathymetric field depends on the characteristics of the data available for assimilation and also, of course, the techniques have become more refined as time passed. Early on the most common method of preparing a gridded bathymetry was to draw the grid on a nautical chart, estimate the average depth in each quadrilateral and keypunch the result for input into the computer. This crude technique is still remarkably accurate when the chart markings are sparse compared to the resolution of the grid, and good judgement is required to estimate the correct value. Another approach was to interpolate from a, hopefully, higher resolution gridded bathymetry if it existed. Then, as larger quantities of sounding data became available in machine readable form, the method of choice was to average the data in each of the grid boxes and possibly smooth the results using a Poisson smoother, for example. This averaging method had the advantage that, for the first time, it produced some measure of variance in addition to the average value.

As an advance over the averaging method, the results described herein were produced using a radius-of-influence method. Given N values $\hat{h}_n$, representing the depth at cast locations $\hat{x}_n$, $\hat{y}_n$, the value of the depth at any point (x_i, y_j) on the regular two-dimensional grid is

$$h_{ij} = \frac{\sum_{n=1}^{N} \hat{h}_n \, X_n(x_i) \, Y_n(y_j)}{\sum_{n=1}^{N} X_n(x_i) \, Y_n(y_j)}, \qquad (1)$$

where the weighing functions are

$$X_n(x_i) = \exp\left\{\frac{-(x_i - \hat{x}_n)^2}{2\sigma_x^2}\right\}, \qquad (2)$$

$$Y_n(y_j) = \exp\left\{\frac{-(y_j - \hat{y}_n)^2}{2\sigma_y^2}\right\}, \qquad (3)$$

and σ_x, and σ_y are the horizontal radius of influence parameters. The radius of influence parameters were set at the size of the grid scale.

In order to perform the optimal assimilation of diverse forms of data into a single field, information regarding the characteristics of each data set must be considered. The first issue is the accuracy of the three quantities, latitude, longitude and depth, which constitute a data point. In practice, meaningful uncertainty levels are rarely provided so that some detective work is necessary to make reasonable estimates. With a large data set, which can be assumed to have uniform characteristics, self consistency tests provide some insight. For example, readings recorded in whole fathoms and subsequently converted to decimal feet are still only accurate to the nearest fathom; therefore, no matter what the precision of the reported data value, the uncertainty is no less than the minimum difference between any two values. Also, if scatter plots of the location of the casts indicate that some proportion of the casts is on land, the analyst can be confident that an equivalent proportion of the values in the water is also in the wrong location. Some estimate of the possible accuracy of the instruments employed and the track record of the observing and archiving agencies or institution is also in order.

Next it is important to assess the representativeness of the data. Even when the depth was accurately recorded the results will be unrepresentative in shallow water if the tidal signal was not removed, as is frequently the case when the data is acquired ancillary to the primary objective of the cruise. Similarly, if the survey is a century old, say, the present depths may be significantly different due to erosion or sedimentation, again primarily in coastal regions. Another consideration is the intended application of the originator. Charts prepared for navigation frequently record the shallowest depth in the adjacent region, whereas for circulation modelling the mean depth is actually the value desired. Data from agencies whose charter involves national defense occasionally exhibit an apparent disinterest in coastal regions that presumably are either of no interest or of great interest for security purposes. The results are inexplicable discrepancies in limited regions between these otherwise representative data and measurements from other sources.

The present objective analysis begins with the NOAA NOS bathymetric sounding archive which for historic reasons is referred to by NOS as the Hydrographic Data set. These data are available in most United States coastal waters and have been carefully acquired using NOAA vessels, processed to remove the tidal signal and archived in a nearly consistent format. The location of the soundings over the entire region is shown in Figure 5D.1, and the local distribution on the Texas-Louisiana is shown in Figure 5D.2. However, as is evident from Figure 5D.2, although the Hydrographic Data covers most of the United States continental shelf regions well, it does not extend to the deep Gulf or to other continental shelves in the region of interest. The first attempt to fill this void was the Navy SYNBAPS bathymetry, a gridded data set on a 5' by 5' grid. As shown in Figure 5D.3, SYNBAPS was satisfactory in the deeper regions of the Gulf and Caribbean, it was transparently inadequate on the continental shelves around the Gulf. Fortunately a second gridded bathymetry prepared at Texas A&M was available. Although it was on a coarser $\frac{1}{8}°$ by $\frac{1}{8}°$ grid, the depths had been digitized from charts with particular attention to the important shelf regions. A sample of the Texas A&M representation of the Texas-Louisiana shelf is shown in Figure 5D.4. Using the radius-of-influence technique of Equation (1) with the NOS Hydrographic Data, the Texas A&M gridded data in the remainder of the Gulf and the SYNBAPS in deeper regions elsewhere several bathymetric distributions were calculated at different resolutions. A sample of the 0.01° by 0.01° resolution bathymetry is shown in Figure 5D.5.

Still the deeper regions were not well resolved, and gaps in the NOS Hydrographic Data led to anomalies even in United States coastal waters. A newer NAVOCEANO product called DBDB5 became available. Although it was still on a 5' by 5' grid, much more attention had been paid to representation of the coastal regions, as shown in Figure 5D.6. Using DBDB5 with the NOS Hydrographic Data produced a much better result.

Future efforts will incorporate the high resolution NOAA multibeam data which, in the Gulf of Mexico, covers the region shown in Figure 5D.7. The multibeam data is available in several forms. The "raw soundings" have an average resolution of approximately 150 meters. The multibeam data are also available in two gridded forms; on a Universal Transverse Mercator grid with a resolution of 250 meters and a geographic grid with a resolution of 463 meters in the north-south direction and in the east-west direction, 412 meters at 27 degrees north latitude, decreasing to the north and increasing to the south. Although the multibeam data offers more than adequate resolution for the present purposes, the NOS chartered coverage of the United States Exclusive Economic Zone is not even complete and, of course, there is no attempt to survey outside of United States continental waters. Therefore, additional data is still required to complete the improved bathymetry of the remainder of the Gulf of Mexico region.

For the purpose of augmenting the coverage in data sparse areas, sources of additional data that can not be overlooked are soundings made during the course of cruises by oceanographic research vessels. Research vessels routinely record a suite of meteorological and oceanographic measurements including depth soundings both underway and on station. A selection of such data has been assembled and archived by NOAA/NESDIS GEODAS - Marine Geophysical Data set. A sample of a U. S. Navy cruise track in the Gulf of Mexico is shown in Figure 5D.8. The strength of these data are that they offer broader coverage, since they are not limited by national boundaries, and are likely to be precise, since they are measured and reported by scientists. The weakness is that, since the depth is not a primary measurement on the cruise, the instrument may not be as carefully calibrated for water column density and the bias due

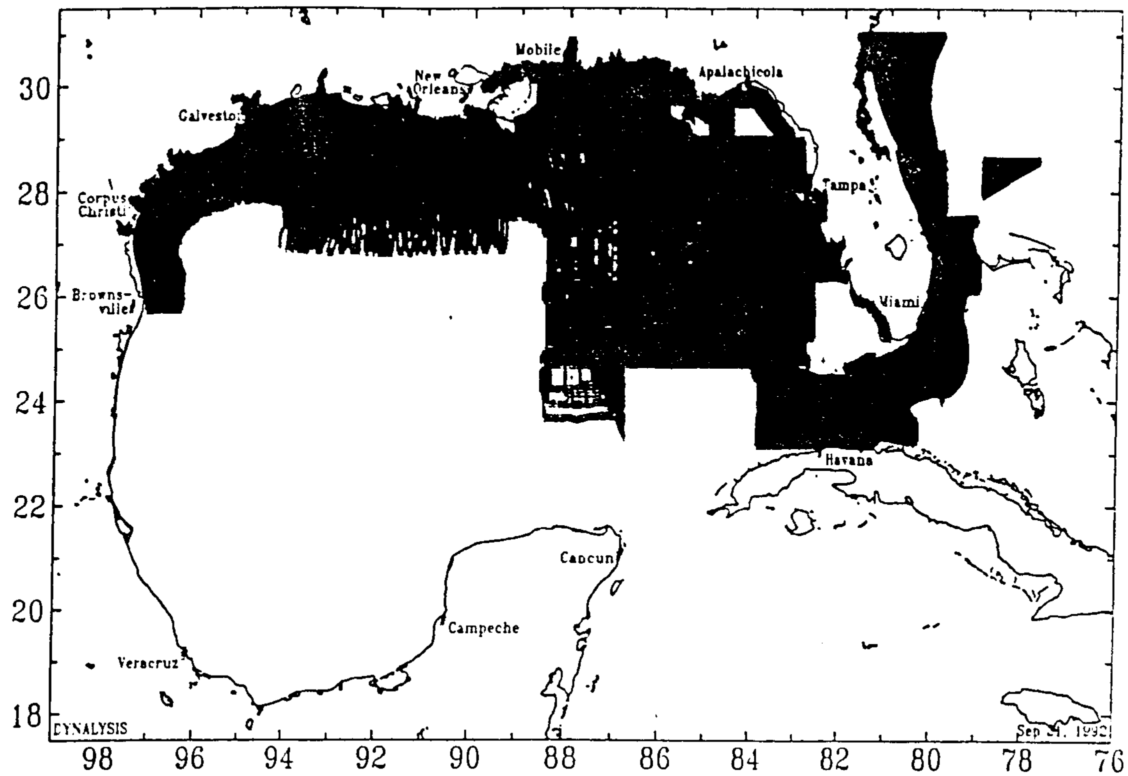

Figure 5D.1. Locations of NOAA/NOS "hydrographic data" soundings archives in the Gulf of Mexico.

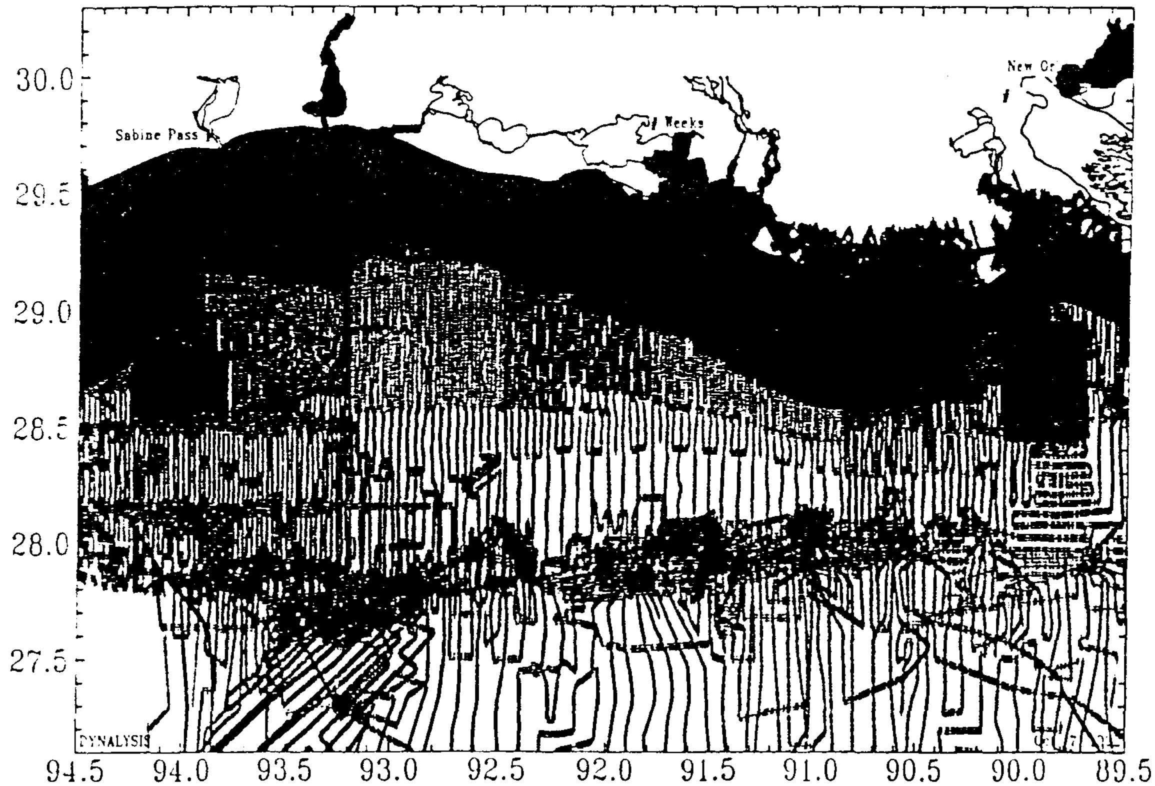

Figure 5D.2. Locations of NOAA/NOS "hydrographic data" soundings on the Texas-Louisiana shelf.

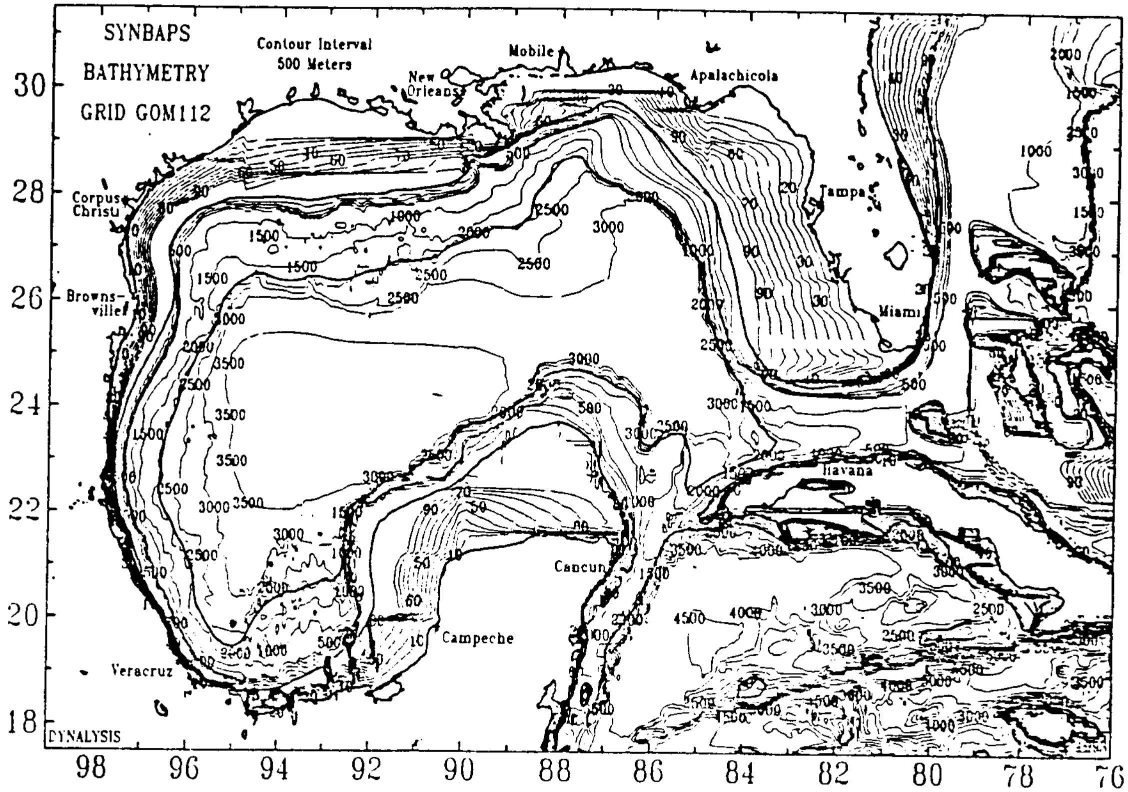

Figure 5D.3. Bathymetric contours of the Navy STNBAPS, 5' by 5', gridded bathymetry.

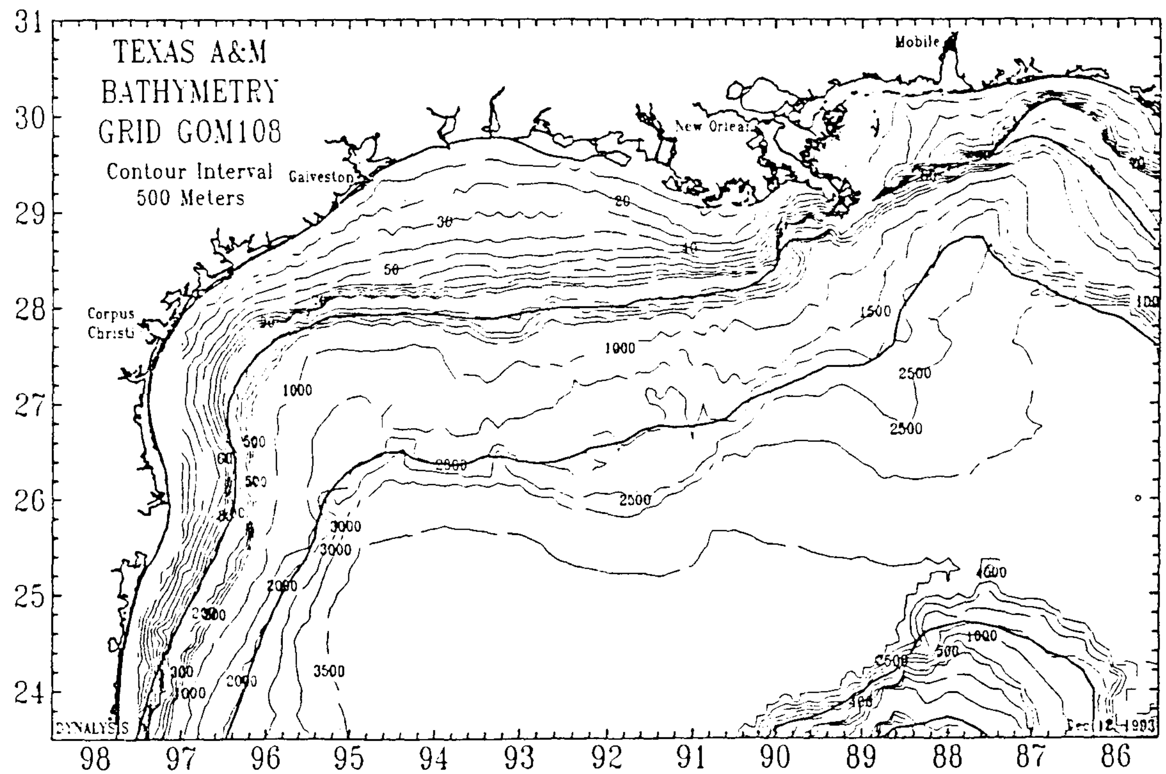

Figure 5D.4. Bathymetric contours of the Texas A&M, 1/8° by 1/8°, gridded bathymetry.

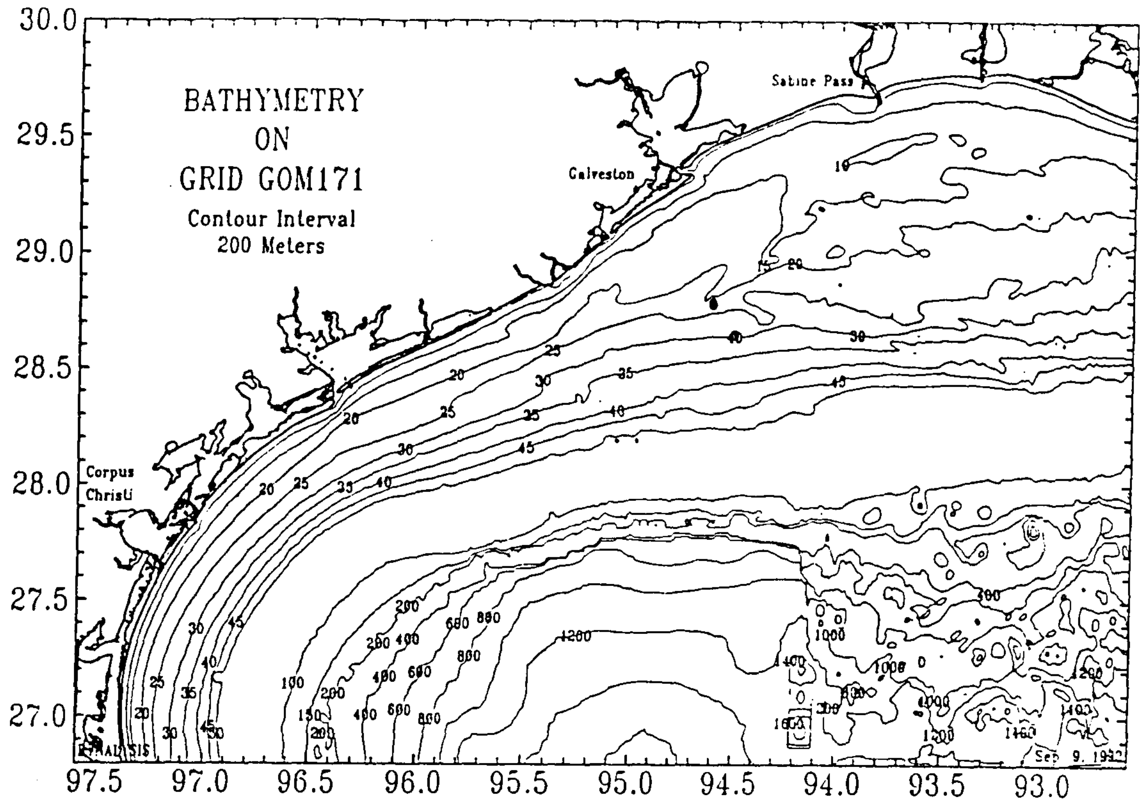

Figure 5D.5. Bathymetric contours of the Dynalysis, 0.01° by 0.01°, gridded bathymetry.

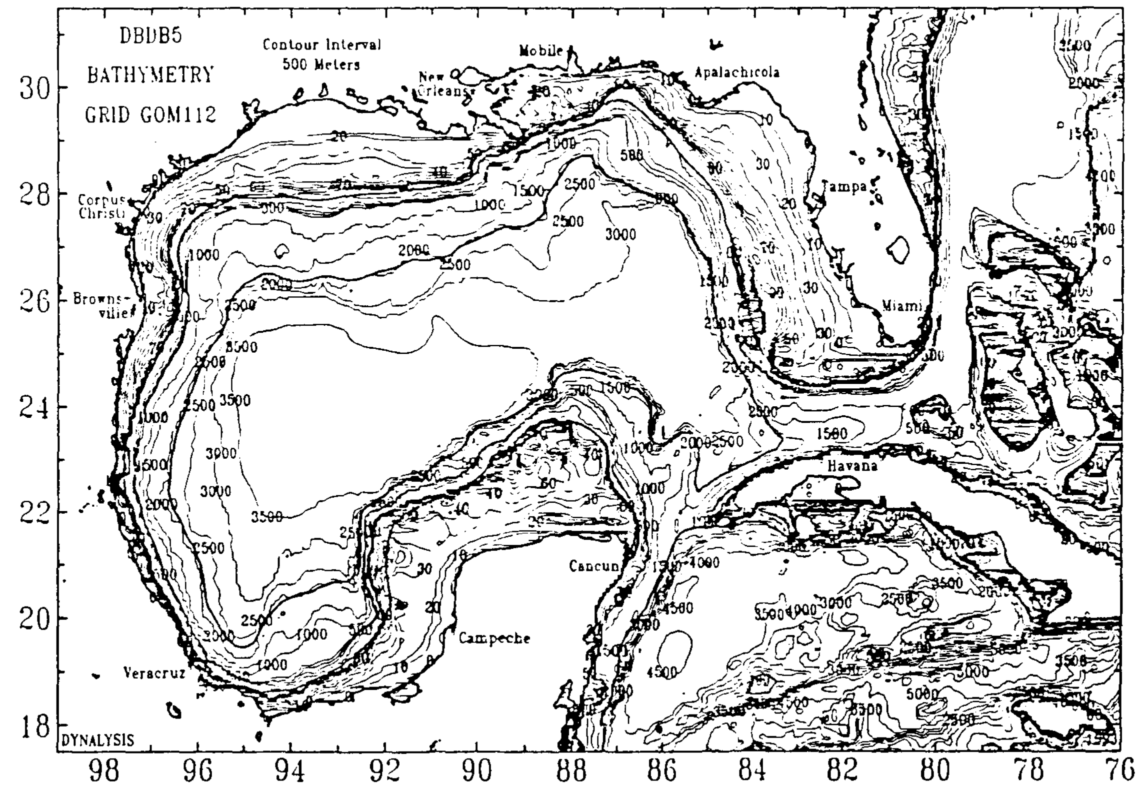

Figure 5D.6. Bathymetric contours of the NAVOCEANO DBDB5, 5' by 5', gridded bathymetry.

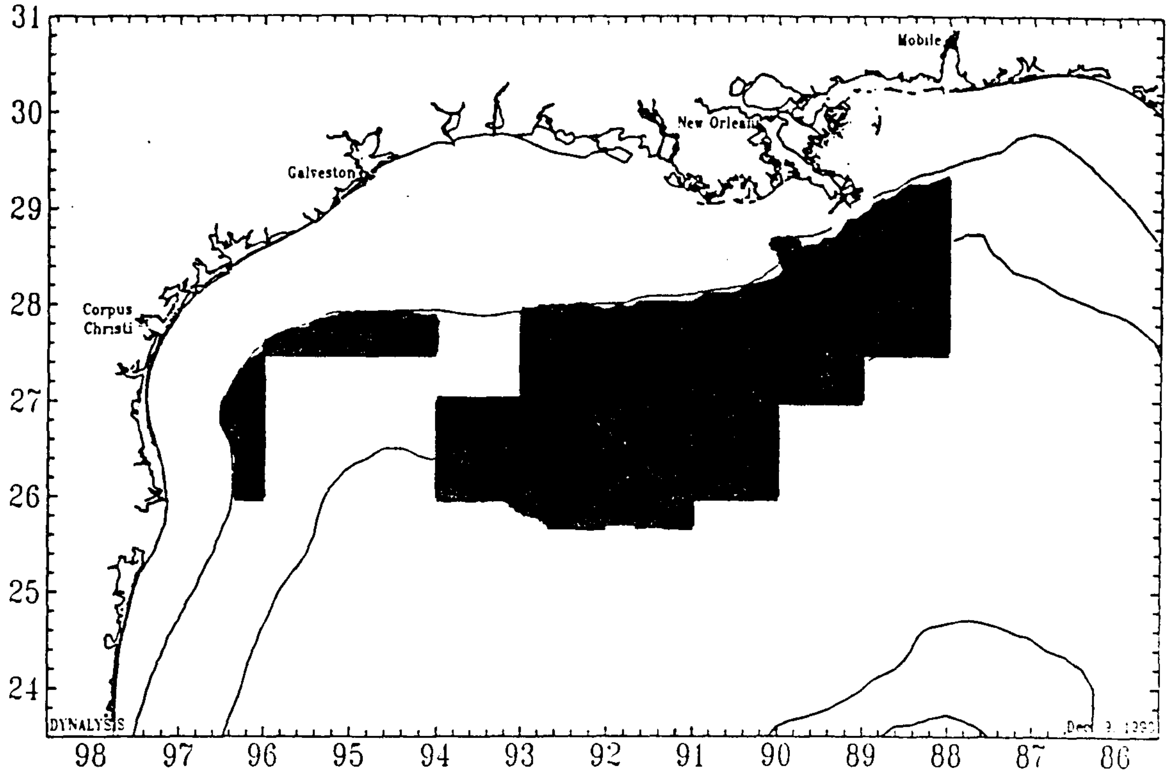

Figure 5D.7. Locations of NOAA/NOS multibeam EEZ data soundings in the Gulf of Mexico.

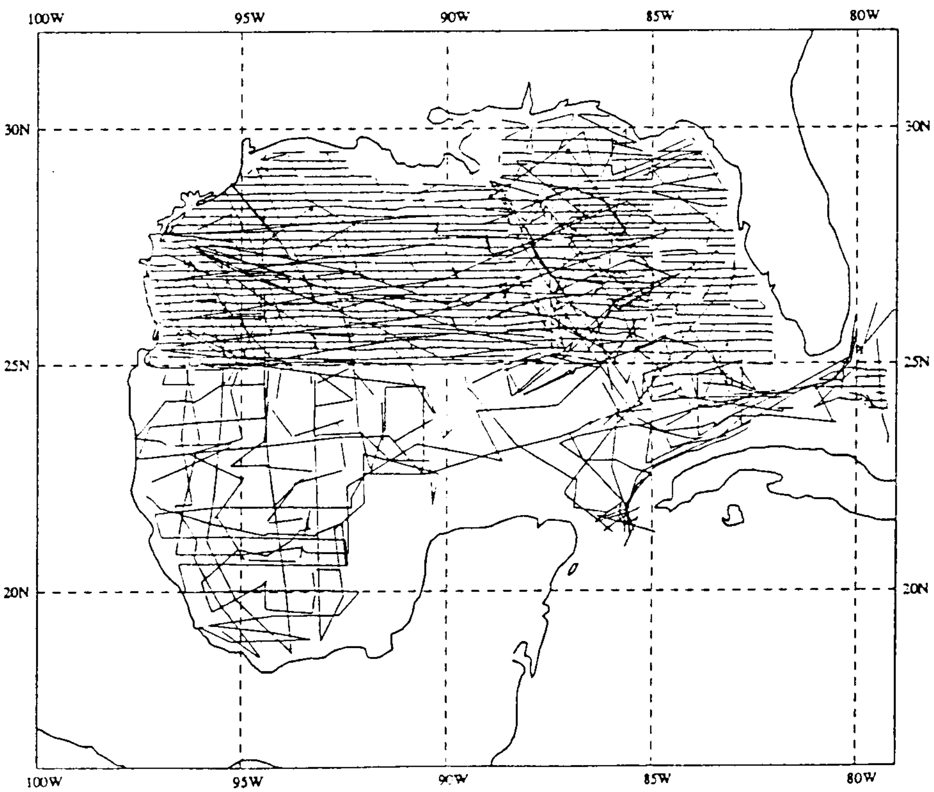

Figure 5D.8. Locations of U. S. Navy cruise tracks in the NOAA/NOS/GEODAS auxiliary bathymetric soundings data archive.

to tidal elevation may not have been removed. The result is that auxiliary sounding data is valuable in deep water where the tidal signal is not significant, but should only be used with caution in shallow water.

The conclusion is that, although much progress has been made in measuring and analyzing bathymetric data, particularly in recent years, the data necessary to support a high resolution bathymetric description of the Gulf of Mexico does not exist at this time. Clearly, however, the technology to acquire the data, single beam sonar for shallow water and multibeam swath sounding techniques in deeper water, does exist and merely awaits the commitment and funding to apply it uniformly over the entire Gulf of Mexico.

NATIONAL DEVELOPMENTS IN BATHYMETRIC MAPPING

Mr. Millington Lockwood
Joint NOAA/USGS Office for
Mapping and Research

INTRODUCTION AND BACKGROUND

Traditionally, the National Oceanic and Atmospheric Administration (NOAA) has provided information relating to the depth of the seafloor in graphic portrayal, i.e., paper map or chart form. The suite of bathymetric maps and nautical charts produced and published by NOAA has been and continues to be the "standard" for navigation, ocean engineering, environmental, and scientific purposes. These maps and charts range in scale from 1:1,000,000 covering large regions, e.g., Gulf of Mexico, to 1:24,000-scale for coastal areas. A catalogue listing the availability of these products is available from NOAA's Coast and Geodetic Survey, (C&GS 1993). Efforts are now underway within NOAA, and other federal agencies to make these maps and charts available in digital form. This will serve the growing community of clients who use computers and other advanced technologies to produce geographic products.

The initiative to make bathymetric data available in digital form began with the signing of the Exclusive Economic Zone (EEZ) Proclamation by President Reagan in March 1983. (McGregor and Lockwood 1985) NOAA, in cooperation with the U.S. Geological Survey (USGS), began an ambitious program to map the sea floor of the EEZ utilizing new bathymetric mapping and sidescan sonar technology. These surveys have produced many heretofore unknown undersea features including a nearly complete view of the Western Gulf of Mexico deep water salt diaper province. (C&GS 1992; C&GS 1993; USGS 1987; Pratson and Ryan in press).The discussion of these mapping efforts has been included in a number of articles (Lockwood in press; Lockwood 1991a, 1991b; Lockwood and Wheaton 1986; Mills and Perry 1992). Detailed articles are included in the Proceedings of the biennial EEZ Symposium sponsored by the NOAA/USGS Joint Office for Mapping and Research. (Lockwood and McGregor 1986, 1988, 1990, 1992, 1994 in press). The National Research Council (NRC) has conducted a comprehensive study to determine the information needs of the community (NRC 1992). In addition to the production of traditional paper and large format atlas products, these surveys resulted in an unprecedented amount of digital data representing significantly more information than can be shown on a paper product. The result was a shift toward the production of map information to digital form. The NOAA National Geophysical Data Center (NGDC), in Boulder, Colorado, serves as the international repository for these data and has been in the forefront in the distribution of digital bathymetric data to the marine community (Taylor and Holcomb in press); (NGDC 1993,1992).

DISCUSSION

In recent years we have detected a significant movement toward the need for the digital rendition of the information included on the bathymetric maps and charts. The emergence of high-speed computer workstations at relatively low cost, geographic information systems (GIS), and a growing community of sophisticated users has placed increased emphasis on digital data vs. traditional graphic products. NOAA and the USGS are now considering the cooperative production of a digital "Topo-Bathy" map series to replace the paper 1:24,000 series (Yeager and Lockwood in press). Several national initiatives have begun to deal with this increased demand. In addition, the maritime navigation community, through the International Maritime Organization and the

International Hydrographic Organization, has begun to converge around the need for digital nautical charts to support the growing Electronic Chart Display and Information System (ECDIS) users (Prahl and Danley 1993).

Three of the major national developments dealing with these demands relevant to the Thirteenth Annual Gulf of Mexico Information meeting are the Federal Geographic Data Committee (Tosta 1994), the Defense Hydrographic Initiative (Doherty 1993 in press), and the NOAA Earth Systems Data and Information Management System (NOAA 1991). Each of these activities has as its central objective the need to accommodate, in a variety of ways, the increasing community of users desiring data in digital form.

THE FEDERAL GEOGRAPHIC DATA COMMITTEE

The Federal Geographic Data Committee (FGDC) was established under Office of Management and Budget (OMB) Circular A-16 (revised in 1990) for the purposes of "Coordination of Surveying, Mapping, and Related Spatial Data Activities" (FGDC 1991). The goals of the OMB Circular are to develop a national digital geographic information resource, to reduce duplication, to reduce the expense of developing geographic data, and to increase the benefits of using available data and ensuring coordination of federal agency geographic data activities. A major objective of A-16 is the development of a National Spatial Data Infrastructure (NSDI) with the involvement of federal, state, and local governments, and the private sector (NRC 1993). This national information resource, linked by criteria and standards, will enable sharing and efficient transfer of spatial data between producers and users (Tosta 1994).

The FGDC has subcommittees organized to manage activities related to various categories of spatial data. Each subcommittee establishes procedures for standardizing data content, quality, and transfer; facilitates the exchange of data; and determines requirements for new data collections. A Subcommittee on Bathymetric Data has been established under the leadership of the NOAA Coast and Geodetic Survey and will serve as the focal point for all spatial data and related mapping in the maritime regions of the Unites States. One of the efforts of the FGDC has been to produce a Manual of Federal Geographic Data Products describing a variety of types of spatial data available from Federal Agencies (FGDC 1992).

THE DEFENSE HYDROGRAPHIC INITIATIVE

The Defense Hydrographic Initiative (DHI) was established in 1991 through an interagency agreement among the Defense Mapping Agency, the U.S. Navy, and NOAA. The fundamental goal of the DHI is to interconnect, at the national level, the hydrographic and bathymetric data of the involved agencies. The fundamental premise is that by sharing a common data base of sea-floor information, the needs of the range of users within and external to the Department of Defense will be met. In fulfilling this goal, DHI will provide the community the means to share and exchange hydrographic and bathymetric data, to define and develop new interagency-products, and to develop new technologies. It will also assist in locating sources of bathymetric data, thus avoiding unnecessary data collection efforts. The needs of DHI member agencies and their users/customers will be satisfied through achievement of three objectives: (1) developing new processes for production of hydrographic and bathymetric products and services; (2) developing new products to improve operational capabilities; and (3) investigating new concepts to improve production and dissemination methods. These will be accomplished through the development of a Hydrographic Source and Assessment System (HYSAS) and a Master Seafloor Digital Data Base (MSDDB). This latter item will serve as the "definitive" source for sea-floor information on a global basis.

There is a multitiered management structure to accomplish the goals of the DHI. A Policy Steering Group (PSG) under the leadership of the DMA provides overall coordination and policy guidance to the DHI. A Technical Steering Group (TSG) currently chaired by a representative from the U.S. Navy is involved in developing and recommending technical, engineering, and scientific strategies, and reflects the broad needs of the defense and civilian communities. To assemble the various elements of the DHI, a Joint Program Office (JPO) has been established within the DMA Systems Center in Reston, Virginia. The main purposed of the JPO is to define system requirements and develop operational capabilities, either through in-house support or under contract.

THE EARTH SYSTEMS DATA AND INFORMATION MANAGEMENT PROGRAM

The Earth Systems Data and Information Management (ESDIM) Program was begun by NOAA in 1989 for the purposes of recovering historical environmental and earth systems data that were in jeopardy of being permanently lost due to deteriorating source material, unknown life span of magnetic media, or were in a computer format that is not generally understood. A secondary objective has been to make these data more accessible either through electronic bulletin boards, use of CD-ROM (Compact Disc-Read only Memory), or by creating new or integrated data sets. In respect to the Thirteenth Annual Gulf of Mexico Information Transfer Meeting (ITM), the data sets of the greatest interest are the digitization and dissemination of the coastline from NOAA nautical charts at a scale of 1:80,000 and the high resolution shoreline from the vast NOAA holdings of T-Sheet at scales of 1:10,000 to 1:20,000. Another area of interest is the completion of the digital data holdings from the NOAA Coast and Geodetic Survey's historical (some as old as 1850) hydrographic survey Smooth Sheets. These survey sheets generally at scales from 1:5,000 to 1:40,000 represent the original source data used to compile contours on bathymetric maps and depth curves on nautical charts. Many of these sheets contain in excess of 20,000 soundings as opposed to 200 or so that can be shown on a nautical chart. Additionally, these data are used to generate gridded data sets at regular intervals that can be used to compute Digital Elevation Models (DEMs) of the seafloor similar to the elevation data on land. The last project of interest is an effort to reproduce, as a raster image, the complete suite of NOAA Nautical Charts.

CONCLUSION

There are several new and exciting activities ongoing within the federal structure related to the improvement in the access to and quality of bathymetric and related sea-floor data and information. Each of these activities contributes in its own way to the National Spatial Data Infrastructure (NDSI) and the National Information Highway efforts of the Clinton Administration. Success of these initiatives will depend upon cooperation and agreement between and among those agencies who generate bathymetric data and understanding of the "needs and requirements" of the users of the data regarding quality, standards, and access. Information about any of the above activities can be obtained by contacting the author
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ADDENDUM

Overview of Federal Consistency Issues

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The 1990 amendments to the Coastal Zone Management Act (CZMA) re-emphasized the importance of, and gave new life to, the CZMA's federal consistency provision. In addition, OCRM, especially under the current OCRM and NOAA leadership, has re-asserted itself in assisting the states and federal agencies with their consistency responsibilities. While OCRM has always advocated early consultation and cooperation to avoid conflicts regarding federal consistency requirements, over the past two years OCRM guidance has centered on federal agency compliance with CZMA and NOAA regulatory requirements. These efforts will undoubtedly continue as there are still a few federal agencies unfamiliar with the benefits of early consultation and coordination with coastal states.

However, OCRM is also embarking on a proactive effort in an attempt to better educate states and federal agencies on the benefits of federal consistency and how federal consistency can be used to resolve potential conflicts in a more orderly, efficient, and cooperative fashion.

With regard to current policy guidance, OCRM's primary message is that the CZMA requires that certain federal activities (including activities performed by the federal government, private activities requiring federal permits and licenses, and federal financial assistance to state and local governments) be consistent with the enforceable policies of a state's federally approved coastal program. With certain regulatory limitations this requirement applies to all activities, whether in or outside the coastal zone, that affect any land or water use or natural resource of the coastal zone. There are no categorical

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exemptions from this requirement. See attached charts on (1) the CZMA Federal Consistency Process for Federal Activities, (2) the CZMA Federal Consistency Process for Federally Licensed or Permitted Activities, and (3) a Summary of Federal Consistency Provisions.

Once this requirement is accepted and understood, the key to successful consistency reviews is early consultation. The earlier states and federal agencies discuss proposed activities and state coastal management program requirements the easier it is for states to conduct their reviews and for federal agencies to obtain state agreement. Most solutions to consistency issues are resolved when the parties cooperate early. A good example is recent efforts by the Minerals Management Service to address state CZMA concerns in outer continental shelf oil and gas activities. Another example is early coordination and agreement between Massachusetts and the Environmental Protection Agency on the designation of an ocean dumpsite for dredged materials. Problems arise when the state coastal management agency does not find out about an activity until late in the process or the federal agency is unaware of consistency responsibilities, or waits too long to address state coastal management program concerns. While many of these problems are resolved through state assertion of consistency or OCRM involvement, some conflicts remain.

Within the last year OCRM has also clarified the following policy areas:

OCRM'S view on federal agencies' issuance of conditional permits: The CZMA section 307 requires that a federal agency may not issue a license or permit unless a state concurs with the applicant's consistency certification or the state's concurrence is conclusively presumed. While conditional or provisional permits may be legally permissible, OCRM discourages their use as a matter of policy. The issuance of conditional permits may give an applicant a false sense of approval, or reduce the flexibility needed for negotiations between a state and an applicant.

Circumstances where federal agencies must obtain state coastal management program permits and include such permit applications in consistency determinations: Federal agencies are required to obtain state permits and to include state permit applications in federal consistency determinations when (1) state permits for certain activities are required by other federal law; (2) the federal activity, whether within or outside the coastal zone, can be reasonably expected to affect any land or water use or natural resource of the coastal zone; and (3) the permit is a federally approved enforceable component of the state's coastal management program (CMP).

Requirements for a single state "Consistency" agency responsible for federal consistency decisions: Under NOAA regulations, a state must designate a single state agency to perform the consistency functions, including formally commenting on all consistency determinations or concurring or objecting to consistency certifications. See 15 C.F.R. § 930.18. Further, the single consistency agency must be the lead coastal management agency, or a single state agency designated by the lead coastal management agency. The single consistency agency may rely on the expertise of other state agencies in formulating its decision, but other state agencies may not be the state lead for consistency reviews or decisions.

The reasons for this requirement are clear: uniform application of a state's coastal management policies, efficient coordination of all state coastal management requirements, comprehensive coastal management review, and providing a single point of contact for federal agencies to discuss consistency issues. State CMPs should ensure that all relevant enforceable policies are considered for a federal consistency review, not just those of a particular state permit program.

State review of listed activities occurring outside of the coastal zone for which a state has not generally described the geographic scope of review: The CZMA expressly provides for state consistency review of federal activities in or outside of the coastal zone, affecting any land or water use or natural resource of a state's coastal zone. The regulations implementing CZMA § 307(c)(3)(A) establish procedures for routine state review of classes of activities listed in a state's coastal management plan (listed activities). The regulations also provide state review of individual activities not covered by the scope of a listing (unlisted activities), if such activities can be reasonably expected to affect the state's coastal zone. See 15 C.F.R. §§ 930.53 and 930.54. If a state chooses to routinely review listed federally licensed and permitted activities occurring outside of the coastal zone but likely to affect the coastal zone, it must generally describe the geographic location of such activities. 15 C.F.R. § 930.53(b). The regulations do not, however, expressly indicate how a state may review listed activities occurring outside of the coastal zone for which a state has not generally described the geographic scope of review.

It is OCRM's policy that the most effective way for a state to review listed activities outside the coastal zone is to describe the geographic scope of a state's review. However, in order to facilitate state review of listed activities occurring outside of the coastal zone absent a geographic scope states should follow the conditions for review of unlisted activities.

Starting the Consistency Review Clock for incomplete consistency applications: NOAA regulations provide states with two alternative means of responding to incomplete consistency applications. First, a state may delay starting the consistency review timeclock until receipt of both the consistency certification, and the complete information and data required pursuant to 15 C.F.R. § 930.58 [15 C.F.R. § 930.60(a)]. States should inform the federal agency of this decision within a reasonable amount of time. Second, a state may start the consistency review timeclock when it receives the consistency certification, even if the necessary data and information are not provided [15 C.F.R. § 930.64(d)]. If the necessary information is not submitted, the state may then object to the consistency determination or certification on the grounds of insufficient information.

State Establishment of a user fees to review a federal agency's consistency determination: Several states have attempted to assess a user fee from Federal agencies in order to cover the costs of processing federal consistency determinations. Generally, federal agencies may be required to pay a user fee if: (1) the fee is a "valid user fee" and (2) the agency determines that the fee is an "allowable expense." First, to be a valid fee, the consistency assessment or user fee must be: (a) non-discriminatory (that is, the fee must apply to all similar private and government agency activities alike); (b) a fair approximation of the costs of the benefits the federal agency receives from the state agency; and (c) the revenues produced by the fees must not exceed the total cost to the state of the benefits to be supplied. Of course Congress can require federal agencies to pay certain fees. OCRM will examine a state's processing fee scheme if submitted to OCRM for incorporation into the state's coastal management program to ensure that the fee system is valid under these terms.

With regard to whether the fee is an allowable expense, the assessed federal agency is in the best position to interpret its laws and regulations to make this determination. OCRM recommends for those states assessing a fee, that if a federal agency has submitted a consistency determination in accordance with NOAA regulations but has not paid the fee, the state initiate its review of the consistency determination and complete its review within the 45-day review period. Otherwise the state risks waiving its right to object to the activity under federal consistency.

These and other specific issues are discussed in more detail in OCRM's first two issues of the Federal Consistency Bulletin. The Bulletins discuss recent significant state consistency issues; OCRM coordination with other federal and non-federal agencies; OCRM policy decisions, guidance, and projects; and recent Secretarial appeal decisions.

OCRM also expects, in early 1994, to release a draft of the Federal Consistency Manual. The Manual will be user's guide to consistency under the CZMA and NOAA regulations.

For states that are developing coastal management programs, there are several things a state can do to ensure a more efficient and effective use of federal consistency. These include:

1. Involve all federal agencies in a meaningful way in the development of the coastal management program, enforceable policies, and consistency procedures.

2. Clearly articulate, in the program document or a state federal consistency guide, the state coastal program's enforceable policies, how the policies are legally

binding under state law, and how they will be applied by the state for consistency reviews.

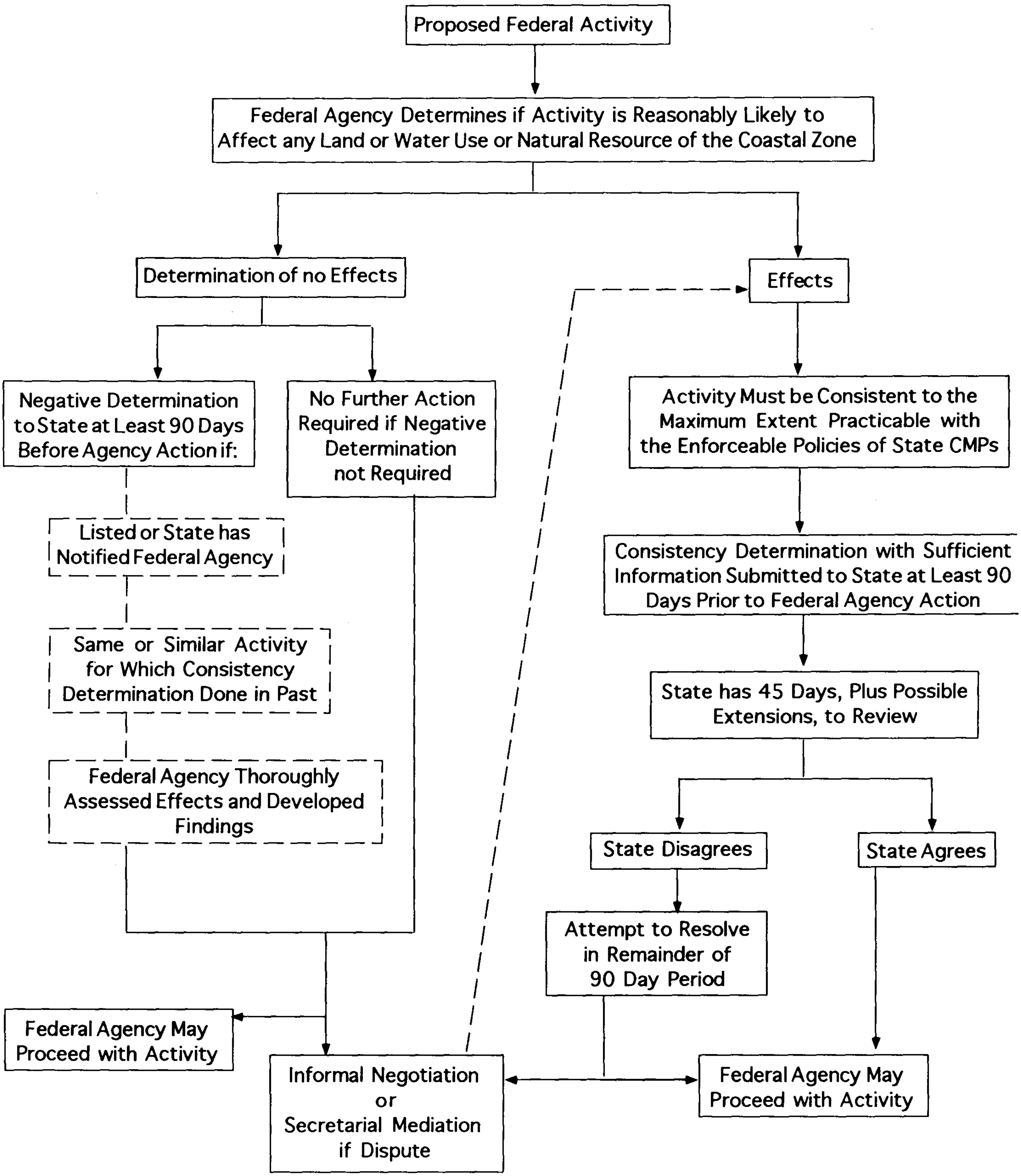
3. Identify the single state agency responsible for all consistency decisions, clearly detailing how the state consistency agency will obtain review and comment by other networked state agencies, and ensure that all relevant enforceable policies are applied to a particular consistency review.

4. It may be helpful to develop agreements with federal agencies for the expeditious and efficient review of repetitious and routine federal activities and federal approvals, while ensuring that all relevant enforceable policies are considered.

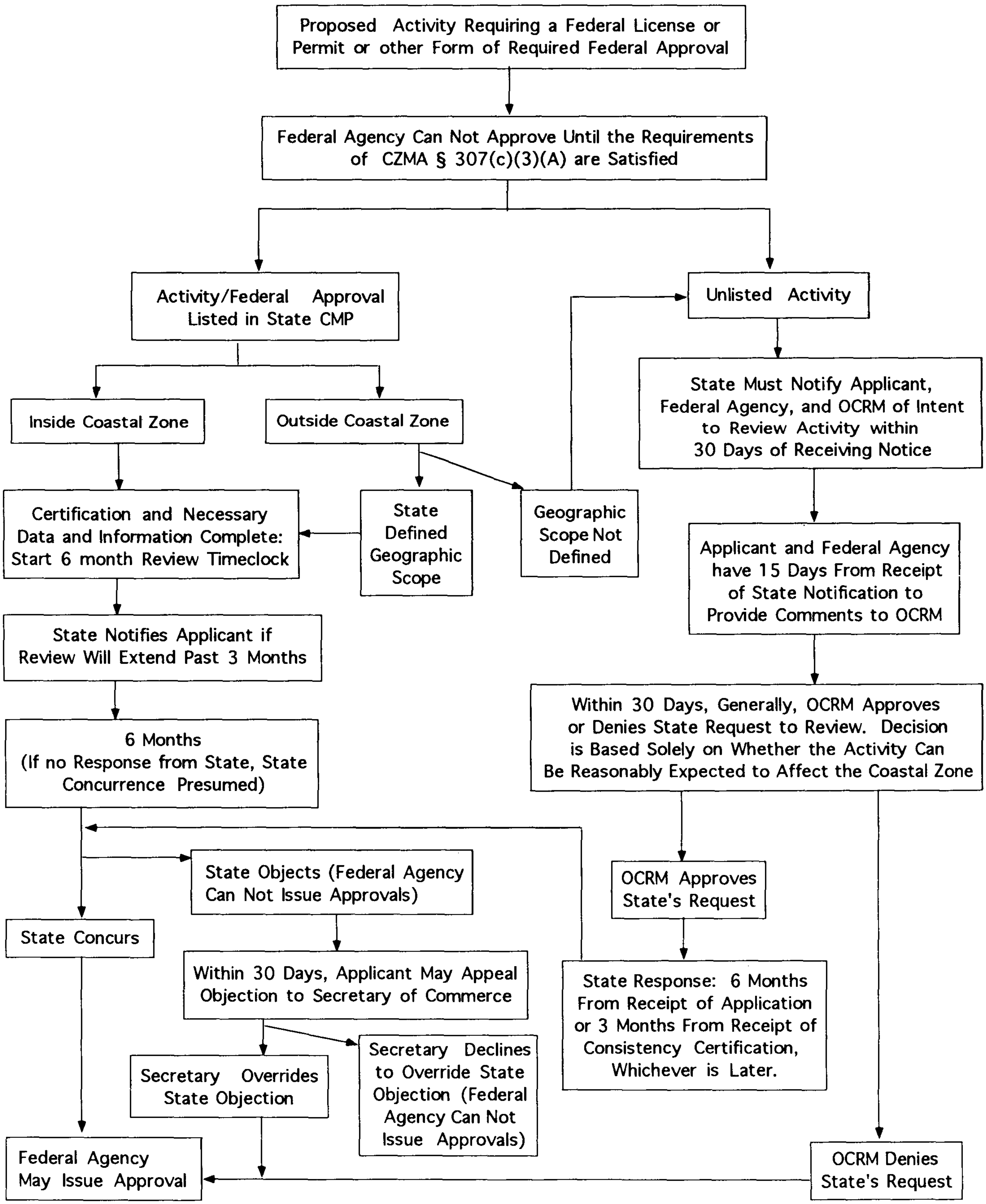
In addition, Federal agencies can assist States developing coastal management programs. Federal agencies should assist in identifying Federal activities, or federally licensed and permitted activities in or outside the coastal zone which reasonably can be expected to affect any land and water uses or natural resources of the coastal zone.

Attachments

CZMA Federal Consistency Process for Federal Activities (CZMA § 307(c)(1); 15 C.F.R. Part 930, Subpart C)



CZMA Federal Consistency Process for Federally Licensed or Permitted Activities (CZMA § 307(c)(3)(A); 15 C.F.R. Part 930, Subpart D)



Consistency Table

Summary of Federal Consistency Provisions

	Direct Federal Actions & Development Projects	Federally Permitted or Licensed Activities	OCS Plans: Exploration Development Production	Federal Assistance to State and Local Govts.
CZMA Section 307	(c)(1)&(2)	(c)(3)(A)	(c)(3)(B)	(d)
Activitiy subject to review, if it ...	Affects any land or water use or natural resource of the coastal zone	Affects any land or water use or natural resource of the coastal zone	Affects any land or water use or natural resource of the coastal zone	Affects any land or water use or natural resource of the coastal zone
Consistency requirement	Consistent to the maximum extent practicable with the CZM program	Consistent with the CZM program	Consistent with the CZM program	Consistent with the CZM program
Who decides?	Federal agency	State CZM agency	State CZM agency	State CZM agency
Time limit	45 days, plus 15 day extension	6 months	3 months - state may extend to 6 months	Clearinghouse schedule
Impact of State Objection	Federal agency may decide to proceed, however, creates possibility of legal action	Federal agency may not issue permit/license	Federal agency may not approve plan or issue permits	Federal agency may not grant assistance
Administrative conflict resolution	Mediation by the Secretary of Commerce (voluntary, non-binding)	Appeal to the Secretary to override state objection	Appeal to the Secretary to override state objection	Appeal to the Secretary to override state objection

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.