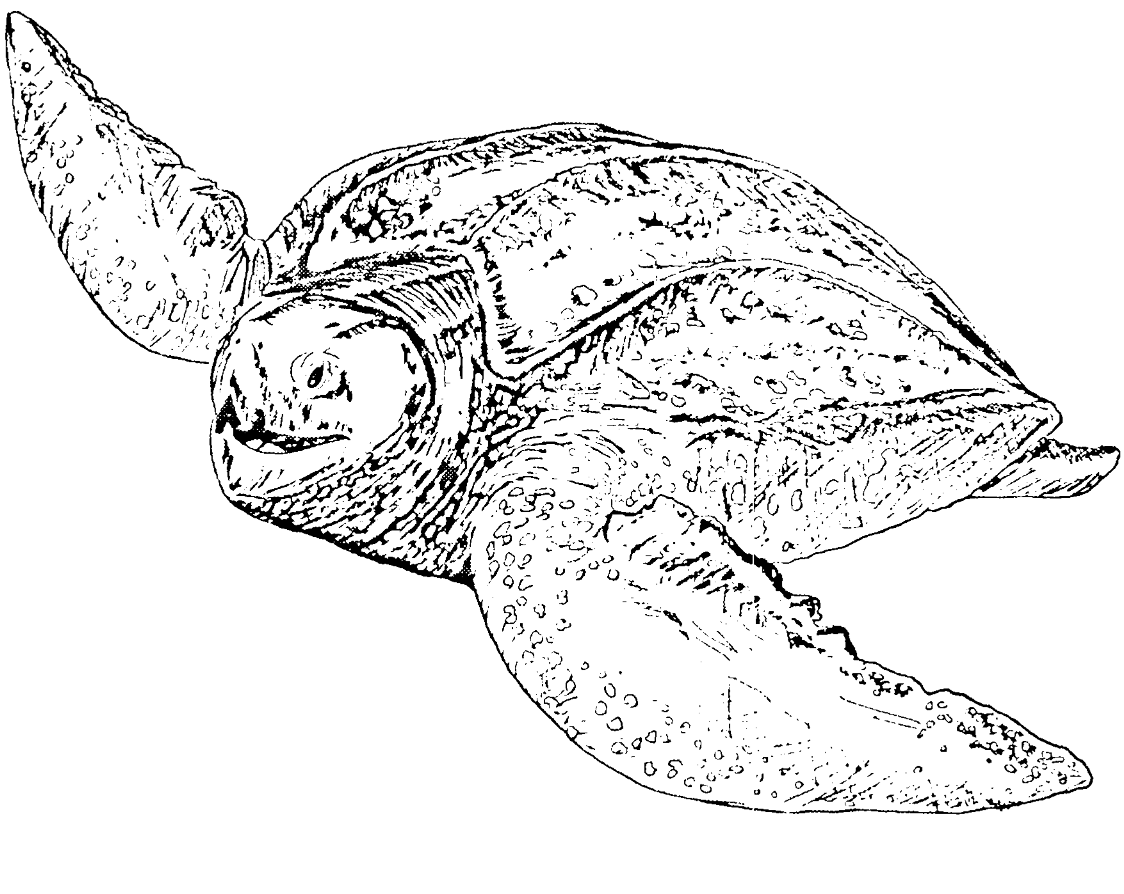
OCS Study
MMS 87-0058

Proceedings
Seventh Annual Gulf of Mexico Information Transfer Meeting

November 1986



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

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November 1986

International Hotel
New Orleans, Louisiana
November 4-6, 1986

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PREFACE

This Proceedings volume presents a concise summary of the presentations and discussions of the MMS's Seventh Annual Information Transfer Meeting (ITM), held November 4-6, 1986 in New Orleans, Louisiana. This volume includes overviews of each session, prepared by each session chairperson and abstracts prepared by each speaker summarizing his or her presentation.

Special thanks are extended to all ITM participants; especially, to the MMS staff responsible for planning and conducting the ITM; to the invited speakers, who have given their time and effort to share information on topics of interest with ITM attendees and proceedings readers; to the staffs of Geo-Marine, Inc., the University of Southern Mississippi's Department of Conferences and Workshops, and the International Hotel, who have provided such excellent logistical support for the meeting and the attendees; and to the general audience of attendees. We appreciate your involvement, interest, and support; all of which contribute to making the annual ITM's successful.

TABLE OF CONTENTS

List of Tables

List of Tables
(cont'd)

List of Figures

List of Figures
(cont'd)

List of Figures
(cont'd)

List of Figures
(cont'd)

List of Figures
(cont'd)

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OPENING PLENARY SESSION

Session: OPENING PLENARY SESSION

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

Date: November 4, 1986

Presentation Title	Speaker/Affiliation
Opening Plenary Introduction Session	Mr. Ruben. G. Garza President Geo-Marine, Inc. and Dr. Richard Defenbaugh Chief, Environmental Studies Section Minerals Management Service Gulf of Mexico OCS Region
Keynote Address: "Environmental Analysis: The Missing Equation"	Dr. John D. Costlow, Jr. Director Duke University Marine Laboratory
Debris and Litter on a South Texas Beach: A Long-Term Study	Mr. Anthony Amos Research Associate University of Texas Marine Science Institute

Opening Plenary
Introduction Session

Dr. Richard Defenbaugh
Minerals Management Service

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

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

The primary purposes of the ITM are to provide a forum for "scoping" topics of current interest or concern relative to environmental assessments or studies in support of offshore oil and gas activities in the Gulf of Mexico OCS Region; to present the accomplishments of the MMS Environmental Studies Program for the Gulf of Mexico, and of other MMS research programs or study projects; to foster an exchange of information of regional interest among scientists, staff members, and decisionmakers from MMS, other Federal or State governmental agencies, regionally-important industries, and academia; and to encourage opportunities for attendees to meet and develop or nurture professional acquaintanceships 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 to the MMS oil and gas program; accomplishments of the agency; and regional information exchange. All presentations are invited, through contacts between the session chairpersons and the speakers, and the meeting support funding is provided through the MMS Environmental Studies Program. All meeting logistical support is provided by a contractor (Geo-Marine, Inc.) and subcontractors selected through the usual Federal procurement process. A proceedings volume is prepared for each ITM, based on abstracts or brief technical papers submitted by each speaker and on session overviews prepared by each session chairperson.

Mr. Pearcy, Regional Director of the MMS Gulf of Mexico OCS Region, formally welcomed the audience on behalf of the MMS, and extended special welcomes to members of the MMS OCS Advisory Board Committees (the Gulf of Mexico Regional Technical Working Group and the Scientific Committee) holding working meetings contemporaneously with the ITM. He described the meeting scope (18 technical presentation sessions, including some 70 individual presentations and several panel discussions) and mentioned several issues of particular interest to the Region.

For example, one dominant current environmental issue is that of risk of death or injury to marine turtles at the time of removal of obsolete platforms from offshore leaseholdings, if the platforms are severed from the seafloor using high explosives. This has been the customary method of removal for many years, and the recent concern about risk to marine turtles (especially to endangered species of turtles) has virtually stopped planned platform removal operations. An ITM session devoted to technical presentations and open discussion about the turtles and platform removal operations is one tool used to work towards solving the problem of removing obsolete, hazardous, or reusable platforms without undue risk to endangered species populations.

Mr. Pearcy recalled an aphorism which likened the transfer of knowledge to the sharing of a candle's light: "to provide my neighbor with what I know is equal to letting him light his candle from mine; it gives him light but does not lessen my light at all." A good analogy to the purpose of the annual ITM's.

Dr. Costlow gave an excellent and thought-provoking discourse on the realities of environmental analysis and planning. He began by observing that two essential elements of an environmental analysis are an acronym and an equation; that the measure of success of the acronym is its pronounceability, and that the utility of the equation is to bring together the factors which must be considered when one approaches any problem.

To illustrate the keynote theme, Dr. Costlow developed an initial equation to serve deliberations about the coastal environment. The equation, "EA = sum of I+E+(C, cubed)" represents the thought that an environmental assessment or analysis (EA) is equal to the sum of interest (I), effort (E) and communication or cooperation (C) expended. Three secondary equations were then shown which address the factors comprising each of the three primary terms.

The first term, interest, was defined using a lengthy equation which addressed involvement in environmental assessment efforts by a variety of interest groups, including bureaucracies, citizens groups, affected industries, the military, marine fishermen, real estate developers, mining interests, tourist interests, historic preservationists, elected officials, and scientists. For each of these groups, hierarchies were described, such as local/state/national organizations or agencies.

The second term, effort, was equated to funding, in dollars. A hierarchy of funding sources (private, state, national sources) was described, as were effort-related attributes which include persistence, strategies, clout, and dedication.

The third term, communication or cooperation, considers two factors: turf (a negative factor) and vision. To underscore the importance of this form, Dr. Costlow expressed it as a cubed term.

Having presented and discussed the many factors which affect an environmental analysis, Dr. Costlow presented a series of slides to demonstrate present environmental values in North Carolina, which might be preserved through effective planning and management. He showed additional slides which illustrated problems which have resulted from unplanned or poorly-managed development.

The point so clearly made by Dr. Costlow was that environmental or social planning must involve a variety of affected or concerned interest groups, all of whom must support, and cooperate in, the planning effort in appropriate ways if the effort is to succeed. Also, the consequences of unsuccessful planning have been, and will continue to be, environmental losses and social situations which will diminish the quality of life in coastal areas in coming generations.

Mr. Amos presented findings of his three-year survey of a 12-km stretch of beach on Mustang Island, Texas.

The survey was begun in 1978 as a casual and avocational study of bird populations. Environmental and social impacts, including oil spills, a hurricane, beachfront development, fish kills, freezes, and a redtide episode have shown the importance of the data gathered and have resulted in a more formal and quantitative study since 1983.

The beach surveys are done from a small truck, driven about three times per week in the early morning along the beach from one access road to another. Observations are made from the truck and are recorded using an on-board computer.

This coastal area supports many activities which affect the beach, including tourism, commercial shrimping and fishing, offshore oil and gas development, residential and vacation beachfront condominium development, etc. Major seasonal environmental forces also affect the beach, including beach sand deposition and removal by winter storms and hurricanes, regular current system reversals, and stranding of varying quantities of flotsam, jetsam, and natural marine debris.

Mr. Amos showed a series of slides with running commentary which illustrated the nature and beauty of the Texas coastal environment in the vicinity of the beach survey area, and of the natural and social factors which affect the beach structure and appearance.

Since the beach survey was formalized as a research project in 1983, observations have been made quantitatively on a number of categories of objects or organisms of interest. Many of these categories are of trash or man-generated debris which ends up on the beach after being discarded or accidentally lost overboard from boats, ships, and oil structures offshore, or from visitors to the beach itself.

Analysis of the observational data indicates seasons or periods of occurrence, or of peak occurrence, of some categories of debris. Some of these peaks correspond to beach tourism, such as beach litter peaks at times of major holidays (college spring break; Fourth of July; Labor Day; etc.) while others correspond to natural phenomena such as seasonal changes in offshore currents (as indicated by occurrence of Mexican bleach bottles) or of marine seasons (as indicated by strandings of marine life, such as jellyfishes, sargassum weed, and the like).

Occurrence of large quantities of trash and debris on the beaches are troubling for a number of reasons. Consequences of the presence of these materials include aesthetic losses, public health concerns about toxic substances in containers, and environmental losses due to toxic substances or to ingestion by birds or other animals of non-digestible materials, losses to the local economy caused by decreased tourism, oil or tar tracked on merchant or motel carpeting, costs of clean-up and beach maintenance, etc. Slides shown of Padre Island National Seashore during peak problem times were appalling, resembling more a city dump than a pristine beach.

Management of the problem is out of hand. Control of the sources of trash and debris is difficult because of the number, variety, and motility of sources, limitations of regulations (especially on the high seas), and difficulty of enforcing littering laws in the face of other law enforcement priorities. An abatement in debris, attributable to offshore oil and gas activities, has been observed, recently, due to industry initiatives to control loss of such debris, or to the slump in industry activities at present, or both. Sadly, some measures taken to respond to beach trash problems, such as clean-up via machines, damage the beach itself.

The message entertainingly but overwhelmingly delivered by Mr. Amos is that trash and debris on the stretch of beach he regularly surveys is repugnant, and perhaps unmanageable at present. Management approaches generally involve response to occurrence of the problem, rather than control of occurrence.

Overall, the Opening Plenary Session was effective and was well received by attendees. The two technical presentations were both excellent and provided two distinct perspectives on environmental analysis. Dr. Costlow's constructive thoughts on the complex mix of personnel, support, and harmony which are necessary for effective environmental planning presented the upside, while Mr. Amos' account of Texas beach observations portrayed a downside environmental and social problem of significant proportion. Attendees left the session charged with an enlightenment of the social realities of large-scale environmental management, tempered by an awareness of the seemingly intractable nature of at least one dismaying problem.

Dr. Richard Defenbaugh is Chief of the Environmental Studies Section of the MMS Gulf of Mexico OCS Regional Office. His graduate work (Texas A&M University: MS, 1970; PhD, 1976) addressed natural history and marine ecology of northern Gulf of Mexico invertebrates. He has been involved with the MMS/BLM environmental studies and assessment programs since 1975.

"Environmental Analysis: The Missing Equation"

Dr. John D. Costlow, Jr.
Duke University Marine Lab

When I was first invited to this meeting I naturally inquired as to the composition of the audience. I as told that we could expect some number of scientists. My response was that I could develop a presentation which would demonstrate my vast knowledge of such scientific matters as "eutrophication". My host went on to indicate that there would also be some people from industry. That meant that it would be necessary to include some aspects of the infamous document with which I am associated, "Fates and Effects of Drilling Muds in the Outer Continental Shelf". Then, considering that there would be private citizens, representatives from state and federal governments, and environmentalists, it occurred to me that perhaps I should also consider the importance and role of two, basic, essential, aspects of any analysis, including environmental analysis: the "acronym" and the "equation".

Concerning the importance of an acronym, reflect on some of those which have not caught the imagination and therefore have done very little to promote the effort they identify, by they scientific or social. For example, imagine a wife telling her husband "You must go out and bowl with the boys this evening because I am having a meeting here of the WCTU". Now you may know that this refers to the Womens Christian Temperance Union. There is a body of opinion which indicates that the WCTU has not been a totally successfully group because it does not have a clean, creative, good, pronounceable, acronym. Another example might be the NAPCA, the National Association for the Prevention of Cruelty to

Animals. In certain areas this is a moderately successful organization but think how successful such a group might have been if it has been as pronounceable as NASA. Everyone recognizes NASA! It is an acronym which you can easily pronounce, you can throw it out at a meeting of important people as if you know exactly what it is all about and what you are talking about, and that basically is what an acronym is for. NATO--you can be almost anywhere in the world, with possibly the exception of the Soviet block countries, and refer to NATO without having to bother to define it.

One must be careful, however, to pronounce acronyms accurately and enunciate them with care. I had a phone call several months ago from the Office of Congressman Walter Jones asking if I would be available to come to Washington and present some testimony on the issue of "cesium A". Well, I did some rather rapid reflective thinking and although I knew that cesium in certain forms was a radioactive substance, I have never heard anyone, even a Washington bureaucrat, differentiate between cesium A and cesium B but then I have not kept up with physics. Gradually, while we discussed what I might say about something which I didn't totally understand, I suddenly came to the conclusion that my friend was actually referring to CZMA, the 1972 Coastal Zone Management Act. In my own home area, CZMA is still about as controversial as cesium but not yet radioactive.

That hopefully will provide adequate focus on the importance of acronyms and their use. But, relative to the question of the environment, it would seem appropriate to leave with you the idea that in developing any form of an environmental analysis program in coastal waters, it is important to develop an acronym which relates to the local geography and interests.

Let us go on to that second essential part of any environmental analysis, the equation. As you are undoubtedly aware, there are some ancient equations which have proven to be extremely useful over thousands of years. On occasion all of us refer to the term "Pi", perhaps in the ancient equation of πr^2. Even after thousands of years this equation persists as a very viable and useful expression. There is also a more recent one, authored by Einstein, which a number of people quote in social and professional circles. I question that many of them, other than Einstein, actually understand it. It does, however, make an impression, correctly or otherwise, that you might know what you're talking about. Seriously, however, equations are extremely useful because if nothing else, they help bring together and relate a multiplicity of factors that one must consider in approaching almost any kind of a problem. Otherwise, as was suggested by the gentleman who introduced me, scientists and others are fully capable of rambling philosophically in the hope that eventually, perhaps at the end of a study or the time when funding is terminated, they will remember why they began the study in the first place and hope that some of the data will fit together in such a way that solutions are apparent.

I believe we have arrived at the point in our deliberations of the coastal environment where it is appropriate to consider developing one or more basic equations, if only for guidance itself, with some evidence that even the Romans were concerned with it, they did not develop any functional equations to assist in their study. About the time of Darwin and the voyage of the Beagle we began to have a more complete appreciation of the complexity of the environment. As man began to take more and more interest in coastal areas, and use them for a greater variety of things, we began to focus on the degree to which we needed to understand it and, where appropriate, consider its management. The early efforts along these lines were rather disoriented and disorganized and unfortunately, some of that continues. Because of the frequent compartmentalization of the sciences, marine biologists have had a tendency to go off into one small corner and focus on miniscule aspects. The chemists occupy a totally different corner to do their thing. The physicists don't even bother to get into a corner: they just sit and stare and draw things but unfortunately, they are the ones that are so competent with equations.

Somewhere in the 1930's, we witnessed the development of the now converted Bureau of Commercial Fisheries. With renewed interest on the part of academia, there was also occasional evidence of a more organized and interdisciplinary approach to a consideration of the coastal environment, the problems which were beginning to emerge at the time of the Second World War, and then, after the war and the tremendous expansion in population and development which followed, we began to see a true concentration of interest in the large and important estuarine and coastal waters of the United States as well as other countries. Concurrent with this we saw the development of the first real scientific granting agency in the United States, the U.S. Office of Naval Research, followed by the National Science Foundation, and then a number of other federal agencies, new as well as reorganized, to consider marine problems, coastal resources, quality of the environment, and basic research oriented to amassing knowledge which would hopefully someday be useful. Thus we now recognize the Environmental Protection Agency, NOAA/NMFS, the Department of Energy, and others. At about this same time, due in part to the publication of Rachel Carson's "Silent Spring", the public began to be aware of emerging problems in the coastal environment and to express more and more concern as to proper management and a balance between utilization and conservation. At that point we began to see a proliferation of legislation at the state and federal levels. The Coastal Zone Management Act, the National Environmental Policy Act, and others, emerged and in my own state, the North Carolina Dredge and Fill Act of 1969, was an early indication of the degree to which even the North Carolina General Assembly was becoming concerned as to how we managed our sensitive coastal environment.

Simultaneously, those of us who were in a position to participate witnessed the development of scientific organizations such as the Atlantic Estuarine Research Society which subsequently proliferated into a number of other regional estuarine research societies and now come together every second year as the Estuarine Research Federation.

Now, what is the real basis for this evolving concern? If one examines eastern North Carolina, there are hundreds of thousands of acres of marshes in this second largest estuarine system in the United States. The average citizen would normally maintain that the destruction of an acre here or there doesn't really matter. They may not realize that slowly but surely we are jeopardizing and eliminating an area that is highly productive. This unusual system, assuming that it is not interfered with by man, will continue to be productive but opportunities for interference continue to increase throughout all the estuarine systems of the United States. Years ago, Dr. L. Eugene

Cronin identified the problem of "multiple use" as the base for his own and his laboratory's interests in early studies on just how a variety of uses could be developed in such a way that neither the estuarine system nor those involved in individual and competing uses would be jeopardized. A variety of local, state, regional, and federal agencies have been developed in more recent years to deal with these issues but all too frequently they operate independently, with totally discrete jurisdiction. Basically we have evolved a tremendous hodgepodge of interests and bureaus to deal with specific interests. From this complexity and multiplicity of effort we have begun to recognize the need to identify specific study areas, and I assume that all of us are now familiar with the large Chesapeake Bay Study. This general approach has now been expanded to similar programs in the Narragansett Bay Study, the Buzzards Bay Study, the Long Island Sound Study, the Puget Sound Study, and, just in the last few months, the one with which I am most personally familiar--the North Carolina Albemarle/Pamlico Estuarine Study.

These programs are intended to bring together a broad spectrum of individual interests to develop some sort of a program and plan for sensible, long-range management of our coastal areas. In a simplistic way, we will hopefully convert socioeconomic and political interests, combined with scientific information, in such a way that information in all of these areas can be translated back into terms that can be used by planners, bureaucrats, and industries which will continue to wish to have access and use of these sensitive coastal areas.

At this point, I began to consider the possibilities of developing the equation which I referred to earlier. I had been assembling a variety of factors which I believed should be considered in any such integrated effort, and I will now present an equation with some explanations as to the individual factors, the role which they are intended to represent and play, and the need to be certain that it is truly integrated.

$$EA = I + E + C^3$$

$$I = (B_1+B_2+B_3)^n + (C_o+C_o^2+C_o^3) + (I_1+I_2+I_3+I_4) + (D\ O\ D) + (MF_c+MF_r) + (R_1+R_2+R_3+R_4) + (M_1+M_3+M_4) + (T_1+T_3+T_4) + (HP_1+HP_2+HP_3)^n + (EO_1+EO_2+EO_3) + (S_1+S_2+S_3)^n$$

$$EA = (F_p+F_2+F_3) + P^4 + S^3 + C + D^n$$

$$C = (-T) + (V)$$

In its simplest form, you can see that environmental analysis or assessment (EA) is equal to the sum of interest (I), effort (E), and communication/cooperation cubed (C3). Now, considering the complexity of all of these basic factors, let us first examine those elements which go into what we have identified as Interest (I). First, let us consider interest at the level of bureaucracy. Obviously, there is never one level of bureaucracy so we must consider B_1 which we will identify as municipal bureaucracy, B_2 which could be identified as the state bureaucracy, and then there is B_3 which is the national level of bureaucracy. All of it of course, can be viewed as the nth power!

Now acknowledging that technically it is the citizens of an area that are actually the owners of estuarine systems, held in trust for them by the government, it would seem appropriate to include then in our equation. Therefore, one must provide for local citizen input (C_o) which is a loose factor for citizen organizations. Since local citizens' groups frequently form confederations at regional or state levels, it is therefore necessary to have representation from these groups (C_{o2}), and following our earlier "logic", C_{o3} would include opportunities for representation by national groups of citizens.

In spite of the opposition which one occasionally receives from environmental groups, it is only reasonable to include representation by industry. Without them, any attempt at management of an estuarine system is similar to organizing a St. Patrick's Day parade in Boston or New York without bothering to invite the Irish! So, industry (I_1, I_2, I_3) again provides opportunities for consideration of local industries, which in many cases have totally different demands from those at the state or national levels. Presumably, in this day of international conglomerates, specific occasions may warrant a further expansion of this to include I_4 for some international representation.

In virtually all of the estuarine programs within this country, there is still another group, the Department of Defense (DOD) which legitimately requires inclusion within the equation. In North Carolina, a sizable portion of our coastal acreage is managed, and presumably leased, by various functions of the Department of Defense. The largest infantry base for the U.S. Marine Corps is in North Carolina, the second largest air wing for the U.S. Marine Corps is there, and there are several other bases serving the needs of the army or the air force. They all have their own interests, they each have their own needs, and if one were attempting to develop an analysis equation without conferring with the General, the Colonel, the Major, or somebody, there is no way that it could be done.

The next factor to be included is Marine Fisheries. You will notice that there are actually two: one, MF_c represents the commercial fisheries, a traditional effort spanning 400 years in eastern North Carolina and MF_r, recreational fisheries. On a relative base, the State of North Carolina last year issued 26,000 commercial fishing licenses, as compared to 2,600 in 1954, and although recreational fishing licenses are not required, and therefore there no hard numbers, there are estimates that somewhere around 600,000 people come to eastern North Carolina each year to enjoy recreational fishing in the estuarine and coastal waters. Both of these groups must be dealt with and, unfortunately, their joint efforts frequently arouse some level of conflict and antagonism.

As you might have expected, R_1, R_2, and R_3, represent real estate developers, providing once again for those at the local level, the state level, and the national level. As in the case of industry, perhaps in this day and age we should include R_4 for the international conglomerates that are acquiring property with the money which they have derived from the sale of liquid gold in this country.

In certain instances, but not necessarily in all, M_1, M_2 and M_3 should be included to represent Mining Interests. In some cases, i.e., oil, the mining involves a liquid with a variety of accompanying problems in drilling, transport, and refining. In other cases what they mine is solid and, as in the case of North Carolina with the phosphate interests, there are a variety of complications, both in terms of reclamation and in terms of elimination of unwanted fresh water, which require that they be included in the equation.

T_1, T_3 and T_4 represents tourism and recreation. In a number of parts of the United States facilities to accommodate these individuals are being developed with tremendous outlays of capital and there is a particular and peculiar series of problems relating to them, including public access to beaches, sewerage collection and treatment, expansion of road systems and the resultant damage to the environment, to name only a few.

In my own particular case, and I was pleased to hear Mr. Pearcy refer to it, I identify a need to include Historic Preservation (HP). At the local, state, and national level there is an ever expanding interest in preserving portions of our heritage. The problems associated with this effort are frequently not well identified or dealt with, at least not within the United States. A number of years ago, the state of Israel wished to develop a large, national institute of oceanography. They identified approximately six sites, distributed around the rather limited area of the coast of Israel, and discovered that their organization equivalent to our EPA required them to do drilling tests. The tests were not intended to determine if the substrate would support the weight of the building but rather to determine whether there was archaeological evidence of historic significance to the nation as a whole. Each of the six sites showed such evidence and because of their devotion to their heritage, it was deemed that there was sufficient evidence to prevent the use of these sites for the institute.

E_o is a totally different group from B_1, B_2 and B_3. E_o represents the elected officials. now, if you ask any citizen to differentiate between those that they have chosen to elect and those who have been "anointed", they would normally identify the bureaucrats as the long-term, "anointed" group whereas the E_o's are those who, as of this week, are wondering whether or not the electorate will send them back to their offices for another two, four or six years. This group is extremely important and the degree to which they are contacted, or not contacted, will frequently determine the outcome and success of any environmental analysis program.

Then we get on to that factor which represents a group that is always vocal and occasionally right, the scientific community (S). And, as with the other groups, we must provide factors for the local scientists, the state scientists, the national scientists, and perhaps on certain occasions, the international scientific community because of the expertise which is available.

Now, E we initially identified as "effort". Effort, also, can be subdivided into a number of subunits. For example, F, obviously, is intended to represent funding--dollars. Here again, there is a question of further delineation in the event that private monies might be available as opposed to government funding from municipal, county, state, regional, and federal sources.

Another factor which should be included is that relating to "persistence" (P). Although I am not confident that it can always be measured, I am confident that we will only at our risk underestimate its importance. As an example, the estuarine sanctuary which lies in front of the Town of Beaufort, North Carolina, was conceived as an idea in 1974. Through the efforts of virtually every one of the interests that I have identified here, at least at the local, state, and federal levels, it was finally dedicated as the "Rachel Carson Estuarine Sanctuary" in 1984. It required an entire decade to move from the idea to its dedication and this is what I refer to as persistence.

"S" is a factor for that sort of thing that very few of us really think about: i.e., "strategy". In the long run, an individual or a group should not go off tilting at windmills in the hope that something might happen some day, someone might get elected who is interested, someone might become available, or some group might take another interest and help in bringing about the satisfactory resolution of a problem. One will find it useful, bordering on essential, to develop a clear strategy with a carefully defined time frame and then double the time frame.

"C" stands for one of those rather nebulous things which I have chosen to identify in this equation as "clout". I am not certain as to just how one measures "clout" and that's a problem with a number of these factors. It is very difficult to put a nice numerical value on them but we all know what "clout" really is. When someone picks up the phone and calls the "right" person, usually one of the two of them has "clout". The actual measure of "clout" is the degree to which something is achieved. So, perhaps it would be more effective to include into our equation the results of "clout" as opposed to a measurement of "clout" itself.

"D" is another one of those factors that is extremely difficult to measure and although I did not check in the Webster's Unabridged Dictionary to determine if it is now obsolete, at one time it certainly deserved a great deal of emphasis. It is "dedication". How many people over and above the issue of "strategy" and "persistence" and "clout" can be determined to have the "determination" and "dedication" to "settle in" for the long haul? Fortunately, there are generally more than one might realize. A number of young people have been brought up over the last 20 years to believe that these coastal estuarine areas and the environments held in trust for them by the state actually do belong to them and they expect, in the future, to have something to say about their ultimate utilization. It is this group to which I look with hope when I think of "D".

The first factor of "cooperation/communication" (C) depends largely on how you wish to visualize it. The negative aspect of this might be identified by the term "turf" (-T). I am certain that each one of us sees the visible, and frequently invisible, nuances of "turf" on a daily and weekly basis. "Don't muscle in on my program, that is my turf!" Although I may be alone in my identification of this factor, judging by the smiles on the faces of a number of people in the audience, many of you know what I am talking about. I can imagine that turf may well have its place under certain circumstances, but certainly not to the immediate destruction of the entire equation.

"V" is another one of those factors which is all too rare in the society at the end of the 20th century. This is "vision". Some people have it and some people don't. Fortunately, over the 200 and some years that this country has been in existence, we have been blessed with a sprinkling of individuals who have had the vision and have had the opportunities to have it translated into the sort of effort which is described in this equation. If it had not been for these groups, many of the things which we have with us today, frequently shared by the rest of the world, would not exist.

So now we have an equation, for better or for worse. I would not pretend that this is a complete, total, final, definitive equation. I am sure that you, representing a variety of interests, can with reflection on your own area of interest feel that in someway you may have been neglected. Well, it was not intentional and I would encourage and challenge you to revise this equation to suit your own geographical, local, cultural, and environmental interests and problems.

In conclusion, I am now going to show a series of slides made available to me by special arrangement which shows eastern North Carolina in 2007. The first set shows eastern North Carolina as it will appear if we are successful in balancing the equation which I have just described to you. The second set shows the level of degradation which can occur, aesthetically, commercially, and culturally, in the event that we do not successfully implement this equation. It is naturally my hope that the set which represents our successful efforts to arrive at multiple use of the estuarine system of eastern North Carolina will be the one which my children and grandchildren will be privileged to see and love.

I thank you.

Dr. John D. Costlow, Jr. is Director of Duke University Marine Laboratory. He obtained his A.A. from Towson State College in 1948; his B.S. from Western Maryland College in 1950; and his Ph.D. from Duke University in 1956.

Debris and Litter on a South Texas Gulf Beach: A Long-Term Study

Mr. Anthony F. Amos
University of Texas

Little did I think when I first drove along the beach of Mustang Island, Texas in 1976, that ten years later I would be making this presentation about litter and debris on the beaches. Driving is permitted on Texas' beaches, so I found a 7-1/2 mile stretch of Gulf beach on Mustang Island where I could pursue my lifelong hobby of observing birds.

Shortly after starting this study, on a casual basis, several events occurred which gave it impetus and eventually turned it into a full-fledged research program with many facets. The first was the Ixtoc oil spill in 1979. I found that I had the only data that existed on how many birds, particularly shorebirds, were oiled or not oiled prior to that spill, enabling comparison of pre- and post-spill oiling of shorebirds. In 1980 came Hurricane Allen which dramatically altered the face of the beach. When the study was started in 1978, there were no structures on this stretch of beachfront where there are now 22 condominiums and other buildings. The beachfront's growing development was another factor that influenced my decision to increase the number of things looked at on this survey. Next came the redfish kill in 1981 that still remains a mystery that some think was conspiratorial and others blame on everything from industry to natural events. In 1983 a big freeze killed vast numbers of fish. The most recent event is the red tide which still lingers--another natural phenomenon that affected not only the fish but the entire coastal community. The count now includes birds, people, cars, dogs, helicopters, other things felt to be disturbing influences, measurement of beach widths, sea conditions, weather, as well as documentation of the continuing development of the beachfront represented by the construction of condominium complexes. One aspect of increased human usage of the beach is that more litter and debris seemed to be left on the beach. The litter and debris is categorized by presumed source as "beachgoing" and "offshore". Beachgoing litter is that material left there by visitors to the beach, while offshore litter and debris washes in from the sea and is left there by the receding tide. Three years ago, tired of not really knowing whether this material was as bad now as it was in "the old days", I started estimating amounts of several kinds of debris and litter.

Conducting this study and living virtually on the beach is proving an excellent way to gain an understanding of the natural processes and resources of a barrier island beach and a small coastal community that attempts to make its living from promoting such things as tourism and fishing, and the impact of these activities on the beach.

I drive a 7-1/2 mile stretch of Mustang Island Gulf beach every other day and have now completed over 1,300 of these trips. In addition to counting birds and people, etc., I "map" their positions along the shoreline. The beach curvature aids in locating the position of things of interest. The vehicle has a sort of Loran-c navigation system. Using a polynomial fitted to the curvature of the coastline and the vehicle's odometer reading, latitude and longitude are determined as a function of distance from an access road. The survey, started with a clipboard on the steering wheel, now uses a Hewlett-Packard 75C computer. a sensor connected to the truck's transmission inputs distance and time automatically. The computer's keyboard is reconfigured to enter species of birds and other survey items, including large litter and debris items. While the prime motivation for this study is actually not beach litter, it is this aspect of it which has gained some public interest. My slides highlight several aspects of this beach, including the litter problem.

Many activities impact the beach, from shrimping and fishing to the operations of the oil industry. With the slump in the oil industry many of the structures and vessels that were used offshore are parked in our waterways and safety anchorages.

The beach undergoes a remarkable change in morphology, from a very wide, clean beach in January, when sea level is generally low and the passage of weather fronts ("northers") push water, debris and litter offshore, to times when there is no beach at all. The action of wind during "northers" sweeping down off the plains at almost weekly intervals during the fall, winter and spring, blows sand out to sea. The rapidity with which erosion takes place is impressive; a storm erodes within minutes a great deal of the beach. During the summer, when there is a low energy period, the back beach area begins every year to support vegetation. However, the policy of allowing vehicles on the beach means this vegetation seldom is able to establish itself because vehicles drive on the shoreward side of the mid-beach area.

An amazing variety and amount of materials, including masses of Sargassum, comes ashore and attracts many animals. Some inhabitants of the beach environment are ghost crabs, ground squirrels, and an occasional coyote at the beach edge to scavenge in the early morning. Brown pelicans, which are making a comeback in the area, require large areas of quiet roosting space, but find it for a very brief time in the early mornings before they are disturbed by human influence. A great number of migrating birds navigate north and south along the coastline. The sea throws up Portuguese man-of-war, periodically in incredible numbers; the cabbagehead jellyfish (Stomolophus) provides a lot of food for many organisms.

The recent red tide killed millions of fish and was almost the final blow to the economy of Port Aransas, at least temporarily, because not only did it create a very unpleasant environment for several weeks, but the publicity was rather hysterical and severe. It was nonetheless a very interesting and extensive phenomenon caused by a popular explosion of the dinoflagellate Ptychodiscus brevis.

Among the things that come ashore are natural debris, natural mortalities, including, during what is called a "fallout of birds", many landbirds that do not make it across the Gulf of Mexico while migrating. I am the local observer for the sea turtle stranding network and this year has been phenomenal in the number of dead or injured sea turtles stranded along our beaches. I am also the local observer for the stranded marine mammal network. The latest stranding was a pigmy sperm whale, a 9-ft, 500-lb animal that was apparently alive when it was first found on the National Seashore, but dead when I got to it. In the last three years we have had 12 live strandings of seven different species of rather unusual offshore dolphins or whales. This may be a reflection of an increase in the number of observations or a real increase in the number of mortalities, but there does seem to be an increase in strandings on our coastline. In fact, the public wonders whether entanglement with or ingestion of seaborne litter might be a factor in this increase in marine mammal, turtle and bird mortality.

Dr. Costlow showed a picture of an ideal beach. However, our shoreline hosts another phenomenon known as Spring Break. In the course of almost 1,400 separate observations over the nine years of this survey I have never found anything more difficult to count than the number of cars and people on the beach at Spring break.

It's much easier to count 6,000 laughing gulls than to do the count of perhaps 100,000 people and 20- to 30,000 vehicles. The vehicles have an impact on the beach, which is torn up by tire-tracks or, under different conditions, compacted to the hard consistency of a roadbed. The most appalling result of that number of people and vehicles on the beach is litter. The littering problem is caused not only by what comes in from offshore; there is certainly a contribution from beachgoers in the more popular parts of the beach. Littering laws are almost never enforced; they are apparently unenforceable. With so large a crowd, the police are just trying to keep people from killing each other, let alone littering the environment. Port Aransas has a fulltime beach-cleaning crew (seven days a week). Within the city limits a $5 per year beach-parking fee is charged. The money goes toward keeping a fulltime cleaning crew. After Spring Break the beach looks nothing like most people's ideal, although many seem to accept it. It appears to be standard operating procedure to throw trash out of a vehicle, especially in a vacation place like the barrier island beaches. Glass bottles become a menace and are now prohibited on the beach. Aluminum cans are not found in great numbers; people remove them for recycling and in the process often leave the rest of the trash strewn about the beach.

There are, in our economically depressed times, certain people who find it necessary to live on the beach for periods of time. They often leave behind a scene at once pitiable and shameful. Sometimes that sojourn on the beach is long-term--several years--until the shack or bus literally falls apart and the people disappear.

The condominiums employ various beach-cleaning machines that clean up everything, including the Sargassum weed. Left alone, the weed plays an important role as a binding agent to hold the sand on the beach. In samples collected from these piles of material cleaned off the beach, weights and calculated volumes indicate that by far the greatest amount of material collected by some of these beach-cleaning machines is sand rather than weed or trash.

We are subjected every now and then to very large oil spills. There are vast problems associated with trying to remove massive amounts of tar, oils and dispersant solutions and disposing of truckloads of contaminated sand. It cannot be taken off-island because that is not allowed by law and it certainly does nothing good for any part of the barrier island environment. One of the things we discovered during the Ixtoc oil spill was that oil flowed down into the tunnels of some of the burrowing organisms, particularly Callianassa, the ghost-shrimp of the shoreline. An emulsion of sand, oil and seawater, being heavier than the water itself, flowed down burrowholes and formed perfect casts. There are periodic, seasonal occurrences of oil on the beaches. It has not been shown conclusively where it comes from: natural seepage from Gulf sediments, or the result of oil industry activities. The geochemists say weathering is such a problem that, beyond a certain amount of fingerprinting, its origin is difficult to determine.

Some very large things sometimes wash ashore. Shrimpboats occasionally get caught on a sandbar. An 80-ft, wooden-hulled shrimpboat stranded at midnight became matchsticks on the beach by 7:00 a.m. Three legs of a jack-up rig, which collapsed in a storm off South Baker Beach, looked as if they were going to be permanent features of the beach. Ingenious man came along with a special vessel, air-jetted a pit to refloat each structure and towed them away.

Because I want to understand the pathways by which man-made debris comes ashore, it is essential to record all accompanying types of debris items, including natural materials. My estimates are for some 40 categories of commonly found materials which I quantify on a scale of 0 to 5; zero is none, 5 is as much as I ever see.

Found frequently on the survey, onion sacks, stuffed with more onion sacks, were a mystery. Shrimpers with freezer compartments use plastic onion sacks to bag and store their catch. One of my trash categories I call "green bottles": these are bleach bottles--their names, emulating Clorox, are Clorolex or Clarasol--that come from Mexico and arrive on our beaches in great quantities. I use these as a crude indicator of when the currents change, coming from the south to the north. Few glass floats are found; most floats used in the fishing and other industries are plastic or metal and come from a variety of countries. The Soviet Union uses a very distinctive kind of plastic and a metal one comes from Cuba, but there are also Japanese, Norwegian and Spanish floats. One cannot quite assume nowadays, in the age of the multinational company, internationalism--especially the Common Market--that something made in Spain actually comes from a Spanish ship. Much of the trash is obviously from Common Market ships.

Containers that are full, sealed and apparently not leaking are often found. The Coast Guard has collected recently over 400 55-gallon barrels off our coastline. They advise that the contents are often toxic substances and that labels are not always accurate. Sometimes barrels at least have labels informing that their contents are not very nice, but quite often they are completely anonymous, battered, leaking. The materials in the majority of these barrels are petroleum-derived products, that is, oils, but some of them are rather toxic. The containers end up on our beach, people drive over them and spatter the contents onto the beach. I turn them over to the Coast Guard to put into their toxic waste dump. The oil industry leaves its names, purchase order and lot numbers on many items. There has been a definite decline in this kind of material in the last few months. It might be said that the oil industry slump is having some beneficial effects on the littering of our beaches.

Another very common item is plastic sheeting, yards of it. Used to cover materials taken out to the oil rigs by service industries or oil companies, it finds its way onto the beach. Once there it remains, covered with perhaps tons of sand. During a recent clean-up organized in Texas by the Committee for Environmental Education, volunteers found there was no way they could remove this plastic without the use of really big digging equipment.

The National Seashore is a very long strip of what should be beautiful, clean sand. Unfortunately, it is not. The Seashore and Mustang Island to the north, are often carpeted by an unsightly assemblage of trash and debris, largely man-made in origin (Figure 1.1). It is like this frequently enough that the Parks Service often gets letters from people who say they will never return to the National Seashore. When this material comes ashore it remains there until a catastrophic event, such as a hurricane, arrives.

We do have a problem and, apart from what it does to the economy, it has a direct effect on the animals. The oiling, of course, affects shorebirds. Some birds eat materials not generally considered to be edible. Immature laughing gulls have been seen trying to eat write-protect rings from 2400-ft reels of magnetic tape. These are used by the seismic exploration industry on their multichannel seismic recording instruments which use a tape once every 20 minutes or so. To protect the valuable data, the write-protect ring is removed and, whether it is thrown directly into the sea or dumped with the trash from the vessel, it eventually finds its way into the sea and onto our beaches. In fact, they constitute another of the survey's trash categories. Broken, the rings look like eels, which is perhaps why birds try to eat them, although gulls attempt to eat brightly colored things, whether or not they look like one of their prey items.

A hawksbill turtle was found with a flipper entangled in an onion sack; the limb grew around the constriction. Another hawksbill, that must have been entangled for weeks, was found emaciated, still alive, but with neck and both front flippers entangled in plastic onion sack. Rescued, it is now recovering in one of our tanks. Birds, especially gulls which are scavengers, are often seen with six-pack-rings around their necks or trailing lengths of monofilament. A leg entangled by monofilament means such birds become snared in power-lines and trees, or the leg so constricted it becomes gangrenous, swells to monstrous proportions, atrophies and eventually drops off.

An attempt has been made in the past three years to quantify the amount of trash, including natural debris, on this beach, to correlate it with measurements of temperature, salinity and currents, and to try to understand how and when it comes ashore. There are so many factors governing the deposition of trash and debris on our beaches--currents, tides, time of year, winds--that it is almost impossible. We might have some equations and put them together to try to find some answers, but none of it is simple. Why is it one morning there are masses of driftwood ashore, while on the previous morning there was none? Why is it that the driftwood disappears in a couple of days and is replaced by Sargassum weed? Perhaps these questions are answerable, but is a very complex set of equations. In the meantime, I will show you preliminary results from my 0-5 ratings system.

Figure 1.2 shows the seasonal distribution of debris items that are natural rather than man-made (although "driftwood" includes finished wood-products as well as tree parts, and the incidence of dead fish on the beach may include those discarded by surface fishermen). Data are averaged bi-weekly over the period of October, 1983 through the present (November, 1986); some 750 separate observations were made during this time. The vertical scale (INDEX) ranges from 0 for none of that category observed, to 5 for the maximum amount I normally see. While this is a personal and subjective evaluation, the frequency of observation (usually every other day, but daily in 1984) do show some basic trends. I will soon be "calibrating" these indices by sorting and weighing debris items at different sites along my study beach at the same time I do the litter estimates.

The two most numerous natural items, Sargassum weed and Portuguese man o'war (Physalia physalis) show a marked seasonal distribution with highest peaks in the spring. Cabbagehead jellyfish (Stomolophus) and seeds of the black mangrove (Avicenna germinans) are washed ashore in the winter months, while the water hyacinth (Eichornia crassipes), a freshwater plant, is most numerous in late summer, coinciding with runoff from Mexican rivers. Even though man-made and natural debris items are frequently washed ashore together, seasonal fluctuations in man-made litter are less obvious from my index data (Figure 1.3). This may be because offshore commercial activities (transportation and oil and gas exploration) are generally not seasonal. There is, however, a definite seasonality in the beverage can category. A peak in spring (Spring Break) and another in summer correspond to increased recreational activity at these times, both offshore and on the beach. The "green bottle" category (Mexican bleach bottle) seems to peak in the summer; presumably the bottles are borne ashore by currents coming from the south.

To fully understand the nature and magnitude of the problem, several other parts of the equation must be evaluated. I have just started to analyze these data and have yet to correlate the litter with my measurements of tides, currents, and weather patterns.

Mr. Anthony F. Amos was born and educated in England. He has training and experience in electronics research and oceanic circulation with special interest in polar oceanography. He is presently a Research Associate at the University of Texas' Marine Science Institute at Port Aransas.

Mr. Amos is the local observer for the National Stranded Marine Mammal and Turtle Networks; official cooperative observer for the U.S. Weather Service and maintains the tide gauge at Aransas Pass. He has an interest in photography and was awarded three prizes in the Audubon Society's 1983 Salon of Photography. Mr. Amos writes a regular column on the beach environment for a local newspaper and is Editor of UTMSI's Newsletter and the institution's brochure.

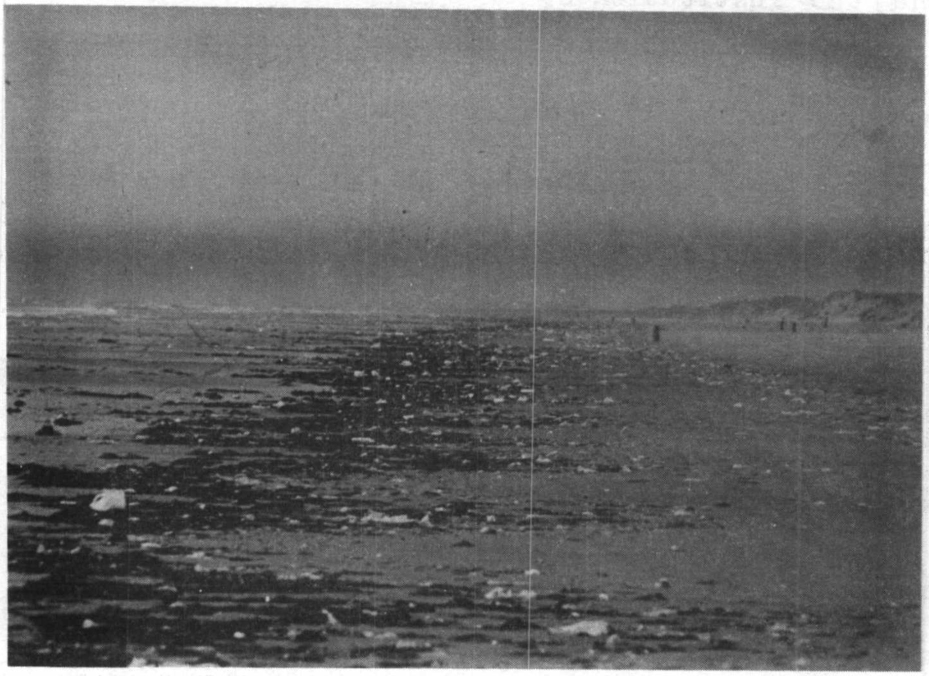

Figure 1.1a.--Mustang Island gulf beach, September 1980.

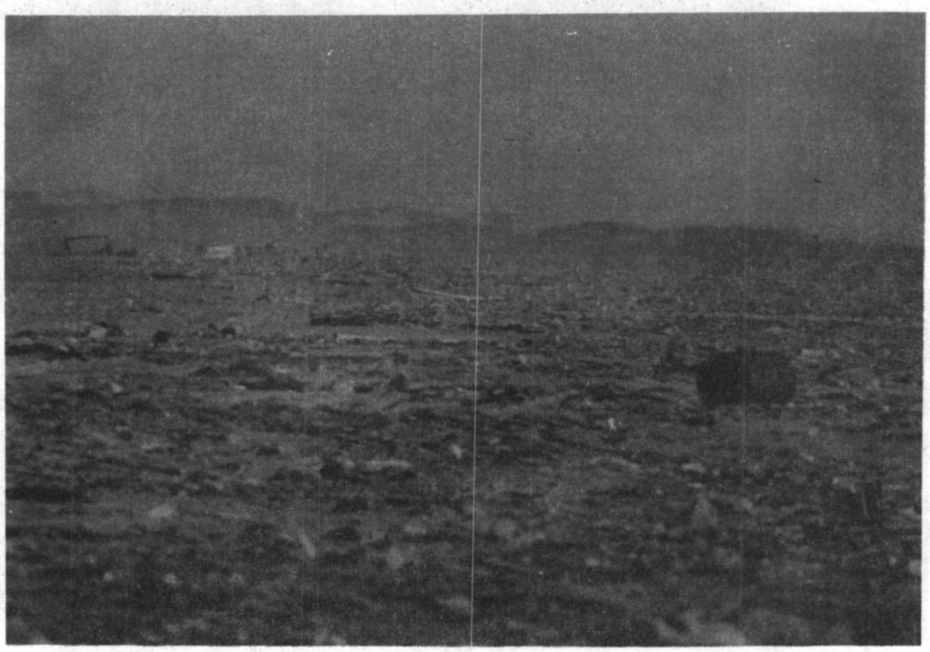

Figure 1.1b.--Padre Island National Seashore, April 1984.

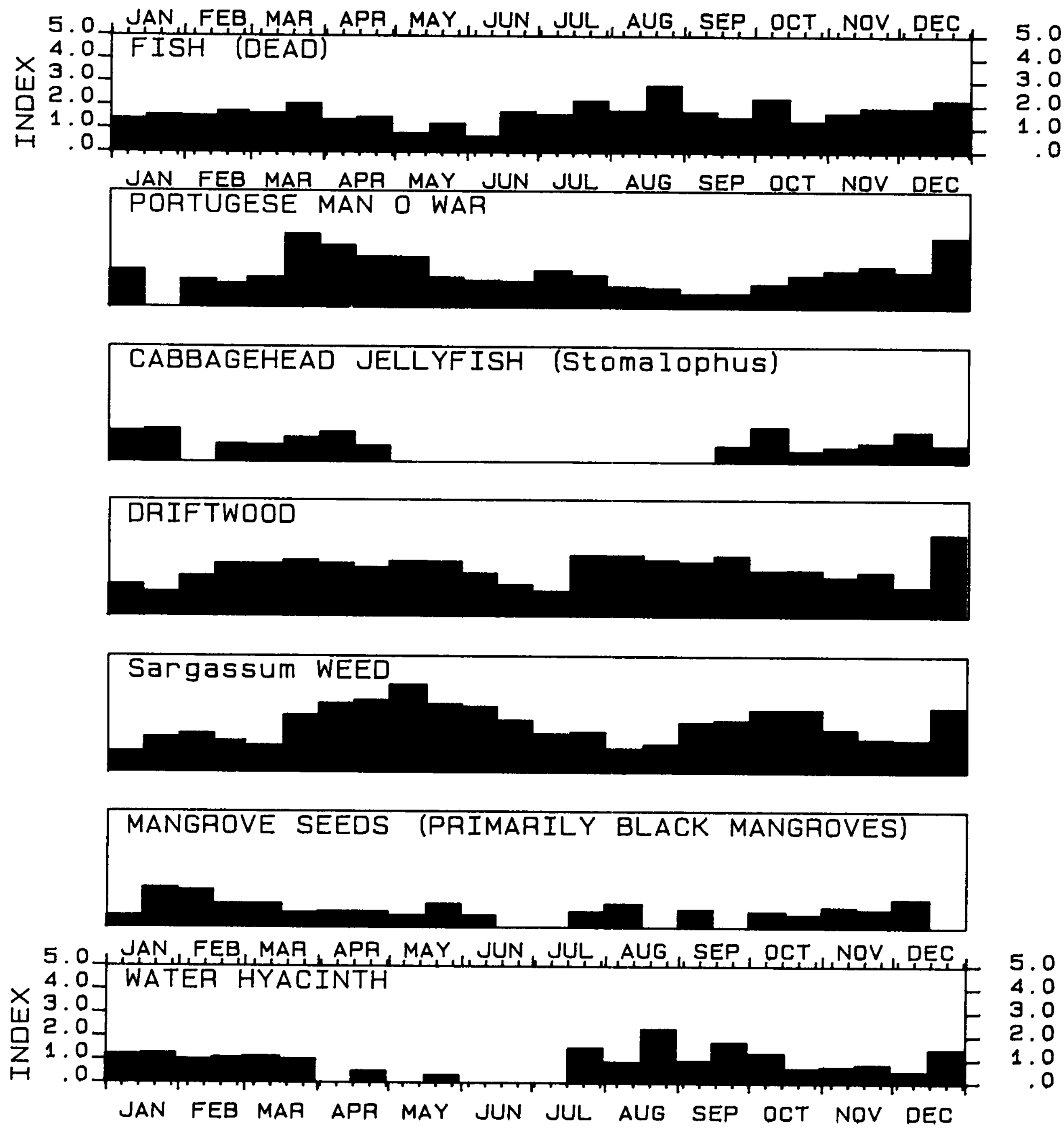

Figure 1.2.--Seasonal distribution of some naturally occurring beach debris (averaged bi-weekly from 750 observations made between October 1983 and November 1985).

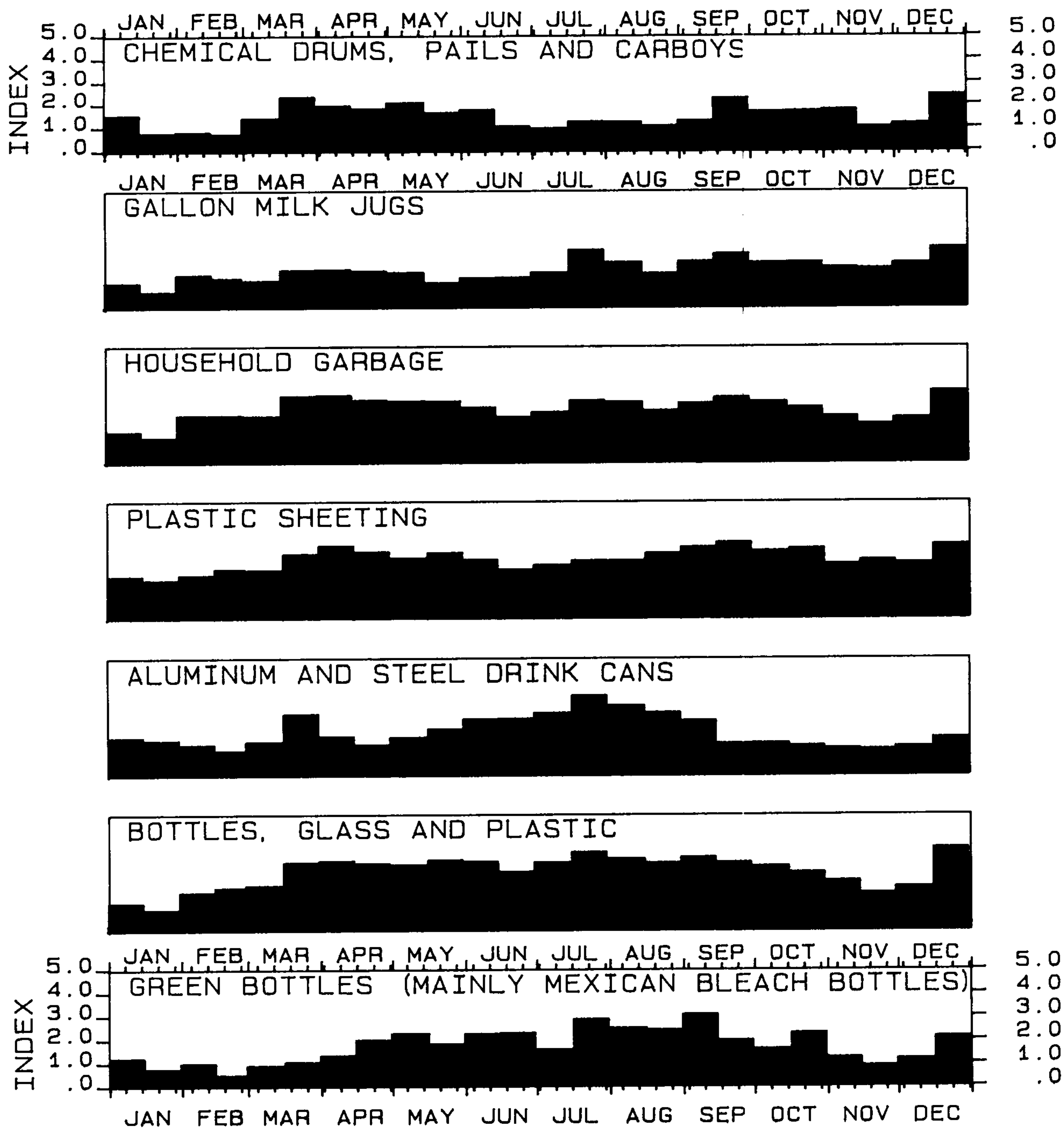

Figure 1.3.--Seasonal distribution of some man-made beach debris (averaged bi-weekly from 750 observations made between October 1983 and November 1985).

WETLANDS LOSS AND MITIGATION

Session: WETLANDS LOSS AND MITIGATION

Chair: Dr. Norman Froomer

Date: November 4 and 5, 1986

Presentation	Speaker/Affiliation
Wetlands Loss and Mitigation: Sessions Overview	Dr. Norman Froomer Minerals Management Service Gulf of Mexico OCS Region
Outer Continental Shelf Development and Potential Coastal Habitat Alteration: Project Overview	Dr. R. Eugene Turner Louisiana State University Center for Wetland Resources
Preliminary Results of the Analysis of Direct Impacts of OCS Pipelines and Navigation Channels on Central Gulf Wetlands	Mr. Robert H. Baumann Louisiana State University Center for Energy Studies
Preliminary Analysis of Salt Water Intrusion in OCS Related Channels	Dr. Flora Chu Wang and Dr. Jerome P.Y. Maa Louisiana State University Center for Wetland Resources
Analysis of Historical Salinity Records in Louisiana Estuaries	Mr. Erick M. Swenson and Dr. William J. Wiseman, Jr. Louisiana State University Center for Wetland Resources
Experimental Field and Greenhouse Verification of the Influence of Salinity Intrusion and Submergence on Marsh Deterioration: A Progress Report	Dr. Irving A. Mendelssohn and Ms. Karen L. McKee Louisiana State University Center for Wetland Resources
Inventory of Historical Sediment Load Records of the Mississippi River	Dr. Richard H. Kesel Louisiana State University Department of Geography and Anthropology
Marsh Sediment Accretion Rates in Vicinity of Man-Made Canals and Natural Waterways	Dr. Donald R. Cahoon, Mr. Ronald D. DeLaune, Dr. Ronald M. Knaus and Dr. R. Eugene Turner Louisiana State University Center for Wetland Resources

Session: WETLANDS LOSS AND MITIGATION (continued)

Presentation	Speaker/Affiliation
Sea Level and Subsidence	Dr. Joseph N. Suhayda Louisiana State University Center for Wetland Resources
Computerized Analysis of Spatial Trends in Wetlands Loss in Louisiana	Mr. Scott G. Leibowitz, Dr. John M. Hill and Ms. Elaine E. Parton Louisiana State University Remote Sensing and Image Processing Lab
Patterns and Rates of Marsh Loss on the Eastern Shore of Chesapeake Bay	Dr. J. Court Stevenson and Dr. Michael S. Kearney University of Maryland Horn Point Environmental Laboratory
Marsh Management Needs and Myths in Louisiana	Dr. R. Eugene Turner, Dr. Donald R. Cahoon and Dr. James H. Cowan, Jr. Louisiana State University Center for Wetland Resources
Mitigating the Impacts of Petroleum Industry Canals in Louisiana's Coastal Wetlands	Mr. David W. Fruge U.S. Fish and Wildlife Service Ecological Services Division
Wetlands Loss: Mitigation of Impacts	Mr. Charles G. Groat Louisiana Department of Natural Resources
Mitigating Pipeline Emplacement Impacts: INGA Perspective	Mr. Michael Krone Midcon Corp.
Mitigation of Environmental Impacts: A National Corps Perspective	Dr. Lloyd F. Baehr U. S. Army Corps of Engineers
Wetlands Loss: Mitigation Plans and the Rights of Private Landowners	Dr. Sherwood Gagliano Coastal Environments, Inc.

Wetlands Loss and Mitigation: Sessions Overview

Dr. Norman Froomer
Minerals Management Service

Wetlands loss in coastal Louisiana continues as a major environmental problem. The 50 square-mile rate of annual loss, first tabulated in 1978, appears to be continuing unabated, with some evidence that the rate may be accelerating. With the recent downturn in the oil and gas industry and Louisiana's concomitant efforts to diversify its economic base, the public is also developing a growing awareness that wetlands loss is an economic, as well as an environmental, issue. The growth and prosperity of Louisiana's seafood industry will depend on the health of the state's estuaries.

Oil and gas activities, pipeline and navigation canals in particular, have been implicated as factors associated with wetlands loss. Minerals Management Service (MMS) became involved in the wetland loss issue about 2 years ago because of concerns over the impacts of the 125 or so pipeline canals and several navigation canals that had been dredged to support Outer Continental Shelf (OCS) oil and gas activities. At that time the scientific community disagreed over the relative importance of canalization in the wetlands loss problem, let alone over the significance of canals dredged to support OCS activities versus canals dredged for onshore activities. Although a number of studies had investigated individual land loss factors, such as sea level rise, sedimentation, and canals, there had been no large-scale comprehensive effort to evaluate the relative importance of the individual factors or to determine how the individual factors interact.

In September 1985, MMS contracted with the Center for Wetland Resources, Louisiana State University (LSU), to conduct a 27-month study, entitled "OCS Development and Potential Coastal Habitat Alteration," into the factors that contribute to wetlands loss and, specifically, into what the OCS involvement has been.

The project has been underway for over a year now. All but one of the speakers during the first two sessions were from the LSU research team. Their presentations were essentially progress reports on the project. There was also a speaker from the Chesapeake Bay area of Maryland who described the marsh loss problem there. The third wetlands loss session was a panel discussion on the mitigation of oil and gas impacts in wetlands.

The first speaker was Dr. R. Eugene Turner, Program Manager for the wetlands study, who described the structure and goals of the project. The goals of the study are (1) to determine why coastal land loss is so high along the central Gulf of Mexico coast and (2) what the contributions of OCS development are to that land loss. Fifteen subtasks are involved, including investigations of (1) sediment source changes, distribution, and deposition; (2) salinity changes, impacts, and synergistic interactions with geologic and biological factors; (3) aerial imagery analyses of the temporal and spatial distribution of landform changes as a function of OCS and non-OCS development; and (4) direct impacts, primarily those impacts related to OCS pipelines and support facilities. The participants in the 15 subtasks that comprise the study are divided among seven colleges at LSU. Working groups have been formed for related research studies in salinity, sedimentation, aerial imagery, subsidence, and direct impacts.

Robert Baumann has been documenting the direct impacts of OCS pipeline and navigation canals. The direct impacts of pipeline construction per unit length is variable. Factors that are being assessed to account for this variation include age of line, diameter of line, number of lines per corridor, habitat type, construction technique, and geologic conditions (i.e., relative age and depth of sediments). To date, inventory and analysis have been completed for 79 pipelines (approximately 31% of the total population). The total direct change of habitat of these pipelines is 4,358 ha over a total pipeline distance of 1480 km. On a per unit length basis, 4.7 ha of wetland habitat are directly lost to open water, spoil, and facility construction for every km of pipeline. Both diameter of pipeline and age of pipeline appear to be important factors accounting for direct impact variation.

The next speaker, Dr. Flora Wang, has been modeling how salt water moves through canals and natural bayous. Her effort involves both a field and a theoretical approach. The Houma Navigation Channel, an OCS-related canal, has been selected as a field site. Field measurements are also being taken at the nearby Petit Caillou Bayou. The purpose of the field work is to characterize the salinity and velocity profiles within the channels under different meteorological and freshwater discharge conditions. The field data indicate that there is a well-mixed water column at the downstream reach of the channel, and then a gradual shift to partially stratified and highly stratified conditions at the upstream part. Another field site in a different hydrological and geological region, unrelated to OCS activity, will be selected to study and compare the saltwater intrusion problem. A theoretical approach is being developed to determine the intrusion length and shape of the salt wedge under different forcing conditions and in different kinds of channels.

Saltwater intrusion is often mentioned as a factor contributing to plant dieback and marsh loss. The next three speakers addressed different aspects of salt-water intrusion: whether it occurred, how it occurs, and how it affects marsh vegetation. Erick Swenson has been working on an analysis of long term salinity records within coastal Louisiana to determine the magnitude of the changes and their relationship to oceanographic and climatic forces and canals. To date, all available data records are on the project's computer. Primary sources for the salinity data have been the Louisiana Department of Wildlife and Fisheries and the U.S. Army Corps of Engineers. The analysis of a data- base composed of records from several different data sources has posed some special problems.

The salinity records have been recorded at different sampling intervals and using different measurement techniques. Also, the data series are of different length and have been stored on different machines with different formats.

Dr. Irving Mendelssohn discussed his and Karen McKee's project to document the extent to which increased water salinity affects marsh plant growth in fresh, brackish, and salt marshes. Experiments are being conducted in both a field and laboratory-greenhouse setting. The influence of submergence on plant growth, both by itself and combined with higher water salinity, is also being investigated. The following specific hypotheses are being tested in the study:

1. Given that saltwater intrusion occurs in a marsh, the increase in salinity will

cause the death of the dominant plant species.

2. Given that subsidence occurs in a marsh, the increase in submergence or flooding will cause the death of the dominant plant species.
3. The interaction of increased salinity and submergence in a marsh causes more rapid deterioration of the vegetation than by either factor alone.

Three plant species, one from each major habitat, were chosen for investigation: Panicum hemitomum-fresh marsh, Spartina patens-brackish marsh, and Spartina alterniflora - salt marsh. In the greenhouse experiment, each species is subjected to a range of salinities and flooding depths. In the field, sections of marsh are moved from their natural location to an area of higher salinity. The interaction of salinity and subsidence was accomplished by transplanting sections of marsh into a higher salinity area at different elevations. The field and greenhouse experiments are still in progress, and definite conclusions cannot be stated at this time. Preliminary results, however, suggest that the survival of fresh marsh species can be adversely affected by increases in salinity to levels above 5 ppt. In contrast, Spartina alterniflora survival is not affected by increases in salinity to levels normally found in Gulf coast marshes, but is reduced by increased soil waterlogging. S. patens appears to show an intermediate response to increased salinity, e.g., its growth is reduced by an increase in salinity, but survives for a growing season.

The sediment discharge of the Mississippi River has historically been a major source of sediment for coastal wetlands in Louisiana. Therefore, any evaluation of factors causing the loss of these wetlands must assess the long-term changes in the sediment discharge of the river. Dr. Richard Kesel reported on his efforts to document historic trends in bed-and suspended-load discharges of the lower Mississippi River. The available database for this analysis is limited largely to maps and file data from the Corps of Engineers and the Mississippi River Commission. Map data consist of hydrographic surveys of the river, dating from 1880 and published at 10- to 20-year intervals. These maps were produced at a 1:10,000 scale. Sediment discharge measurements are incomplete prior to 1963. One approach that Dr. Kesel has used to analyze the data has been to determine changes in the storage capacity of the river. The major areas of sediment storage within the channel are point bars, channel islands, and crossings or bars in the channel. A major change in the amount of sediment discharge should be reflected in these parameters. Any such changes are being assessed by measuring the composite cross-sectional area of channel reaches and the volume of exposed (active) channel and point bars. A preliminary analysis of the data for the 200 mile stretch of the river from Cairo to Memphis suggests that the river was aggrading its channel between 1880 and 1911. This condition may be representative of times prior to large-scale human interference. After 1911, the channel has undergone degradation. The greatest period of erosion occurred between 1911 and 1948 when most channel modification were initiated.

Dr. Donald Cahoon has been working on a project to evaluate canal impacts on sediment accumulation and vertical accretion in Louisiana's coastal marshes. Rates of sediment accumulation and vertical accretion are being measured in back marsh areas behind OCS pipeline canal spoil banks, oil and gas access canal spoil banks, and natural streambanks. Both recent and long-term sedimentation rates are being analyzed by three techniques Recent sedimentation rates are being evaluated by two marker techniques, using inert clay and inert rare earth stable isotopes. Long-term vertical accretion rates are being determined by Cs137 and Pb210 analysis of soil cores, which provide a 25- and 100-year integrated annual accretion estimate, respectively. The field work has been designed to compare sedimentation rates behind canal spoil banks to rates behind natural streambank levees. Sedimentation rates are being analyzed in impacted salt, brackish, and fresh marshes along the coast, including both the Mississippi River Deltaic and Chenier Plains.

Vertical accretion of marsh surfaces must keep pace with local relative sea level rise in order to sustain a viable marsh. Dr. Joseph Suhayda reported on his efforts to determine an absolute sea level datum for the Louisiana coast and to assess the impact of fluid withdrawal on subsidence. Dr. Suhayda used data on relative sea level rise and data on ground subsidence to derive estimates of absolute subsidence. Using independent data sets, Dr. Suhayda estimates that an average subsidence rate of 2 mm/yr has occurred over the past 40 years, with decadal maximum rates being as high as 20 mm/yr. A theoretical model was also used to estimate subsidence caused by fluid withdrawal associated with onshore oil and gas development. The spherical-tension model that was used suggested that compaction of the upper few hundred meters of sediments is primarily responsible for the surface subsidence and not fluid withdrawal from deeper reservoirs.

The last speaker from the LSU study team was Scott Leibowitz who has been using high resolution digital imagery to assess impacts of OCS activities on wetlands loss. Habitat maps for 1956 and 1978 were obtained for three study areas: (1) the Lafourche study area located to the east of Bayou Lafourche, a distributary that was abandoned by the Mississippi River about 400 years ago; (2) the Terrebonne study area adjacent to the Atchafalaya River, the most recent Mississippi River distributary that today captures 30% of the system's flow; and (3) the Cameron study area located in the western part of the state outside of the influence of the Mississippi River. Preliminary analyses have been performed on the Terrebonne and Cameron study areas. These analyses include determination of acreage of marsh type, marsh loss, and type of marsh loss. In both study areas, conversion of land to inland (as opposed to coastline) open water was the major form of land loss (72% and 93% of all loss for Terrebonne and Cameron, respectively). The Cameron data set was analyzed to determine whether canals and pipelines contribute to land loss. If canals are related to land loss, loss rates adjacent to canals should be higher than rates far from them. To test this hypothesis a proximity analysis was performed with percent land loss plotted as a function of distance to natural channels. Loss rates increase from 11% at 1 km from a canal to 39% at 100 meters. Beyond 1 km, the rate becomes random. For natural channels, the opposite trend was seen: loss rates decreased from 34% at 1 km to less than 10% at 100 meters.

Dr. J. Court Stevenson, from the University of Maryland, discussed coastal marsh loss patterns on the Eastern Shore of the Chesapeake Bay. In the past, the coastal wetlands there were thought to be stable, if not aggrading. Studies conducted during the past few years, however, indicate that 3900 ha of marsh in the Blackwater Wildlife Refuge were converted to open water from 1938 to 1979. The Blackwater marshes do not have a significant riverine source of sediments, and the marsh soils show an accretionary deficit. Other factors that may contribute to marsh loss here are hydrologic alterations associated with a road constructed across the marsh, muskrat grazing, and marsh burning. Estuarine marshes in the Nanticoke River are also experiencing land loss despite a large source of alluvial sediments. Dr. Stevenson hypothesizes that sediment inputs were high in the 1800's in association with land clearing for agriculture, but reductions in agricultural land use as well as sediment control practices have significantly reduced sediment delivery in the estuary which has affected marsh stability.

The third session on wetlands loss was a panel discussion on the mitigation of oil and gas impacts.

The session began with each panelist providing a brief presentation on his or his agency's/company's perspective on the mitigation of oil and gas impacts. David Fruge explained the U.S. Fish and Wildlife Service's (USFWS) involvement in permitting oil and gas activities in coastal wetlands. He described actions that his agency often recommends to minimize oil and gas impacts. These include directional drilling from existing drill slips, using a spray dredge to avoid spoil bank formation, cutting gaps in spoil banks to facilitate water exchange, plugging canals to reduce saltwater intrusion, using board roads instead of canals for access, backfilling canals, and routing canals through open water instead of marsh. The USFWS usually recommends that permittees compensate for remaining unavoidable impacts with offsite mitigation. The USFWS is also involved in plans to mitigate the ongoing impacts of existing oil and gas canals.

Michael Krone discussed the gas pipeline industry's concerns about installing pipelines in a habitat undergoing such dramatic alterations. His discussion focused on five main points:

1. While canals have certainly had an impact, there are a number of other natural and man-induced factors which need to be considered in a discussion of wetlands loss. Each situation will be distinct and, therefore, there is no one "cure-all" remedy.
2. The interstate transmission industry has since the mid-1970's used the push-pull method of construction for pipeline emplacement to minimize canal impacts. These new techniques reduce environmental impact to acceptable short-term levels.
3. The current lack of regulatory consensus concerning wetlands construction protocol is causing the industry problems in both acquiring permits and predicting future construction windows. The lack of research in this arena exacerbates the problem.
4. New marsh management plans to mitigate wetlands loss are not well conceived because they focus on saltwater intrusion models rather than subsidence. Potentially, these plans could cause more harm than good.
5. The Gas Research Institute is initiating an extensive R/D program to improve the response of various wetland types to pipeline emplacement. The anticipated 5-year research effort has a funding level between one and four million dollars.

Dr. Charles Groat described the State of Louisiana's responsibilities, on the one hand, to allow for the multiple use of coastal resources and, on the other hand to establish the proper balance between development and conservation. The State's control over this balance is through the permitting process. To compensate for the unavoidable impacts on wetlands that do occur as a result of permitted activities, permit conditions commonly call for the applicant to do restoration work in areas previously impacted or to undertake projects to improve conditions in the permit area.

Dr. Sherwood Gagliano emphasized in his presentation the rights of private landowners in the mitigation process. Most of the wetlands in coastal Louisiana are privately owned. Yet, mitigation plans often seem to assume that the wetlands are public resources. The goals and opinions of the landowner are often not included in marsh management planning decisions. In fact, the landowners may not even be informed of public meetings in which the future use of their lands is being considered. As a group, landowners have a sense of stewardship for their property and have initiated conservation plans often at their own expense. In fact, the desires of landowners to protect their property from land loss should be looked upon as a resource in the overall strategy to conserve the State's wetlands.

Dr. Lloyd Baehr presented a perspective on the Corps of Engineers's position on mitigation. He described the legal basis for the Corp's involvement in this issue through the permitting process. The Corps considers mitigation throughout the public interest review process. The Corps District Engineer normally is responsible for determining the type and extent of mitigation to be included as conditions to any permit. Mitigation efforts can be required onsite or offsite. The Corps often requires project modification to minimize adverse project impacts. The Corp's forthcoming consolidated final regulations implementing the Section 404 program contain, for the first time, a section devoted to its mitigation policy.

Dr. R. Eugene Turner from the Center for Wetland Resources, Louisiana State University, discussed the assumptions that underlay marsh management strategies. If the principals which form the basis for many marsh management decisions are examined, many turn out to be untested hypotheses and not scientific fact. Although many of the hypotheses appear to be logically derived from observations of marsh processes, it will be unwise to initiate management strategies based upon these hypotheses until they have been rigorously tested. An analysis of the hypotheses underlying marsh management is useful for the purpose of focusing research needs and understanding what scientific support exists for a certain management strategy.

Dr. Norman Froomer is a former member of the Environmental Studies Staff of the MMS Gulf of Mexico OCS Regional Office. He earned a Ph.D. in geography and environmental engineering from Johns Hopkins University and was previously on the faculty at the University of New Orleans. He is presently managing Honey Island Farms of Carriere, Mississippi.

Outer Continental Shelf Development and Potential Coastal Habitat Alteration: Project Overview

Dr. R. Eugene Turner
Program Manager
Louisiana State University

The Minerals Management Service project "Outer Continental Shelf Development and Potential Coastal Habitat Alteration" is in the 14th month of a 27-month contract. The goals of the project are 1) to determine why coastal landloss is so high along the northern Gulf of Mexico coast, and 2) what the contribution of OCS development is to that landloss. Fifteen subtasks are involved including investigations of 1) sediment source changes, distribution, and deposition, 2) salinity changes, impacts, and synergistic interactions with geologic and biologic factors, 3) aerial imagery analyses of the spatial and temporal distribution of landform changes as a function of OCS and non-OCS development, and 4) direct impacts, primarily those impacts related to OCS pipelines and support facilities. The Task One report "Methodology Development" is completed, and work on all 15 subtasks in on schedule. Current emphasis is on field and laboratory studies.

The participants in the subtasks are divided among 7 colleges at Louisiana State University. Working groups have been formed for related research studies in salinity (4), sedimentation (4), aerial imagery (2), subsidence (1), and direct impacts (3). Progress reports are given at this meeting in the following areas:

- Direct impact of OCS Pipeline and Navigation Channels (Baumann and Reed)
- Salt Water Intrusions in OCS Related Channels (Wang)
- Historic Salinity Records (Wiseman and Swenson)
- Interactions of Saltwater and Submergence (Mendelssohn and McKee)
- Inventory of Historical Sediment Loads in the Mississippi River (Kesel)
- Marsh Sediment Accretion Rates (Cahoon, Delaune, and Knaus)
- Long-term Sea level and Subsidence Rates (Suhayda)
- Spatial Trends in Wetland Loss (Hill and Leibowitz)

Each research team will make a separate concise report on their activities, and the working groups will synthesize a summary on their respective subject area. A final report will deal with the contribution of OCS development activities to the overall landloss rates. The report is due September 30, 1987 (draft), and December 31, 1987 (final).

Dr. R. Eugene Turner is a Professor of marine sciences in the Center for Wetland Resources, Louisiana State University. He is Program Manager for the MMS contract on habitat modification in the coastal zone. His interests include wetland management, mitigation and restoration, biological oceanography, and fisheries ecology. Dr. Turner received his Ph.D. from the University of Georgia.

Preliminary Results of the Analysis of Direct Impacts of OCS Pipelines and Navigation Channels on Central Gulf Wetlands

Mr. Robert H. Baumann
Louisiana State University

Direct impact analysis is one of some 14 task-level efforts which, combined, strive to separate out the various factors that have contributed to the severe loss of wetlands along the Central Gulf Coast (Bolivar Roads, TX, to Waveland, MS). This specific task seeks to determine the relative contribution of direct impacts of OCS activities on wetland loss. Those OCS activities that directly contribute to wetland loss are the construction of pipelines, navigation channels, and related facilities.

The direct impact of pipeline construction per unit length is variable. Factors being assessed to account for this variation include age of line, diameter of line, number of lines per corridor, habitat type, construction technique, and geologic conditions (i.e., relative age and depth of sediments).

To date, inventory and analysis have been completed for 79 pipelines (approx. 31% of total population) that are geographically confined to that portion of the study area from Vermilion Parish eastward through Lafourche Parish. The total direct impact area (direct change of habitat) of those 79 pipelines is 4,358 ha over a total pipeline distance of 1480 km (Table 2.1). On a per unit length basis, wetland habitats are directly lost to open water, spoil, and facility construction at a rate of 4.7 ha per km of pipeline constructed (Table 2.2). Non wet-land habitats have a substantially lower rate of impacts per unit length.

Regional geologic variations such as depth of Holocene and relative age of sediments within the Mississippi Deltaic Plain do not appear to be a source of variation in direct impacts based on single factor analysis.

On a per unit length basis, both diameter of pipeline and age of pipeline appear to be important factors in accounting for direct impact variation. Impacts per unit length tend to increase with increasing pipeline diameter (Figure 2.1) and with increasing age of line (Figure 2.2) although not in a linear fashion. Differences in construction equipment required for different groups of diameter size may explain the former while improvements in method of construction, new construction regulations, and the effects of canal widening over time may contribute to the later. Multiple factor analysis along with case study investigations requiring operator assistance (knowledge of construction techniques used) will be conducted to further resolve these possible sources of variation.

Corridor size cannot yet be evaluated as a source of variation because of too few samples. The direct impacts of navigation channels are being treated separately from pipelines because of the substantially greater impact per unit length and impact allocation questions. A total of 25 navigation channels have been identified as avenues for OCS traffic based on U.S. Army Corps of Engineers vessel count data.

Completion of the above efforts are expected by March 1987.

Mr. Robert H. Baumann is Associate Executive Director of the Center for Energy Studies at Louisiana State University. He has been involved in wetland loss research for over ten years and has published related articles in journals such as Science and J. Sedimentary Petrology as part of his broader interest in sedimentary process.

Preliminary Analysis of Salt Water Intrusion in OCS Related Channels

Dr. Flora Chu Wang
and
Dr. Jerome P. Y. Maa
Louisiana State University

INTRODUCTION

Wetland losses and gains are the result of many interacting hydrological and geological factors. The changes are caused by both natural processes and human activities. In the Louisiana Coastal Plain, salt water and fresh water meet at many places; in estuaries and inlets, in navigation channels and natural bayous. Due to the density difference, the salt water tends to penetrate inland and to form a salt wedge underlying the freshwater layer.

This study attempts (1) to analyze the behavior of saltwater intrusion in the major navigation channels that support OCS development activities along the coast of Louisiana, and (2) to determine the degree and extent of saltwater intrusion that may contribute indirectly to wetlands loss. A typical example is the Houma Navigation Channel, located in south-central Louisiana (Figure 2.3).

CHARACTERIZATION OF SALINITY PROFILES

The major forcing functions that affect the length and the shape of salt wedges in channels are fresh water discharge, tidal amplitude, and prevailing wind. Four types of salinity profiles can be characterized (Figure 2.4), depending on the physical dimension of the channel and the relative magnitude of the above, forcing functions.

1. Well Mixed -- in a shallow channel, when the tidal current dominates and the fresh water discharge is low, the salinity profile is quite uniform in the water column, and the velocity profile follows a simple logarithmic distribution.
2. Partially Stratified -- when the freshwater inflow is high and the tidal range is moderate, there are salinity differences between surface and bottom, and the salinity gradient is apparent in the water column.
3. Highly Stratified -- when the freshwater discharge is moderate and the tidal range is high, the salinity difference in the surface and bottom becomes large, a sharp salinity gradient is then formed in the water column.
4. Saline Wedge -- in a deep channel, when the river discharge is high and tidal range is low, salt water intrudes beneath the fresh water, and a salt wedge front is formed. As the advancing phase of front ceases, the saline wedge becomes stationary or arrested.

FIELD STUDY

The Houma Navigation Channel, and OCS related canal, was chosen as a pilot study site (Figure 2.3). The channel connects Terrebonne Bay with the Inter-coastal Waterways near Houma City at a distance of about 23 miles. The channel depth is about 20 ft. The channel is subjected to a one foot tidal range from the Gulf of Mexico under various river discharge conditions.

Two field trips were conducted at the site. The first was September 20, 1986. Several phenomena were observed: (1) from Cocodrie (Gulf side) to Dulac (about 10 miles from Cocodrie), the salinity profile was well mixed; (2) from Dulac to Celestin (16 miles upstream), the profile became partially stratified; and (3) from Celestin to Houma, the salinity profile was highly stratified; the surface and bottom salinity at Houma were 3 and 9 ppt, respectively. Figure 2.5 displays the variation of salinity (depth-averaged) with the distance from Cocodrie.

The second survey was held during October 17-19, 1986. Similar, well mixed behavior near Cocodrie was observed on 18 October. However, the length of salinity intrusion was shortened to about 10 miles from Cocodrie (Figure 2.5). This is because of the high fresh water discharge from the upstream drainage basin due to heavy rainfall occurring prior to our field trip. These data demonstrate the importance of fresh water discharge on the salt wedge length (Figure 2.5).

THEORETICAL APPROACH

A theoretical approach for determining the intrusion length and the shape of salt wedge has been given by Schijf and Schonfeld (1953). Their approach was based on assumptions of a two-layered flow system with no salt exchange across the interface, a constant interfacial stress, a negligible bottom layer velocity, and, hence, the zero bottom stress. Their one-dimensional momentum and continuity equations have been used to solve the problem of the arrested saline wedge in an ideal estuary by Harleman (1961). Officer (1976) further modified their approach and presented the following equations to calculate the length and the shape of the saline wedge.

$$\frac{f_i \gamma}{2h_o} x = \frac{1}{4} n_2^4 + \frac{3}{2} n_2^2 + (8 + \gamma)\left(n_2 + 3 \log \frac{3-n^2}{3}\right)$$

with $n_2 = h_2/h_o$ and $\gamma = \rho_1 q^2/(\rho_2-\rho_1) g h_o^3$

where f_i is the interfacial friction coefficient, x is the longitudinal distance from wedge front, h_0 is the total water depth, h_2 is the thickness of the bottom layer, q is the fresh water discharge per unit width, P_1 and P_2 are the density of fresh and salt water respectively. The above equation reveals that the length of a saline wedge is dependent on the fresh water discharge and the channel depth. A computed result depicting this relationship is shown in Figure 2.6.

PRELIMINARY CONCLUSIONS

Field data indicate there is a well-mixed water column at the downstream reach (Gulf side) of the channel, and then a gradual shift to partially stratified and highly stratified conditions at the upstream part. A second field site in a different hydrological and geological region, unrelated to the OCS activity, will be selected to study and compare the salt water intrusion problem.

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Dr. Flora Chu Wang is Professor of Department of Marine Sciences and Coastal Ecology Institute, Center for Wetland Resources, Louisiana State University. She received her Ph.D. in civil engineering from Stanford University. Her special interests are in the areas of systems analysis in water resources, and river mouth mechanisms and deltaic processes. This work is part of her general interest in mathematical and computer modeling.

Dr. Jerome P. Y. Maa is a post-doctoral research associate in the Coastal Ecology Institute, Center for Wetland Resources, Louisiana State University. He received his Ph.D. in coastal and oceanographic engineering from University of Florida. His special interest is in the area of cohesive sediment transport.

Analysis of Historical Salinity Records in Louisiana Estuaries

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and
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INTRODUCTION

This project is a portion of a larger scale study being funded by the Minerals Management Service entitled "Outer Continental Shelf Development and Potential Coastal Habitat Alteration." The project consists of the analysis of the available long term records of salinity within the Louisiana coastal zone to determine the magnitude of changes and their relationships to climatic and oceanography forces. The major purpose of the analysis is to address the possible impacts of canals (oil field, navigation, OCS pipeline) on the salinities in the Louisiana coastal zone.

The salinity regimes in the marshes have been inferred to have changed in recent decades due to a combination of both natural climatic variations and man's activities, mostly canal construction. Thus, the study will focus on 1) developing an understanding of the temporal and spatial patterns of the salinity regime; 2) investigating the factors that control salinity (climatic and anthropogenic). Long-term salinity, stream flow, and climatic data are available at several locations within the state. The organization of these data records and the subsequent analysis of these data are the goals of this task.

To date, all of the data records are on the LSU computer, and the organization of the database is about 90% complete. Although preliminary analyses have been completed on some of the data, this paper will concentrate chiefly on the organization of the database and the techniques being employed to analyze the data.

THE DATA BASE

The primary sources for the salinity data are the Louisiana Department of Wildlife and Fisheries (LDWF) and the U. S. Army Corps of Engineers (COE) Stream flow data are available from the U.S. Geological Survey (USGS) and, weather data are available through the National Climatic Data Center (NCDC). The data we presently have are summarized below. Indicated are the number of data records of a given length, in years (Table 2.3).

The LDWF data are from continuous recorders, with a sampling interval, in most cases, of one hour. The COE salinity data are from daily water samples, which we then titrated to determine chlorinity. The USGS streamflow data are daily discharges, and the NCDC weather data are surface observations taken every three hours. All of the data were available in some sort of computer compatible format.

METHODS

Organization of the Data Base

The organization of the various data sets into final forms for analysis consists of the following general steps:

1. Inventory the data set to locate gaps in the record.
2. Compute daily means for LDWF and NCDC data.
3. Edit daily mean data set and delete value if less then 80% of the hourly observations are present.
4. Compute the monthly means from edited daily means data set.
5. Edit monthly mean data set and delete value if less than 80% of the daily observations are

present.

6. Use resulting edited data set of monthly means for all analyses.

ANALYSIS OF THIS DATA BASE

The analysis of a database composed of records from several different sources pose some special problems. The first of these was getting the data onto the LSU computer. The data sets came from different machines, with different formats for each machine. In some cases, retrieving the data in a form compatible to the LSU computer was a somewhat lengthy process. More serious problems concern the data itself. The database is made up of parameters with different sampling rates (e.g., the LDWF salinities are hourly, the COE salinities are daily). It must be determined whether these data- bases are compatible. In addition, the data-base is composed of series of varying lengths. The possible effects of series lengths on the significance of the resulting trends must be taken into account. Lastly, the system we are dealing with is complex with variability occurring on time scales ranging from hours to years. The appropriate averaging period for the analysis must be determined. At present, we feel that monthly means will suffice.

Data analysis is being conducted using both standard statistical analysis and time-series software packages. A number of such packages are available through the LSU System Network Computer Center (SNCC). The analysis can be divided into 5 general categories:

1. Comparison of the two salinity databases (COE, LDWF). This will be accomplished by simple linear statistics, using either correlation or regression analysis.
2. Investigation of the temporal changes in the means and variance. This will be accomplished with linear statistics and/or the use of ARIMA Models.
3. Investigation of the relation between salinity and the various environmental forcing functions (wind, streamflow, water levels, and precipitation). This will be done through the use of both linear statistics (correlation, ANOVA) and standard time series analysis (spectrum analysis, cross-spectrum analysis) where appropriate.
4. Investigation of canal effects. This will be accomplished through the use of linear statistical comparison of canalled and non-canalled areas and by before-after project comparisons if the data sets available prove to be appropriate to such analysis.

The anticipated results of the above analysis are as follows:

1. Description of the short-and long-term salinity regime as related to climatic influences.
2. Description of the long-term salinity changes as they relate to canal dredging.

ACKNOWLEDGEMENTS

We thank the Louisiana Department of Wildlife and Fisheries (Mr. Barney Barrett, Mr. Ron Gouguet, Ms. Jan Bowman and Mr. Harry Schaffer) for giving us access to their salinity data. Mr. Rodney Mach of the U.S. Army Corps of Engineers supplied us with an inventory of chlorinity station locations and dates of record. The Louisiana Department of Environmental Quality (Mr. Ken O'Hara and Mr. Stacy Richardson) allowed us the use of their VAX computer to

retrieve the COE data. Mr. Max Forbes of the U.S. Geologic Survey supplied the stream gaging locations and dates of records. Several colleagues at LSU gave assistance and advice. Dr. Jim Power of the Coastal Fisheries Institute (CFI) supplied us with copies of the LDWF data in a format suited for the LSU computer. Ms. Deborah Fuller and Dr. Richard Condrey (both at CFI) gave advice and information regarding the LDWF data sets, which they are also working with. Mr. Carlos Garces of the Department of Experimental Statistics, helped in transferring some of the LDWF data to us.

Mr. Erick Swenson is a research associate at the Coastal Ecology Institute at Louisiana State University. He has been studying the effects of canals on the marsh hydrologic regime. His general interests include currents, salinity, and water level measurements in estuarine and marsh systems. Mr. Swenson received his MS in earth sciences (Oceanography Concentration) from the University of New Hampshire in 1978.

Dr. William J. Wiseman, Jr., is a Professor in the Department of Marine Sciences and Coastal Studies Institute at LSU. He received the BSEE, MS, MA, and Ph.D. degrees from the Johns Hopkins University. His present research interest include shelf and estuarine dynamics and geophysical signal processing.

Experimental Field and Greenhouse Verification of the Influence of Salinity Intrusion and Submergence on Marsh Deterioration: A Progress Report

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and
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Despite the popular notion that saltwater intrusion is a major factor causing wetland loss, marsh deterioration due to increased salinity has neither been documented in the refereed literature nor experimentally reproduced. Straight-line canals are believed to allow penetration of saline waters into brackish and fresh marshes which, under normal circumstances and hydrology, would not be subject to such a change in salinity. Although increases in salinity due to saltwater intrusion into fresh marshes could result in vegetative dieback, brackish and salt marshes contain plant species which are adapted to growth in saline water. In these cases, mechanisms other than saltwater intrusion, i.e., subsidence/increased submergence, sediment and nutrient deprivation, must be considered as potential causes of the extensive dieback and deterioration observed in salt and brackish marshes in Louisiana.

The major goal of this study has been to investigate the effect of increased salinity on the dominant plant species in each of three major marsh types by simulating saltwater intrusion under field and greenhouse conditions. The effect of increased submergence or flooding on these same plant species is also being determined exclusive of, and in conjunction with, salinity effects. The following hypotheses are being tested in this study:

1. Given that saltwater intrusion occurs in a marsh, the increase in salinity will cause the death of the dominant plant species.
2. Given that subsidence occurs in a marsh, the increase in submergence or flooding will cause the death of the dominant plant species.
3. The interaction of increased salinity and submergence in a marsh causes a more rapid deterioration of the vegetation than by either factor alone.

Three plant species, one from each major habitat, were chosen for investigation: Panicum hemitomon--fresh marsh, Spartina patens--brackish marsh, and Spartina alterniflora--salt marsh. In the greenhouse, each species is being subjected to a range of salinities (depending upon the species) and flooding depths. The investigation of one species--Panicum hemitomon--has been completed, and another with Spartina alterniflora is underway. The results of the experiment with P. hemitomon demonstrated that this species could survive an increase in salinity up to 9.5 ppt for a period of one month. However, growth at this highest salinity level was significantly reduced compared to the control at 0 ppt. Stem elongation at intermediate salinity levels (1.2, 2.4, 4.9 ppt) did not appear to be greatly reduced compared to the control. Total live aboveground biomass was reduced from approximately 20 g pot^{-1} in the control to 10 g pot^{-1} in the 9.5 ppt salinity level. The measurement of proline (which accumulates in plant tissues in response to salinity stress) in the leaf tissue of P. hemitomon demonstrated that this species was moderately stressed at 9.5 ppt, slightly stressed at 4.9 ppt, and not at all at lower salinity levels. Increased submergence of P. hemitomon under greenhouse conditions did not have a major effect on the growth of this species. Similar experiments which will be conducted with S. patens and S. alterniflora will be completed by the spring of 1978.

For the fresh marsh species, an increase in salinity to approximately 5-10 ppt was planned. However, due to a major storm event, salinities at the recipient marsh, which normally are 6-7 ppt, were increased to 15 ppt just a few days following transplantation of Panicum hemitomon to this area. As a result of this unexpectedly high increase in salinity, which lasted only for a few days, 100% mortality of the P. hemitomon occurred. However, the cores had been invaded by the annuals, Panicum dicotomiflorum and Pluchea camphorata., which were common in this area at this time of year. The P. hemitomon controls in the donor marsh (0-2 ppt) did not experience a significant reduction in survival. Although samples from this experiment are still being processed, stem densities indicated that the growth of P. hemitomon was also affected by increased submergence.

In contrast to the fresh marsh species, the two salt-tolerant species, Spartina alterniflora and S. patens, survived an increase in salinity from 10 to 20 ppt. although S. patens was initially affected by the sudden increase in salinity, substantial regrowth had occurred in most cases by October 1986 when this experiment was terminated. All analyses have not been completed for this species, but initial results indicate that increased salinity alone will not cause the death of this species during one growing season. However, stem densities were reduced by increased salinity. Waterlogging appeared to have some effect on the % survival of this species, particularly in combination with an increase in salinity. S.

alterniflora survival was not adversely affected by an increase in salinity level, but was substantially reduced by an increase in submergence; in some cases, a decrease in elevation 10 cm resulted in 100% mortality of this species.

Because this project is not yet completed, conclusions can not be stated at this point. However, preliminary results suggest that the survival of fresh marsh species such as Panicum hemitomon can be adversely affected by increases in salinity to levels above 5 ppt. In contrast, Spartina alterniflora survival is not affected by increases in salinity to levels normally found in Gulf coast marshes, but is reduced by increased waterlogging. S. patens appears to show an intermediate response to increased salinity; e.g., its growth is reduced by an increase in salinity, but survives for a growing season. The interaction of increased salinity and waterlogging may have a greater effect on this species than by either factor alone.

Dr. I.A. Mendelssohn is an associate professor of marine science at Louisiana State University. His primary research interest include flood-tolerance in wetland plants, factors controlling the growth of wetland plants, barrier island plant ecology, and stress physiology. His research experience not only involves wetland systems in Louisiana, but has extended to other regions of the U.S., as well as Canada, Australia, Belize, and The Netherlands.

Dr. Mendelssohn received his B.S. degree in biology from Wilkes College, his M.S. degree in marine science from the Virginia Institute of Marine Science, and his Ph.D. in botany from North Carolina State University.

Karen L. McKee received a B.S. degree in zoology from Mississippi State University and a M.S. degree in botany from North Carolina State University.

Ms. McKee is a Research Associate in the Center for Wetland Resources, Louisiana State University where she has worked for the past nine years. Her primary research interests include flood tolerance and salinity tolerance in wetland plants, stress physiology and energy metabolism in plants, and wetland deterioration. Although her primary research experience has been in salt marshes of the east and gulf coasts of the U.S., she has conducted research in freshwater marshes in Canada, man-made marshes in the Netherlands, and mangrove forests in Australia and Belize.

Inventory of Historical Sediment Load Records of the Mississippi River

Dr. Richard H. Kesel
Louisiana State University

The sediment discharge of the Mississippi River has historically been a major source of sediment for the coastal wetlands in Louisiana. Therefore, any evaluation of factors causing the loss of these wetlands must assess the long-term changes in the sediment discharge of the river. The sediment discharge has been affected by both natural events and man-made structures. A qualitative estimate of the magnitude of these factors is illustrated in Figure 2.7. As noted in the figure, many of the factors influencing the sediment discharge are largely man- made and have occurred after 1900. These factors have altered both the bedload and the suspended load regimes of the channel. The river prior to 1900 has been considered generally to be unaffected by man-made structure.

Systematic measurements of sediment discharge on the Mississippi River are available since 1951. Based on these data, it has been suggested that there has been a 50 percent decrease in the suspended load of the Lower Mississippi River during the past 35 years. This decline has been attributed to revetment construction and subsequent reduction in bank caving. Any analysis based on such a short period of record cannot, however, recognize longer term cyclic changes that may be present. Because only sporadic sediment data is available prior to 1950, it is difficult to extend this analysis back in time. Some indirect estimates of historic changes in the sediment regime of the river have been made using channel geometry and various stage-water discharge relationships. There is general agreement, based on this evidence, that the channel has been deepened, indicating degradation in the upper and middle portions, possibly extending as far downriver as Memphis. In some reaches, the river bed has been lowered an average of 11 feet, with depths exceeding 15 feet being recorded. This is thought to be largely the result of the high concentration of training dikes located throughout this portion of the river. Downriver from Memphis there has been an increase in stage readings which would suggest aggradation of the river bed. This has resulted in a reduction in sediment-carrying capacity of the channel and an increase in the amount of maintenance dredging required for navigation. This appears to represent a down-valley movement of bedload sediment from the upper and middle reaches of the Mississippi River. Since 1900, levees have played an increasing role in confining sediment loads that, under natural conditions, would have passed overbank on the flood plain and into coastal wetlands. This confinement has increased sediment movement downriver. Levee confinement is believed to have contributed to the increased bed sediment supply and is partly responsible for aggradation of the channel bed.

The purpose of this study is to evaluate and analyze the historic evidence that can be used to document changes or threads in the sediment discharge of the lower Mississippi River. The available data base for this analysis is limited largely to maps and file data from the Corps of Engineers and the Mississippi River Commission. The first detailed hydrographic data for the lower Mississippi River are available from 1851, followed by a series of hydrographic surveys of the river published from 1880 to the present by the Mississippi River Commission. These latter survey maps are available for 1880, 1911, 1921, 1931, 1948, 1964, and 1975, at a scale of 1: 10,000. File data is quite variable. Before 1930, sediment and hydraulic measurements are scarce, although some observations were obtained on suspended load as early as 1851. Collection of sediment data between 1930 and 1962 was intermittent and was generally gathered at major gaging stations along the river (e.g. U.S. WES, 1931, 1935). A major effort to collect sediment discharge and hydraulic data began in 1963 when the Corps of Engineers initiated its potamology program. The focus of the program, however, is limited to the Vicksburg District between the Arkansas River and Natchez, Mississippi. Data gathered include hydrographic surveys, bed form profiles, current direction, water surface profiles, and sediments samples of suspended and bed load. Much of the data gathered under this program has yet to be analyzed.

It is evident that the methods of analysis used in this study are restricted by this limited data-base. Several approaches are being attempted to achieve the objectives of this study. First, any changes in the amount of sediment discharge passing through a given portion of the river should be reflected in the sediment storage capacity and morphology of the channel. The major areas of sediment storage within the channel are point bars, channel islands, and crossings or bars in the channel. A major change in the amount of sediment discharge should be reflected in these parameters. Any such changes are being assessed by measuring the composite cross-sectional area of channel reaches and the volume of exposed (active) channel and point bars. This information is being compiled, in part, using a 2400 series Numonic digitizer.

1. Composite cross-sections. A river segment that is changing its position through time and space presents a number of problems. It is difficult to analyze and compare the channel geometry at a particular cross-section through time because its position relative to other periods has shifted as the river migrates. The location of the cross-section may also change its relative position with the river segment. The use of a composite cross-section provides a basis for quantitative comparison of the channel segment in space and time. The length of the channel segments is determined by the planform geometry of the channel (e.g., meandering or straight reaches). The hydrographic survey maps sounding profiles taken every 800 to 1000 feet along the river channel. Therefore, a meandering reach two miles long would include 10 to 13 sounding profiles across the channel. A computer program has been developed to produce a composite (mean) cross-sectional profile for a particular reach.

2. Active point bars. The point bar on a meandering river represents an area of temporary storage for suspended and bed load sediments. The active portion of the bar is bounded by two distinct topographic levels which correspond to average extremes of river stage. The Average Low Water Plane (ALWP) on the hydrographic survey maps delineates the lower boundary of the active point bar. The upper boundary is delimited on the survey maps by the riverward extent of dense willow trees. The area of the active bars can be digitized and the volume of sediment calculated. The results of these two approaches provide corroborative data for channel segments that can be used for quantitative estimates of sediment discharge variations. These variations can, to some extent, be compared to existing sediment discharge observations.

The volume of sediment stored on point bars along 200 miles of the Mississippi River channel from Cairo to Memphis have been measured. The results of this are summarized in Table 2.4.

These data suggest that the river between 1880 and 1911 was aggrading its channel and may represent conditions prior to man-made changes (Figure 2.7). After 1911, the channel has undergone degradation, the greatest period of erosion occurring between 1911 and 1948 when most channel modifications were initiated. The period from 1948 to 1973 was marked by a 21% decrease in sediment load which is equal to the over-all change noted from 1880 to 1973.

Dr. Kesel is professor of geomorphology in the Department of Geography and Anthropology at Louisiana State University. His main interests are in fluvial geomorphology with particular interest in the Mississippi River and tropical rivers in Central America.

Dr. Kesel received his BS in geology and geography from E. New Mexico University, an MS degree in geography from the University of Nebraska, and his Ph.D. in geography from the University of Maryland.

Marsh Sediment Accretion Rates in Vicinity of Man-Made Canals and Natural Waterways

Dr. Donald R. Cahoon,
Mr. Ronald D. DeLaune,
Dr. Ronald M. Knaus
and Dr. R. Eugene Turner
Louisiana State University

PROJECT HISTORY

More than 50 square miles of Louisiana's coastal wetlands are disappearing annually due in large part to the sinking and deterioration of interior wetlands (i.e., that portion of the marsh beyond the edge of natural streams). The rate of submergence of these wetland areas is directly linked to the ability of land building processes (organic matter and mineral matter accumulation) to keep pace with the present rate of sea level rise (i.e., sea level is rising faster than the marsh surface is aggrading). It has been suggested that the canals may exacerbate the aggradation deficit by altering local hydrology and thus affecting the accumulation of organic and mineral matter.

The purpose of this two-year study is to evaluate canal impacts on sediment accumulation and vertical accretion in Louisiana's coastal marshes. Analysis of the results will be coordinated with those of other investigators studying the impact of canals on organic matter accumulation through the effects of salt water intrusion (Drs. Mendelssohn, Wang, and Wiseman) and the influence of historic changes in Mississippi River sediment supply on marsh building rates (Dr. Kesel).

Rates of sediment accumulation and vertical accretion are being measured in back marsh areas behind OCS pipeline canal spoil banks, oil and gas access canal spoil banks, and natural streambanks. Both recent and long-term sedimentation rates are being analyzed by three techniques. Recent sedimentation rates are being evaluated by two-marker techniques, using inert clay and inert rare earth stable isotopes. These methods give reliable estimates of sediment deposition during the immediate past, with the clay best suited for fresh marshes. Long-term vertical accretion rates are being determined by ^{137}Cs and ^{210}Pb analysis of soil cores, which provide a 25-year and 100-year integrated annual accretion estimate, respectively. Whenever feasible, all three techniques are used together at a site.

The field work has been designed to compare sedimentation rates behind canal spoil banks to rates behind natural streambank levees. To do this, sediment markers were placed in the marsh 50m behind the natural or man-made levee. Whenever feasible, small wooden platforms were constructed for this purpose (with appropriate controls) in order to minimize disturbances to the marsh surface during marking. Also, the influence of canals on sediment distribution and vertical accretion across the marsh is being investigated at selected sites by sampling every 10m along a 50m-125m transect beginning immediately behind the natural or man-made levee. Sedimentation rates are being analyzed in impacted salt, brackish, and fresh marshes along the coast, including both the Mississippi River Deltaic and Chenier Plains. A list of the comparisons we are testing, along with the marsh type and technique used, is attached (see Table 2.5).

ACCOMPLISHMENTS

We are now completing the first year of this two year study. During this time, we have established the goals of the study, finalized our experimental design (see list of comparisons), and completed site selection. Marking and coring commenced this past summer and will be completed by next month. Sample collection and analysis is ongoing and will continue through next summer.

SIGNIFICANT FINDINGS

Because data collection and analysis is ongoing, it is too soon to draw significant conclusions from this study. It should be noted, however, that all three techniques are well suited to this analysis, give reliable data, and are working as expected.

RECOMMENDATIONS

For the reasons noted above, it would be premature to make recommendations on preliminary results at this time. However, we strongly recommend the experimental approach used in this study -- a coordinated field effort using different techniques with overlapping applications. This provides a broad experimental base for data interpretation and reinforces the value of the data. Also, we recommend that additional investigations of vertical accretion be done to evaluate the impact of other man-made alterations of the coast.

Dr. Donald R. Cahoon is an Assistant Professor of Research at the Coastal Ecology Institute, Center for Wetland Resources, Louisiana State University. He is the Associate Manager for Science for the MMS contract on potential habitat alteration in the coastal zone. His interests include resource management, wetlands ecology, primary production processes, and education. Dr. Cahoon received his M.S. and Ph.D. degrees from the University of Maryland.

Mr. R. D. DeLaune is an Assistant Professor in the Laboratory for Wetland Soils and Sediments at Louisiana State University. He has conducted research dealing with factors controlling marsh formation and deterioration in coastal wetlands. He is an author of over 70 publications and has been instrumental in applying 137Cs and 210Pb dating techniques for use in developing a better understanding of coastal processes along the Louisiana Gulf Coast.

Dr. Ronald M. Knaus is an Associate Professor of Nuclear Science in the Graduate School of Louisiana State University. He has developed two methodologies crucial to the study and ageing of the very recent flocculent materials found in marshland sediment. First is a cryogenic coring device that preserves the stratigraphy of sediment and the second is a stable tracer methodology to label sediments as they form at the water-sediment interface.

Dr. Knaus received his BA and MS degrees from San Jose State University in biology and science education, respectively. He received his Ph.D. in radiobiology from Oregon State University.

Dr. R. Eugene Turner is a Professor of Marine Sciences in the Center for Wetland Resources, Louisiana State University. He is Program Manager for the MMS contract on habitat modification in the coastal zone. His interests include wetland management, mitigation and restoration, biological oceanography, and fisheries ecology. Dr. Turner received his Ph.D. from the University of Georgia.

Sea Level and Subsidence

Dr. Joseph N. Suhayda
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This task is concerned with determining an absolute sea level datum for the Louisiana coast for this century and assessing the impact of fluid withdrawal on subsidence. There is an experimental and a theoretical component to this task. The experimental component uses existing data on relative sea level rise (RSL) and data on ground subsidence to derive estimates of absolute subsidence. Sea level in the Gulf of Mexico has been rising at an average rate of about 3.3 mm/yr for the last 50-60 years, with a marked increase during the decade of 1963 to 1972, when it rose about 100 mm (10 mm/yr). Data on RSL, reported by the Louisiana Geological Survey indicates an average rise of about 5.2 mm/yr over the period 1942 to 1982, with a marked increase during the decade of 1963 to 1972, when RSL rose about 300 mm (30 mm/yr). These are independent data sets and suggest that even with the limitations of this data set, an average subsidence rate of about 2 mm/yr has occurred over the last 40 years, with decade maximum rates being as high as 20 mm/yr. Comparisons with subsidence measured at Galveston indicate Louisiana has similar rates (5 to 7 mm/yr), but are much less than the maximum rates observed in the Houston area of 300 mm/yr. A suggested sea level curve for coastal Louisiana is presented and discussed.

The theoretical model being used to estimate subsidence due to fluid withdrawal, called the spherical-tension model, is discussed. Using the model and the known subsurface geotechnical properties of Louisiana coastal sediments, preliminary conclusions indicate that compaction of the upper few hundred meters of sediments is primarily responsible for the surface subsidence and not fluid withdrawal from deeper reservoirs. The model also predicts that compaction rates for sediments will be different from subsidence rates by factors of 1.5 to 2.

Dr. Joseph N. Suhayda is an Associate Professor of Civil Engineering, Louisiana State University. He received his Ph.D. in 1972, Scripps Institution of Oceanography, University of California, San Diego. Dr. Suhayda's research area of interests include coastal processes, coastal engineering and marine geotechnics. He has published over 30 journal articles, book chapters and conference proceedings. Dr. Suhayda has been a graduate committee member on 31 M.S. and Ph.D. committees, and major professor for 8 M.S. and Ph.D. students. He teaches in the Department of Marine Science and Civil Engineering; he has developed courses in gravity waves, sediment dynamics, coastal engineering and marine geotechnics; and he has conducted coastal field studies in Louisiana, Florida, California, Alaska (north slope) and Washington in the United States, and in Grand Cayman, Barbados, Brazil, Germany and China. Dr. Suhayda is a consultant to USGS, U.S. Naval Oceanographic Office, several major oil companies and oil service companies, and to several state agencies and local governments in Louisiana.

Computerized Analysis of Spatial Trends in Wetlands Loss in Louisiana

Mr. Scott G. Leibowitz,
Dr. John M. Hill
and
Ms. Elaine E. Parton
Louisiana State University

High resolution, digital imagery are being used as part of a study to assess the impacts of OCS activities on wetland loss in coastal Louisiana. Habitat maps for 1956 and 1978, produced by Coastal Environments, Inc., of Baton Rouge and digitized by the U.S. Fish and Wildlife Service at Slidell, La., were obtained for three specific study areas: (1) the Lafourche study area is located to the east of Bayou Lafourche, a distributary that was recently (ca. 400 years before present) abandoned by the Mississippi River; (2) The Terrebonne study area lies adjacent to the Atchafalaya River. This is the most recent of the Mississippi distributaries, and currently captures 30% of the system's flow; (3) the Cameron study area, in the western part of the state, is outside of the direct influence of Mississippi delta-building processes. Sediments in this region are either reworked from old, abandoned Mississippi deltas, or deposited by local rivers. The three study areas were chosen so that different geological environments would be presented.

Preliminary analyses have been performed on the Terrebonne and Cameron study areas. Fresh marsh is the most abundant habitat in the Terrebonne area, accounting for nearly 470 sq. km, or 40%, of the study area. Saline marsh accounted for 326 sq. km in 1956 (28%). Between 1956 and 1978, the area experienced a net land loss of 97 sq. km. Total land loss was actually higher, however, since this value was partially offset by land-building processes such as the emergence of the Atchafalaya delta in 1973. By 1978, 14% of the 1956 land was lost. Loss of fresh marsh accounted for 66% of this value, with saline marsh accounting for 29 percent. Rates of loss for fresh and saline marsh (loss as a percent of 1956 habitat area) were 18 and 11%, respectively.

The Cameron study area, in contrast, is dominated by saline marsh, containing over 246 sq. km, or 48% of the study area. Fresh marsh accounted for 116 sq. km (23%) in 1956. This study area experienced a net loss of 70 sq. km in the 22-year period. Of the original 1956 land, almost 17% was converted to water by 1978. Saline marsh accounted for nearly 75% of the total loss in Cameron, with fresh marsh accounting for the remaining 25 percent. Loss rates for saline and fresh marsh were 23 and 16% of their respective 1956 habitat area. Loss rates for fresh marsh were therefore similar for both study areas (16-18%), whereas loss rates for saline marsh were twice as high in Cameron.

For both study areas, conversion of land to inland open water was the major form of land loss (72 and 93% of all loss for Terrebonne and Cameron, respectively). In Terrebonne, conversion of land to canal and pipeline or loss due to expansion of natural channels accounted for 10-15% each, with shoreline erosion accounting for only 2 percent. In the Cameron area, conversion to canal and pipeline, expansion of natural channels, and shoreline erosion each accounted for 2-3% of all loss. Thus, expansion or creation of new ponds and lakes in the dominant cause of land loss in both of these study areas.

The Cameron data set was analyzed to determine whether canals and pipeline contribute to land loss. It was hypothesized that if canals and pipelines are a cause of land loss, then loss rates adjacent to these features should be higher than rates far from them. To test this, a proximity analysis was performed, with percent land loss plotted as a function of distance to natural channels. It was found that loss rates increase from 11% at 1 km from canal and pipelines to 39% percent at 100 m (Figure 2.8). Beyond 1 km, the rate becomes random. For natural channels (rivers, streams, and bayous), the opposite trend was found: loss rates decreased from 34% at 1 km to less than 10% at 100m (Figure 2.9). This is consistent with our understanding of how natural channels contribute sediment to adjacent land, stabilizing it and making it less prone to loss.

In the near future, the proximity analysis will be carried out on the Terrebonne and Lafourche data sets, in order to determine whether geologically varied areas give similar results. In addition, canal and pipelines will be separated into OCS and non-OCS categories, to see whether this has any effect. Initial results seem to indicate that this type of proximity analysis will allow the separation of natural causes of land loss from man-made factors.

Mr. Scott G. Leibowitz and **Ms. Elaine E. Parton** are both Research Associates at the Center for Wetland Resources at Louisiana State University, Baton Rouge. **Dr. John M. Hill** is an associate professor in the Department of Civil Engineering at LSU. All three are associated with LSU's Remote Sensing and Image Processing Laboratory.

Patterns and Rates of Marsh Loss on the Eastern Shore of Chesapeake Bay

Dr. J. Court Stevenson
and
Dr. Michael S. Kearney
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The Chesapeake Bay contains about 125,000 hectares of tidal wetlands, with 38% consisting of brackish marshes which have formed over recently submerged upland terraces and 35% existing in estuarine meanders of major tributaries. The latter, plus the tidal-freshwater marshes (comprising another 21% of the tidal wetlands) were thought to be stable if not aggrading in Chesapeake Bay due to accelerated sedimentation after settlement. The first indication that wetland loss might be a significant problem in Maryland was found in the extensive submerged upland marshes on the eastern shore.

At Blackwater National Wildlife Refuge 3800 ha of marsh was converted to open water from 1938 - 1979. Although the period of most accelerated marsh loss coincided with a very high population level of muskrat grazing which caused extensive "eat-outs," other factors such as periodic burning and hydrological alterations also seemed important in triggering the marsh decline. For example, the rate of vertical accretion (measured by lead-210 activity in sedimentary horizons) upstream of the road which had been constructed across the center of Blackwater marsh was less than ~ 4 mm/yr apparent sea level (ASL) rise in this region. In contrast, the accretion rate of at least one major marsh downstream seemed to be keeping pace with ASL. The accretion differences were correlated with reduced sheet flow across the marsh surface which promoted waterlogging upstream. Low nitrogen content of marsh plants suggested that nutrient uptake by roots was inhibited by extended periods of submergence when redox in soils was low. As marsh productivity decreased at Blackwater marsh, extensive burning and muskrat activity exacerbated losses by consuming in situ carbon production, resulting in the formation of bare spots which became shallow ponds.

Once the marsh mat became fragmented in the Blackwater system and the underlying unconsolidated ooza layer was exposed, the marsh became increasingly susceptible to wave erosion. Once the ponds were formed, the depressions deepened and elongated in the direction of the prevailing winds (NW-SE), indicating that wave activity became a dominant erosive force in this system. This erosion in the interior ponds has formed large portions of open water and leads to as much as 14 Kg/m^2 of sediment being exported per year from Blackwater NWR. Measurements of sediment input from two upstream tributaries did not come close to balancing the net export downstream which is a strongly "ebb dominated" tidal channel. We speculate that this "ebb domination" may be associated with the hydrological constriction of the Blackwater marsh system which induces a tidal jet after storm surges. Thus, major storms such as hurricanes (two of which did extensive damage in 1933), appear to exacerbate erosion of sediments in the Blackwater River. Thus, hurricane effects in Maryland are opposite of those hypothesized for Louisiana marshes.

Shortly after the Blackwater study was complete, the metal accumulation potential of marshes along a major estuarine tributary was studied along the Nanticoke River, a system where no wetland losses were previously reported. Accretion rates were determined using radiometric ^{210}Pb activity plus pollen dating and varied from 1.8 to 7.4 mm/yr. As is the case in Louisiana, highest accretion rates were found on the channel margins in upstream levee marshes, whereas the downstream interior marshes in the Nanticoke Estuary have very low sedimentation rates. The latter marshes are similar to Blackwater (i.e. submerged upland marsh type) and appear to be sediment starved since they are distant from potential sources of sediments (i.e. farmland, eroding shorelines, etc.). The tendency for progressive marsh losses downstream was confirmed by detailed comparison of aerial photography taken in 1938 (Figure 2.10) and 1985 (Figure 2.11). Surprisingly, several estuarine meander marshes appear to be declining in the vicinity of Vienna, midway up the Nanticoke. This observation was verified by local muskrat trappers who have abandoned trapping several marshes because they have been deteriorating so rapidly that they are now too unconsolidated to maintain traplines.

Further historical analysis of the creeks of meander marshes was carried out using U.S. Geodetic Survey charts from the late 1800's. This analysis reveals an interesting variation of open water formation involving not interior pond coalescence, but progressive opening up at the head of tidal channels in meander marshes of the Nanticoke Estuary. Also, tidal channels appear to change course and widen considerably over time in this system. Thus the pattern of marsh loss now appears different upstream and downstream in the Nanticoke Estuary. Since this estuary has no significant modification in hydrology, the 50 hectare/yr marsh losses appear to be the result of increasing sea level and possibly sediment starvation due to restrictions in inputs over the last 50 years. We hypothesize that sediment inputs were significant in the 1800's due to maximum land clearing for agriculture, but reductions in agricultural land as well as sediment control practices (instituted over the last 50 yrs), have significantly reduced sediment delivery in this estuary.

In summary, the following appear to be common features of eroding marshes in the Chesapeake and Louisiana:

- Reduced sediments input to the estuarine system from upland sources.
- Low tidal energy with tidal amplitudes < 1 m.
- Most apparent deterioration appears in waterlogged backmarsh areas.
- Burning is carried out for management of muskrat

trapping.

- Salinities do not appear to be increasing dramatically, but there are episodic inputs of seawater (containing sulfates) during storm surges and hurricanes.

The significant difference between the marsh loss in these areas is the absence of extensive alterations due to canal construction and virtually no oil and gas extraction in the Chesapeake Bay region compared to Louisiana's deltaic system. This suggests that although hydrological alterations can be important (as at Blackwater) the overall processes of sediment starvation, coastline subsidence (due to compaction of underlying sediments), and accelerating sea level rise may be the fundamental driving mechanisms behind marsh losses in the Chesapeake Bay and Mississippi Delta regions.

Dr. Stevenson is currently an associate professor at the University of Maryland, Center for Environmental and Estuarine Studies, specializing in the ecology of submersed aquatic vegetation and wetland ecosystems. He received his B.S. in biology from Brooklyn College, his M.S. from the City University of New York, and his Ph.D. in botany from the University of North Carolina at Chapel Hill.

Dr. Kearney is currently an Assistant Professor in the Geography Department at the University of Maryland, College Park Campus, specializing in coastal geomorphology. He received his B.S. in geology from the University of Illinois at Urbana and his Ph.D. from the University of Western Ontario in Canada.

Marsh Management Needs and Myths in Louisiana

Dr. R. Eugene Turner,
Dr. Donald R. Cahoon
and
Dr. James H. Cowan, Jr.
Louisiana State University

Successful marsh management and reduction of the present high land-loss rates in coastal Louisiana are often difficult, occasionally possible, and explicitly sought by almost everyone involved in the management of Louisiana coastal wetlands. But, compared to other natural management sciences such as fisheries or water pollution control, we have relatively little experience addressing this complex issue with such broad economic, social and political consequences. For example, it has been less than 10 years since the high land-loss rates (50 sq. miles per year) were revealed, since wetland scientists begun to understand how wetlands began to be established. The problems have appeared quickly and there is a meager detailed scientific basis for understanding what has caused these land-loss problems and an even shallower basis to support meaningful actions. Thus, our experience is limited, the database is smaller, and we are on a collision course with reality as the Louisiana coastal resources diminish at about 0.8% annually.

Decisions will be made, of course, even if the information base is inadequate. It is our contention and plea that we should continually examine the assumptions underlying these decisions. Though most would agree this is a prudent course in theory, it is not obvious in practice nor are the consequences or not doing so trivial.

There is an old geologist's saying: "I would not have seen it if I hadn't believed it." This quote reminds us of how easily our perceptions of reality are not, in fact, completely accurate, they may even be false. Science serves society by continually reestablishing what some of the facts are and leaving the choice of several alternatives to resource managers. Both managers and scientists are only human, and so mistakes often occur. Scientists have the luxury of completing additional experiments to further test conclusions and perceptions; managers are often stuck with irreversible and strenuous decisions. Whether we are scientists interested in management issues or managers eager for a scientific groundwork for making decisions, our assumptions influence what we conclude in ways not always evident. Misinterpretations or beliefs that are unsubstantiated by facts (assumptions) may be called myths, even if true, and everyone, except saints (perhaps), has their share of myths. If we allow these myths to influence management practices without acknowledging them for what they are, management decisions may be even more difficult, more expensive, and less workable. We reviewed two examples of this (shrimp and canal dredging), and then discussed some marsh management assumptions we think need further study.

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Dr. Donald R. Cahoon is an Assistant Professor of Research at the Coastal Ecology Institute, Center for Wetland Resources, Louisiana State University. He is the Associate Manager for Science for the MMS contract on potential habitat alteration in the coastal zone. His interests include resource management, wetlands ecology, primary production processes, and education. Dr. Cahoon received his M.S. and Ph.D. degrees from the University of Maryland.

Dr. James H. Cowan, Jr. is a Research Associate in the Coastal Ecology Institute, Center for Wetland Resources, Louisiana State University. He has recently completed an evaluation of marsh management plans in the Louisiana coastal zone for use by the U.S. Environmental Protection Agency. This work is part of his general interest in fishery recruitment and the transport implications of semi-impounding wetlands as a management practice.

Dr. Cowan received his B.S. and M.S. in biology and marine biology/ichthyology, respectively, from Old Dominion University in Norfolk, Virginia and his Ph.D. in marine science from Louisiana State University.

Mitigating the Impacts of Petroleum Industry Canals in Louisiana's Coastal Wetlands

Mr. David W. Fruge
U. S. Fish and Wildlife Service

Oil and gas exploration and production activities conducted in Louisiana's coastal wetlands usually require permits issued by the (COE) under the authority of Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act. Under the authority of the Fish and Wildlife Coordination Act, the U. S. Fish and Wildlife Service (FWS) provides recommendations to the (COE) to mitigate the impacts of those activities on fish and wildlife resources. Most of the FWS's mitigation emphasis in coastal Louisiana is placed on vegetated wetlands, especially those that support migratory waterfowl, other migratory birds, estuarine fishery resources, and other fish and wildlife of federal interest.

Petroleum industry canals are a major source of wetland loss in coastal Louisiana. Directional drilling is often recommended in an effort to avoid or substantially reduce access canal dredging; however, use of this technology is sometimes technically or economically not feasible. When canal impacts cannot be avoided and are significant, the FWS recommends measures to minimize, reduce, rectify, or compensate for habitat damages.

Canal-related impacts can be minimized or reduced by reducing drilling slip width to the minimum size needed, using a spray dredge to avoid spoil bank formation, cutting gaps in spoil banks to facilitate water exchange, plugging or damming canals to reduce saltwater intrusion, using board roads instead of canals for access, and routing canals through open water instead of marsh.

In some cases, canal impacts can be rectified. Backfilling of canals is recommended when adequate material for that purpose is expected to be available. Loss of spoil bank volume prior to canal abandonment often makes this technique ineffective. Planting of spoil banks with oaks and baldcypress is sometimes recommended where canals are dredged in forested wetlands. Creation of marsh with spoil deposited in open water is occasionally recommended as a mitigation technique.

The FWS usually recommends that permittees compensate for the remaining unavoidable impacts of petroleum industry canals on wetlands. This usually includes implementing measures to reduce ongoing loss of existing wetlands, such as installation or repair of water control structures, plugs, or shoreline stabilization features. Excavation of crevasses to facilitate new marsh creation and mitigation banking is another option used to compensate for unavoidable wetland impacts. The FWS is working with Tenneco on a pilot mitigation banking project in Terrebonne Parish, Louisiana.

Mitigation of the ongoing impacts of the large number of existing petroleum industry canals is also needed. Comprehensive wetland management and freshwater introduction from the Mississippi and Atchafalaya Rivers offer the greatest promise in this regard. Two major freshwater introduction structures along the lower Mississippi River have been authorized by Congress and await construction. A third major freshwater diversion structure has been recommended by the COE, but will require Congressional authorization.

There is widespread recognition of the adverse impacts of canals on coastal wetlands, and a growing acceptance by the oil and gas industry of the need to mitigate those impacts. With continued cooperation among regulatory and advisory agencies and the oil and gas industry, we can continue to improve our effectiveness in mitigating the impacts of petroleum industry canals on Louisiana's coastal wetlands.

Mr. David Fruge is presently Field Supervisor for the Lafayette, Louisiana Field Office of the U.S. Fish and Wildlife Service's Division of Ecological Services. Fruge has been extensively involved in the evaluation of Federally funded and Federally permitted projects affecting coastal and inland wetlands in Louisiana. He has published several scientific and popular articles on wetland loss in coastal Louisiana, the implications of that loss to fish and wildlife, and measures that could be taken to reduce those losses.

Wetlands Loss: Mitigation of Impacts

Mr. Charles G. Groat
Louisiana Department of
Natural Resources

The State and Local Coastal Resources Management Act of 1978 calls for the multiple use of coastal resources and for the establishment of a proper balance between development and conservation in Louisiana's coastal area. Guidelines established to control permitting activities and conditions attached to permits are important tools in reducing adverse impacts and attempting to achieve the difficult balance.

Unavoidable impacts on wetlands do occur as a result of permitted activities. To mitigate these impacts, permit conditions commonly call for the applicant to do restoration work in areas previously impacted or to carry out projects to improve conditions in the project area. Minimizing adverse impacts of coastal resources development will require changes in guidelines and documentation, that the benefits accruing from developments of wetlands for various uses, outweigh the negative economic impacts that result from destruction of wetland ecosystems.

The state has enacted a coastal protection program to implement projects designed to reduce coastal land loss.

Mr. C. G. Groat is State Geologist and has administrative responsibility for the Louisiana Geological Survey, Coastal Management Division, and Coastal Protection Program, all in the Department of Natural Resources.

Mitigating Pipeline Emplacement Impacts: INGA Perspective

Mr. Michael Krone
Midcon Corp.

The preceding sessions on wetlands loss have generally focused on the hydrologic impact of exploration, production, and transmission canals on the direct conversion of wetlands to open water (estimated at 2% of total wetlands loss), as well as the indirect impacts of canals on wetlands loss (estimated at 30% and much higher). This presentation is geared to provide an Interstate Natural Gas Association of America perspective which includes five main points:

1. While canals have certainly had an impact, there are a number of other natural and man-induced factors which need to be considered when discussing wetlands loss. Each situation will be distinct; there is no one "cure-all" remedy.
2. The interstate transmission industry has, since the mid-1970's, used the push-pull method of construction for pipeline emplacement to minimize canal impacts. These new techniques reduce environmental impact to acceptable short-term levels.
3. The current lack of regulatory consensus concerning wetlands construction protocol is causing our industry problems in both acquiring permits and predicting future construction windows. The lack of research in this arena exacerbates the problem.
4. New marsh management plans to

mitigate wetlands loss are not well conceived because they focus on salt water intrusion models rather than subsidence, potentially causing more harm than good. Salt water intrusion has not been documented in the literature as yet, although it is referenced often.

5. The Gas Research Institute is initiating an extensive R/D program to improve the response of various wetland types (eg. fresh, brackish, and salt) to pipeline emplacement. The anticipated 5-year research effort has a funding level between one and four million dollars.

Industry, in concert with regulators and research institutions, will be taking a much closer look at the problem of wetlands loss in the near term. This concerted effort at understanding the extent of the problem will precede practical alternatives to slow down the erosion of our valuable wetlands.

Mr. Michael Krone holds the B.S. degree from the University of California and an M.S. degree in oceanography from Texas A&M. He has worked as an environmental analyst with United Gas Pipeline and as Research and Development Coordinator for Midcon. He is currently involved with the MMS Coastal Impacts Study and the proposed Gas Research Institute Wetlands Research program to improve recruitment response and construction protocol for various wetlands.

Mitigation of Environmental Impacts: A National Corps Perspective

Dr. Lloyd F. Baehr, Jr.
U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers Regulatory Program is guided by the definition of mitigation contained in the Council on Environmental Quality's Regulations for Implementing the Procedural Provisions of NEPA. These regulations describe five elements of mitigation including avoidance, minimization, rectification, reduction or elimination, and compensation.

The Corps considers mitigation throughout the public interest review process and does not view it in a stepwise manner. The Corps District Engineer normally is responsible for determining the type and extent of mitigation to be included as conditions to any permit.

Comments and accompanying recommendations from the various resource agencies are very important to the Corps in assessing and quantifying losses, and in determining the appropriate mitigation required.

Mitigation efforts may be required onsite or offsite. In many cases, the Corps requires project modifications to minimize adverse project impacts. Further mitigative measures may be required to satisfy legal requirements, including those related to the Section 404 (b) (1) guidelines and Endangered Species Act. Other mitigation measures may be required as a result of the public-interest review process.

The Corps continues to decline to use the public-interest review to require permit applicants to provide compensatory mitigation unless that mitigation is required to ensure that an applicant's proposed activity is not contrary to the public interest.

The Corps' forthcoming consolidated final regulations implementing the Section 404 program contain, for the first time, a section devoted to its mitigation policy. The policy statement is a compilation of existing Corps policy for mitigation in the regulatory program.

Dr. Lloyd F. Baehr, Jr. is presently with the Permits Unit at the U.S. Army Corps of Engineers, New Orleans District. He presently represents the Corps on the Regional Technical working group for the Gulf of Mexico Region of the Minerals Management Service.

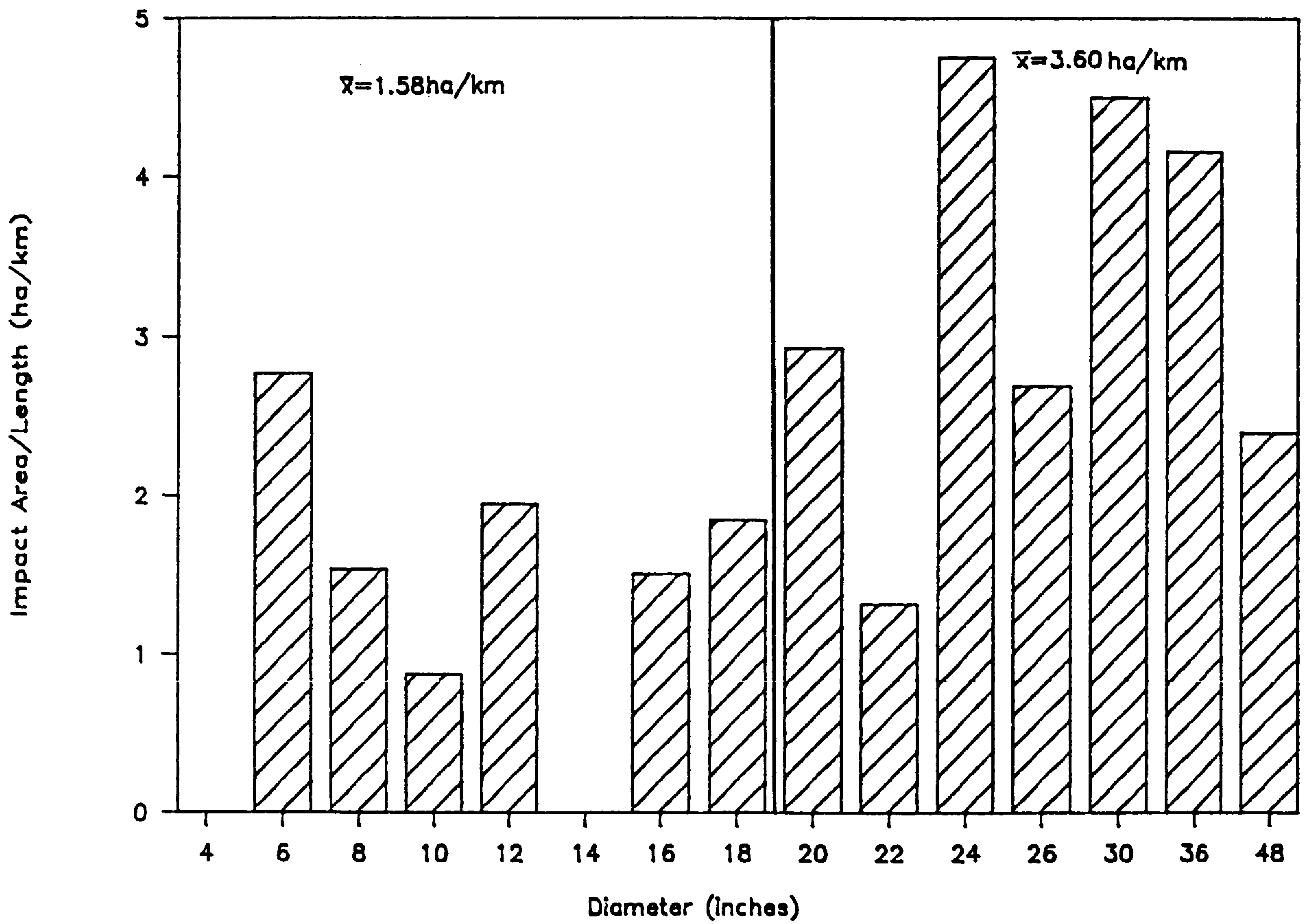

Figure 2.1.--OCS pipelines - direct impacts by diameter.

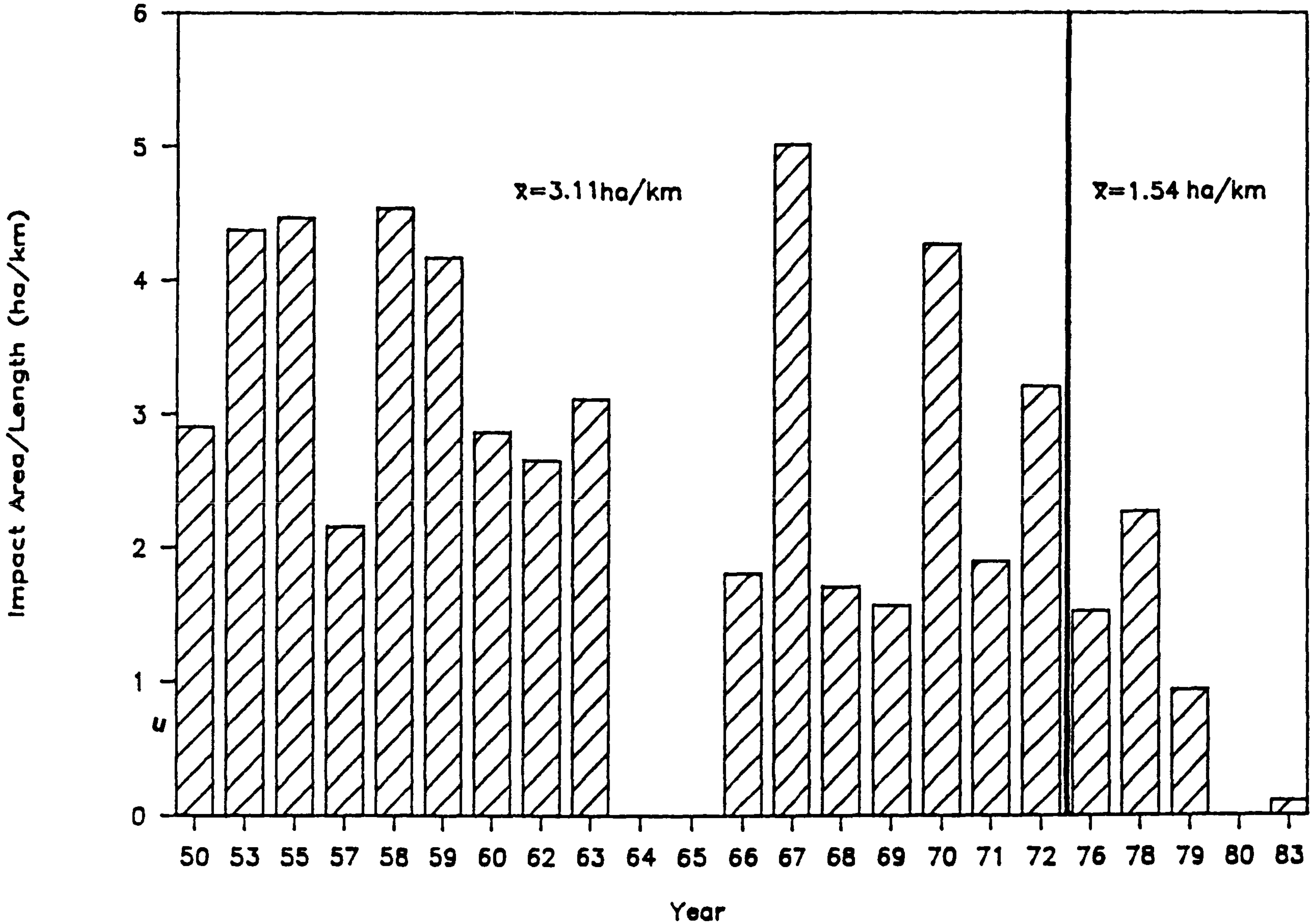

Figure 2.2.--OCS pipelines - direct impacts/time.

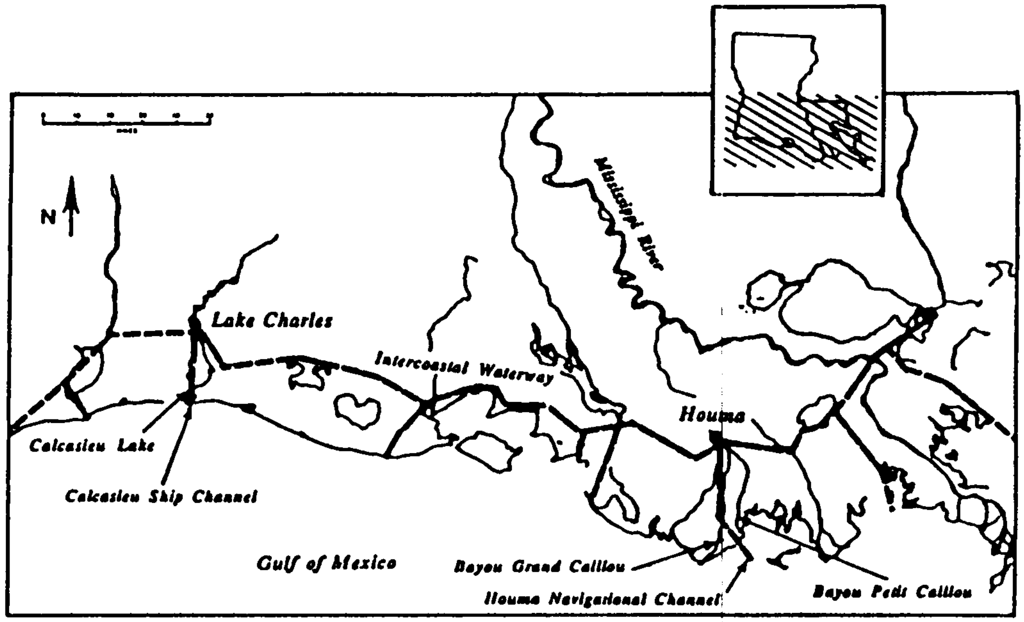

Figure 2.3.--Map showing the location of Houma Navigation Channel.

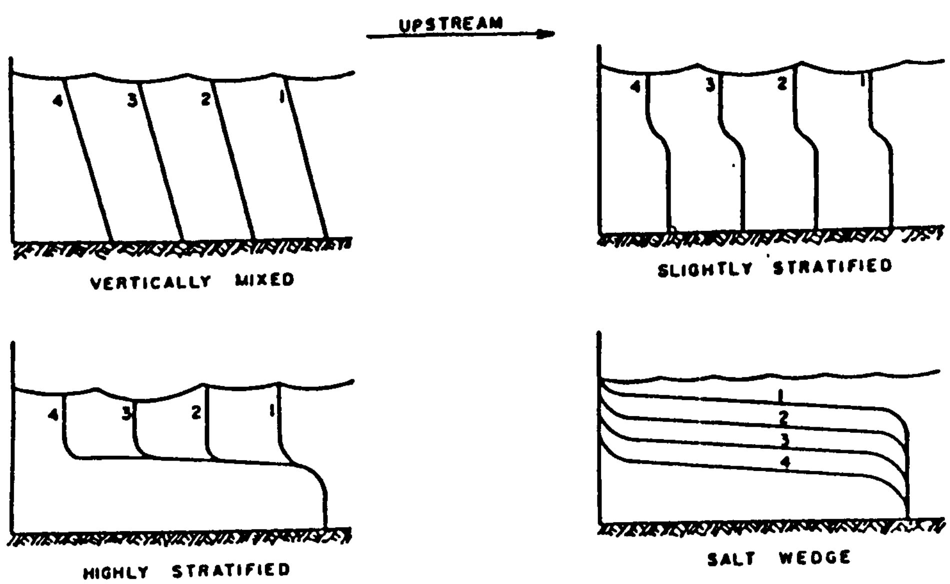

Figure 2.4.--Characterization of salinity profiles.
(Stommel and Farmer, 1953).

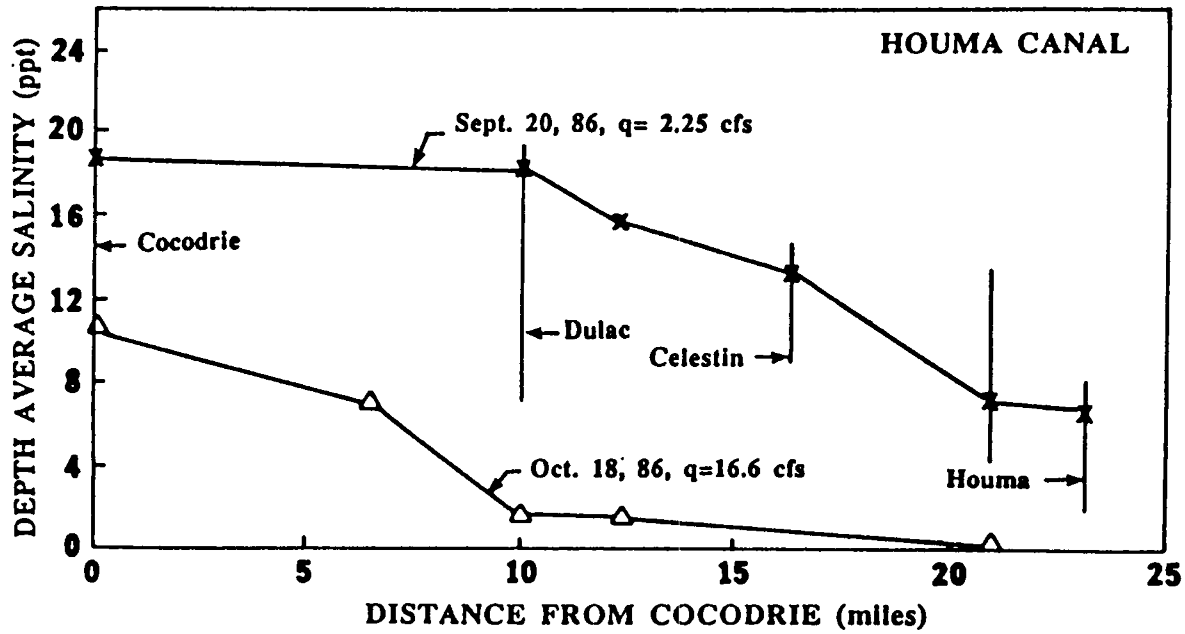

Figure 2.5.--Field measurement of salinity variations with the distance from Cocodrie (September 20 and October 18, 1986).

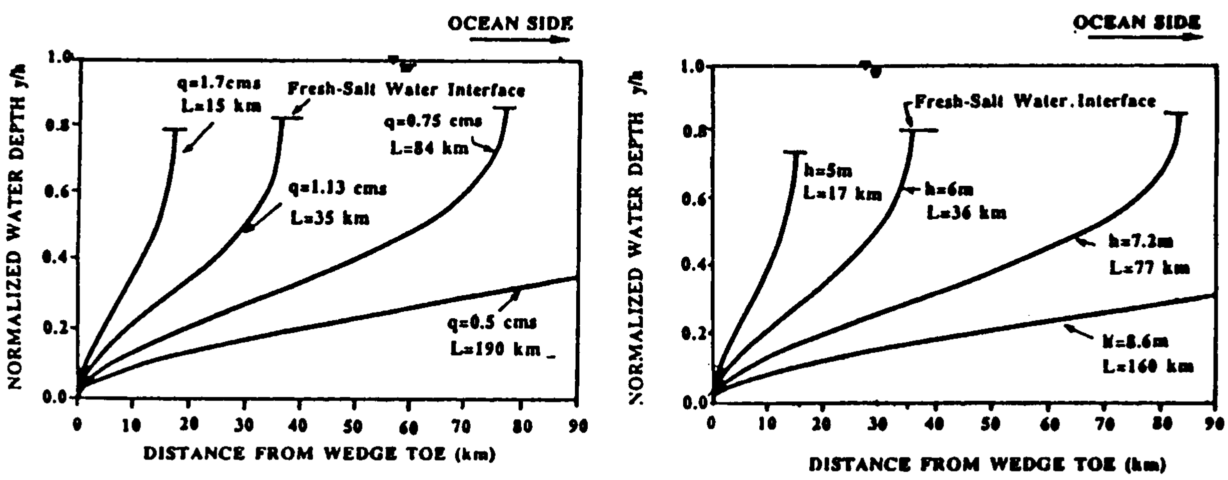

Figure 2.6.--Computed results showing the relationship of salt wedge length on the fresh water discharge and the channel depth.

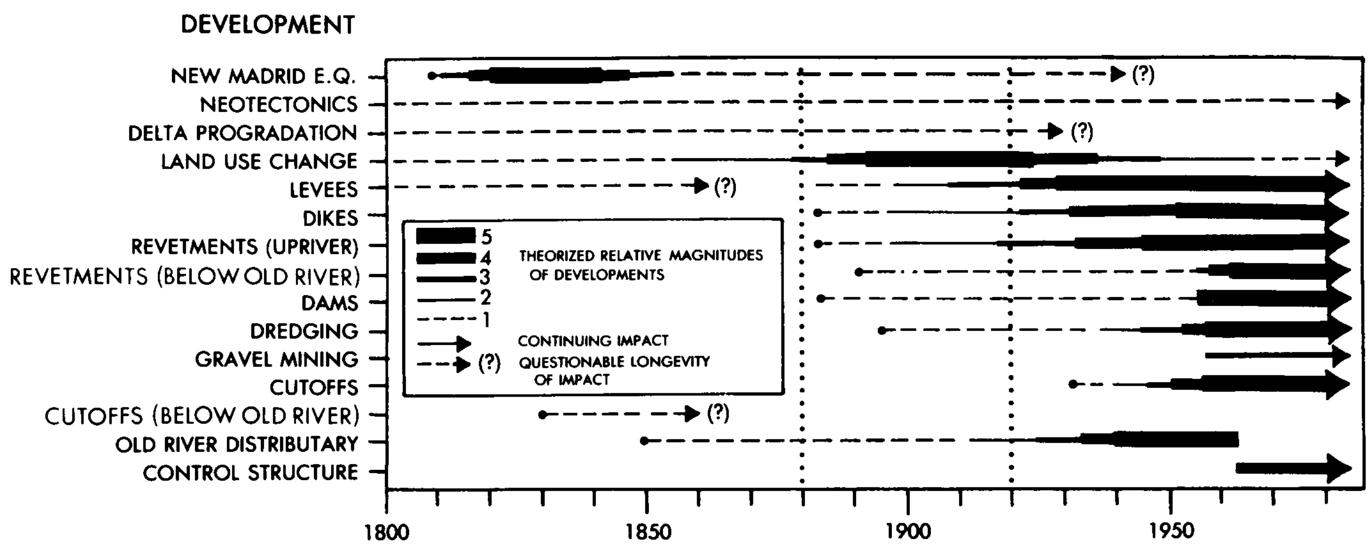

Figure 2.7.--Qualitative estimates of the magnitude of events that may have caused changes in sediment discharge of the Lower Mississippi River (prepared by R. Kesel, LSU).

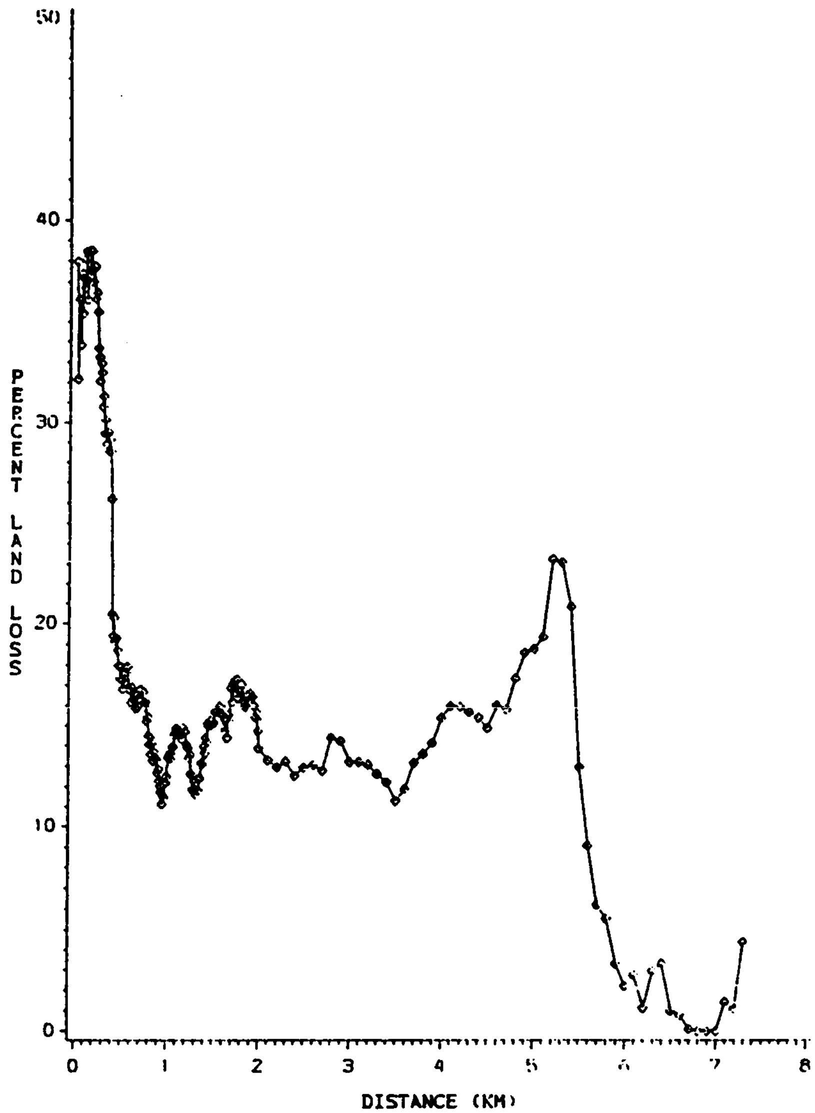

Figure 2.8.--Relationship between land loss and distance to canal and pipeline.

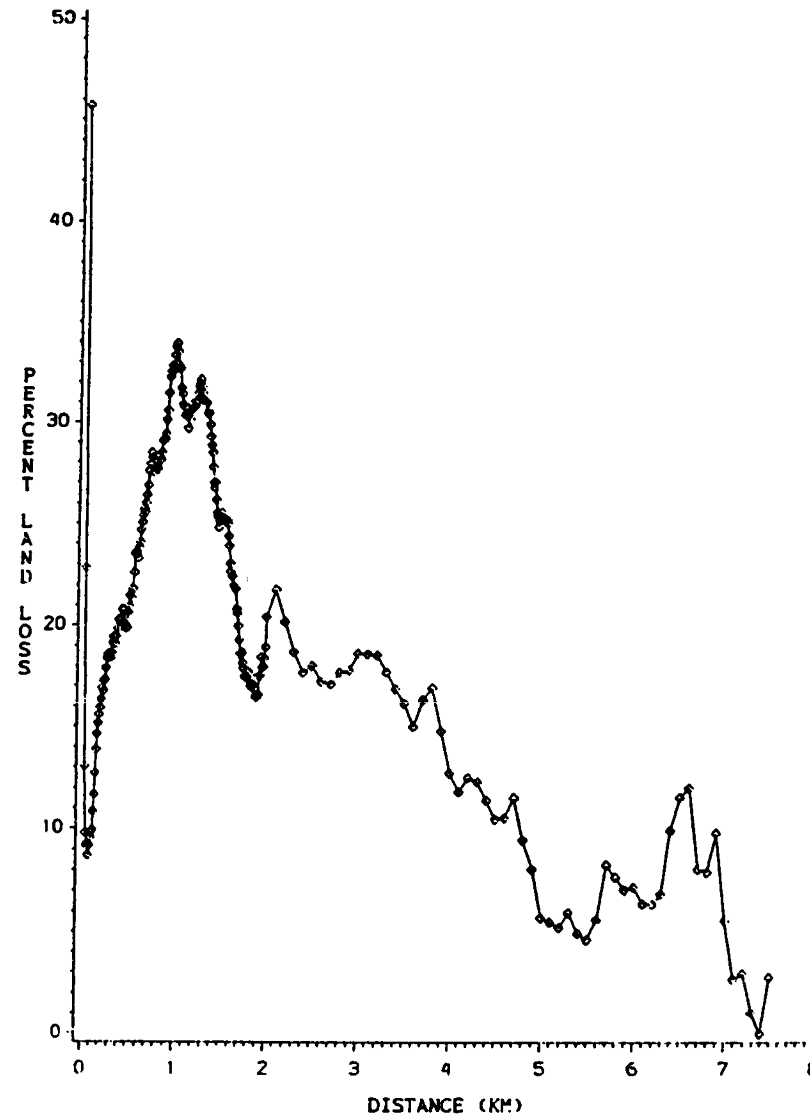

Figure 2.9.--Relationship between land loss and distance to natural channels.

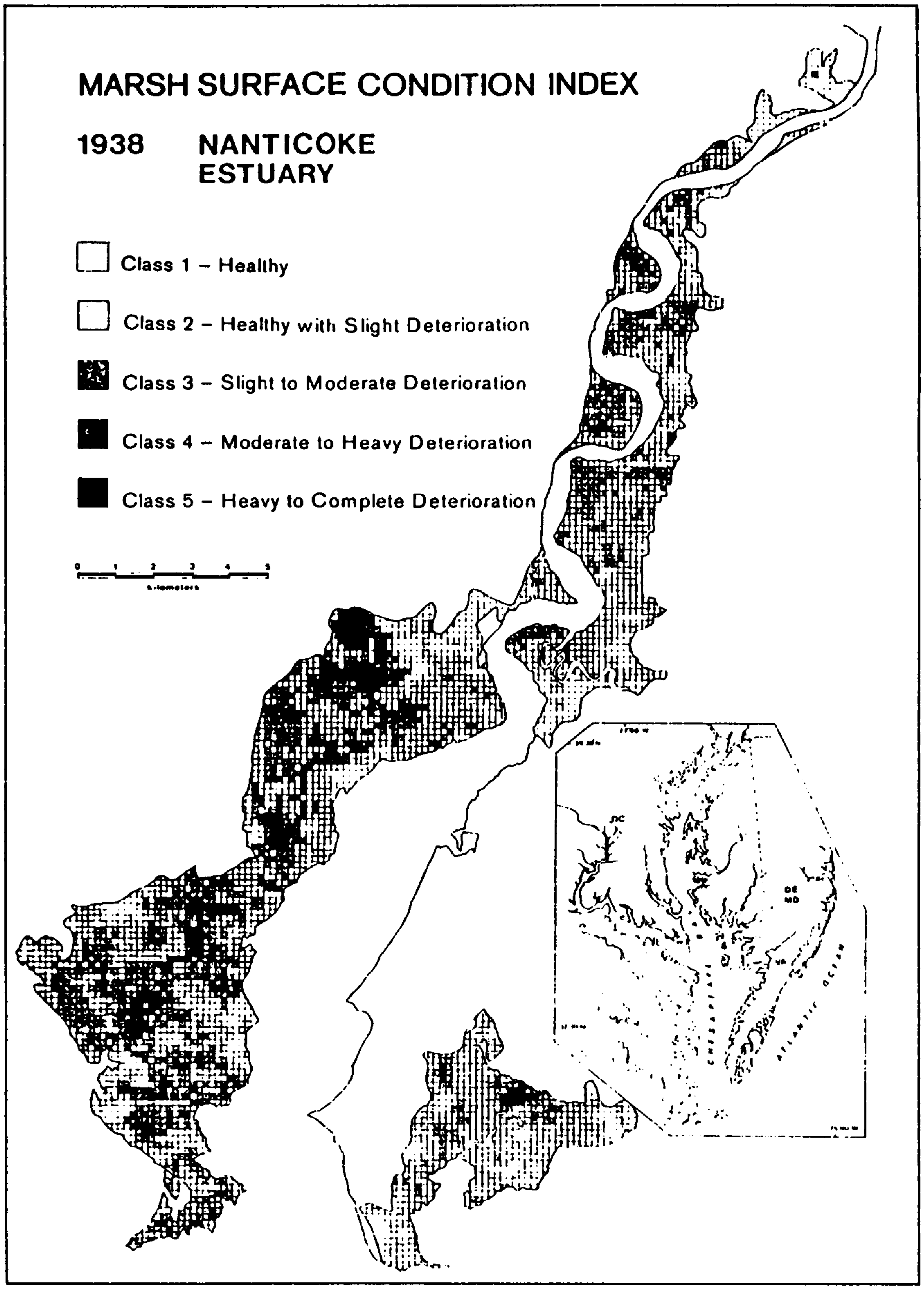

Figure 2.10.--Detailed aerial photography of Nanticoke Estuary in 1938 illustrating marsh area.

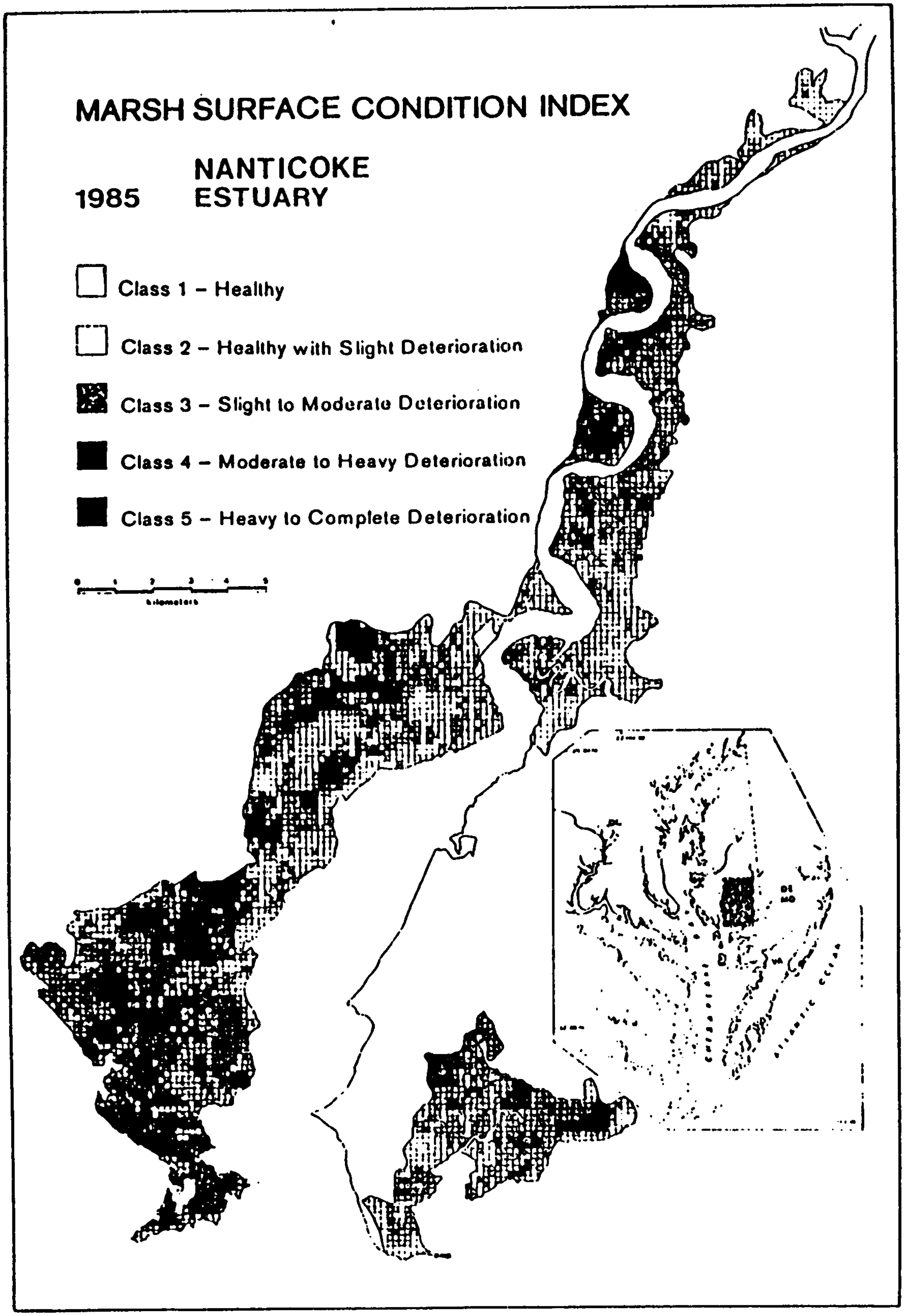

Figure 2.11.--Detailed aerial photography of Nanticoke Estuary in 1985 illustrating progressive marsh losses downstream.

Table 2.1

OCS Pipelines - Total Impacts - 79 Lines

	Length (km)	Area (ha)
Canal	1473	2973
Spoil	355	1373
Facilities	7	12.7
TOTAL	1480	4358

Avg. Impact Area Per Unit Length = 2.95 ha/km

Prorated Total Length = 4,868 km

Prorated Total Area = 14,336 ha (53.76 mi2)

Table 2.2

OCS Pipelines - Direct Impacts by Habitat

Habitat	Length (km)	Area (ha)	ha/km
Dune/Beach	2.2	0.4	0.2
Salt M.	278	1409	5.1
Brackish M.	160	651	4.1
Intermediate M.	118	540	4.6
Fresh M.	224	1134	5.1
Forested Wetlands	109	475	4.4
Open Water	454	111	0.2
Non-Wetland	132	3.4	<0.1
Spoil	2.4	33.3	13.7
TOTAL WETLANDS	890	4,210	4.7

Table 2.3

Number of Data Records (stations) of a Given Length (in years) of the Data Sources. The record length is defined as: (ending data)-(starting date). This table does not reflect reduced lengths due to gaps in the records.

Record Length	3	8	13	18	23	28	33	38	43	48	53	>55
LDWF (Salinity)	6	3	2	4	0	1	0	0	0	0	0	0
COE (Salinity)	3	2	5	5	7	7	8	1	0	0	0	0
USGS (Flow)	0	0	1	1	2	2	0	0	4	6	0	2
NCDC (Weather)	0	0	0	0	1	0	0	1	0	0	0	0

Table 2.4

Mississippi River Point Bar Volume Changes Cairo to Memphis

	1911	1948	1963	1973	1880-73
$ft.^3 x 10^8$	86.66	-77.18	-23.24	-33.96	-57.52
% change	32	-22	-8	-13	-21

change from 1984 to 1973 = - 21%

Table 2.5

Backmarsh Sediment Distribution Comparison

Comparison	Marsh Type	Sediment Marker
Behind Natural Levee *vs* Continuous Spoil Levee	Salt	Clay, Chemical
	Brackish	Clay, Chemical
	Fresh	Chemical
Transect Analysis Behind Natural Levee *vs* Spoil Levee (0-10-20-30-40-50 m)	Salt	Clay, ^{137}Cs
	Brackish	^{137}Cs
	Fresh	Chemical, ^{137}Cs
Transect Analysis Behind Pipeline *vs*	Salt	Clay, Chemical
Behind Natural Levee *vs* Discontinuous Spoil Levee	Salt	Clay, Chemical
	Brackish	Clay, Chemical
	Fresh	Chemical
Behind Continuous Spoil *vs* Discontinuous Spoil Levee	Salt	Clay, Chemical
	Brackish	Clay, Chemical
	Fresh	Chemical
Within Impoundment with Flow *vs* Impoundment Without Flow	Fresh	Chemical
Behind Natural Levee *vs* Within Impoundment	Fresh	Chemical

NORTHERN GULF OF MEXICO CONTINENTAL SLOPE PROGRAM

Session:	NORTHERN GULF OF MEXICO CONTINENTAL SLOPE PROGRAM
Co-Chairs:	Dr. Robert M. Avent Dr. Benny J. Gallaway
Date	November 4, 1986

Presentation Title	Speaker/Affiliation
Northern Gulf of Mexico Continental Slope Program: Session Overview	Dr. Robert M. Avent Minerals Management Service Gulf of Mexico OCS Region
Program Overview and Physical Setting for the Northern Gulf of Mexico Continental Slope Study	Dr. Benny J. Gallaway LGL Ecological Research Associates, Inc.
High Molecular Weight Hydrocarbons in Gulf of Mexico Continental Slope Sediments and Organisms	Dr. Mahlon C. Kennicutt II Texas A & M University Department of Oceanography
Bathymetric Distribution of Some Megafaunal Invertebrates and Fishes	Dr. Willis E. Pequegnat LGL Ecological Research Associates, Inc.
Hydrocarbon Seepage and Seep Communities on the Louisiana Continental Slope	Dr. James M. Brooks, Dr. Mahlon C. Kennicutt II, and Dr. Robert R. Bidigare Texas A&M University
Spatial Distribution Patterns in Chemosynthetic Communities.	Mr. Gregory S. Boland, Mr. Ian Rosman, and Dr. Joshua S. Baker LGL Ecological Research Associates, Inc.

Northern Gulf of Mexico Continental Slope Program: Session Overview

Dr. Robert M. Avent
Minerals Management Service

This session convened to review the most recent findings of the Minerals Management Service's (MMS) Northern Gulf of Mexico Continental Slope Study Program. The presentations covered the present state of knowledge of the Gulf from MMS-sponsored biological, sedimentary, hydrographic, and chemical investigations. This is an active four-year program designed to obtain a basic descriptive and reasonably synoptic view of the major features of United States waters in anticipation of future oil and gas development.

The deep Gulf has been generally viewed as moderately warm (>4°C), biologically depauperate, American Mediterranean Sea, and a zoogeographic extension of the Atlantic Ocean and Caribbean Sea. The northern Gulf of Mexico slope has three major physiographic components: the Louisiana-Texas slope and Sigsbee Escarpment to the West; the West Florida Slope and Escarpment to the East; and the Mississippi Fan or "Cone", off the Mississippi Delta. Relatively little abyssal plain exists, and the maximum depth of the Gulf (about 3800m) approximates the average world-wide ocean depth. The slope is incised by the Alaminos Canyon, the Mississippi Trough, and the DeSoto "Canyon".

The Gulf of Mexico has been one of the most poorly-studied of American waters, with the main body of biological information coming from historic cruises of the U.S. Steamer Blake in the last century, and much more recent cruises of R/V's Alaminos and Gyre of Texas A&M University and Pillsbury and Columbus Iselin of the University of Miami.

The rapidity of development of oil and gas reserves in deep waters is less a matter of available technology than likely economic return, and the encroachment of the industry onto the slope is no longer a dream but reality.

The presentations in this session were given by scientists of LGL Ecological Research Associates Inc. (LGL, the prime contractor) and Texas A&M University (TAMU, the prime subcontractor) of Bryan/College Station, Texas, under contracts 14-12-0001-30046 and 14-12-0001-30212, administered from the Gulf of Mexico Outer Continental Shelf OCS Region of MMS. Following a brief welcome, introduction, and review of program planning, Dr. Robert Avent introduced Dr. Benny Gallaway, LGL Program manager. He described program organization, structure, sequence of activities, and rationale. The principal investigators were organized under the Program Manager along with numerous consultants for program review, taxonomic assistance, and special topical assistance. The program evolved under advice from the Gulf of Mexico Deep-Sea Science Advisory Committee which periodically recommended the course of research. The four-year program (two at-sea, data-collection years, a third analysis year, and a final information synthesis year) first sampled three transects, one in each Gulf of Mexico MMS planning area (Cruises I and II). The central Gulf transect was then expanded to assess zonation across the slope (Cruise III). Cruises IV and V assessed the between-transect areas (West-Central and East-Central) at specific depths and known conditions of hydrocarbon contamination and topography. Cruise VI employed a research submersible to investigate the structure of remarkable chemosynthetic communities at oil seeps in the central Gulf. The data and samplings included benthic infauna and epifauna and sediments, hydrographic measurements, and benthic photography. Dr. Gallaway then described water-mass distribution across the slope and its relationship to previously published accounts of biotic zones and horizons. He followed with a sediment characterization (grain-size, organic carbon, and carbonate content) and photographic evidence of community structure and bioturbation. This presentation made depth and east-west comparisons, and set the stage for presentations to follow.

Dr. Mahlon Kennicutt (TAMU) followed with results of analyses of high molecular weight hydrocarbons (HMWHC) in sediments and representative megafauna tissues. Sediments contain an admixture of terrigenous, petroleum, and planktonic hydrocarbons, with relative compositions varying with location, water depth, sediment type, and time of sampling. The HMWHC concentrations in sediments were generally lower than previously reported. Variability along isobaths is at least as high as that on a given transect from the shelf to 3000 m deep. The HMWHC's values in animals were highly variable but dominated by presumed planktonically derived compounds. Crustaceans reflected lower amounts of HMWHC's than surrounding sediments (terrigenous plant biowaxes). Isolated cases of petroleum contamination may have reflected presence of tar in the trawls.

Dr. Willis Pequegnat presented an impressive suite of biological data and preliminary analyses resulting from the samples of large, mostly-motile invertebrates and fishes ("megafauna") obtained by one-to two-hour trawl tows across the slope. He presented tabular data giving one an appreciation of the high megafaunal species diversity of the slope. To date, 537 invertebrate and 149 fish species have been trawled up. But in perspective, these numbers pale in comparison with the infauna (about 1,000 species to date, many of which are new to science). Each cruise has added significantly to the number of species, and there is reason to believe that many species remain undescribed. Dr. Pequegnat argued in favor of the existence of predictable faunal zonation, referencing rates of faunal change with depth and displaying cluster diagrams which demonstrate station (and depth) similarities in faunal composition. Similar patterns exist for fishes and crustaceans. He invoked depth (pressure) and food availability as factors probably more important than currents, predation, and sediments, for example. He presented evidence for restricted depth distribution of numerous species of decapods and fishes from the eastern transects where stations were placed in a pattern crossing and along representative isobaths to test faunal depth fidelity. This presentation was restricted primarily to megafaunal species because several major infaunal taxa are still in an incomplete stage of identification and analysis.

The two papers which followed described unexpected chemosynthetic communities discovered first by TAMU researchers led by Dr. James Brooks in a region characterized by oiled sediments, oil and gas seeps, and gas hydrates. Under MMS direction and approval, the Slope Program established stations in these areas of contamination for further sampling and photography. After reasonably good success in capturing and photographing chemosynthetic animals, the research team was awarded a modification to pursue detailed studies using a research submersible. In addition, under an agreement with MMS, the Offshore Operators Committee (OOC) funded additional sampling in suspected seep areas, characterized by geophysical wipeout zones.

Dr. James Brooks (TAMU), in a presentation authored by him, Drs. M.C. Kennicutt, and R. Bidigare, reported the results of their research for the OOC which sprang from a working hypothesis that "where there are sufficient hydrocarbons and/or hydrogen sulfide seeps on the shallow slope, there are chemosynthetic organisms." In 39 trawls at "wipe-out" sites, chemosynthetic tube worms, clams, and mussels (or their remains) were found in 21, 10 and 4 trawls, respectively. Carbon isotope analyses of selected animals confirmed their chemosynthetic nature. Turrid gastropods demonstrated both chemosynthesis and heterotrophism. Examinations of mussel gills demonstrated the first known symbiosis between a methanotrophic bacterium and an animal. Piston cores taken at each site produced seven examples of oil staining. Subsequent joint work between TAMU and LGL using a submersible demonstrated dense chemosynthetic communities and massive oil and gas seepage in Green Canyon Block 185. This was described by Ian Rosman in the next paper jointly authored by G. Boland, I. Rosman, and Dr. J. Baker.

Mr. Rosman reported on fine-scale (10-100 m) observations of chemosynthetic communities on "Bush Hill," a small knoll at 550 m depth previously found to contain oiled sediments. Samples of sediment and organisms were periodically collected using samplers deployed on the four dives of the Johnson-Sea-Link submersibles. Videotape examination subsequently fixed the positions and abundances of dense clusters of the vestimentiferans, *Lamellibrachia* and *Escarpia*, and their associated diverse fauna. Beds of mussels existed in close proximity to continuous gas seeps. Bacterial mats overlay benthic accumulations of oil which bubbled upward when disturbed. An intriguing association between the bivalve *Acesta* and vestimentiferans was repeatedly observed, the former always located upon the latter, with the anterior end of the worm inserted into the clam's mantle cavity. Numerous other motile epifaunal species were observed and some collected. Two similar dives at another promising location (Green Canyon Block 234) yielded only sparse beds of Pogonophora and a single cluster of *Lamellibrachia* sp.

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

Program Overview and Physical Setting for the Northern Gulf of Mexico Continental Slope Study

Dr. Benny J. Gallaway
Program Manager, Gulf of Mexico
Continental Slope Study
LGL Ecological Research
Associates, Inc.

Beginning in 1983, the Gulf of Mexico Regional Office of Minerals Management Service (MMS) initiated a multiyear study of the continental slope of the northern Gulf of Mexico. The overall purpose of this program was to develop a basic knowledge of the components of the deep Gulf fauna, their environment and ecological processes in advance of pending petroleum development.

The scope of the program includes physical-chemical characterization of water masses overlying the bottom at depths between 200 and about 3000m; the sedimentary characteristics of the bottom; and the abundance, structure and distribution of the bottom-associated animal communities at these depths. The groups of animals being investigated include the meiofauna (infauna passing through a 300 micron sieve but retained on a 63 micron sieve), macrofauna (infauna retained on a 300 micron sieve), and the megafauna (organisms large enough to be captured in trawls or observed in photographs). The program also includes the charge to characterize present levels of hydrocarbon contamination in the sediments and selected biota in anticipation of petroleum resource development beyond the shelf-slope break.

STUDY AREA AND METHODS

Our sampling strategy was organized around three, five-station transects with one located in each of the three Gulf of Mexico Lease Planning Areas. Stations were located along each transect such that one was sited in each of Pequegnat's (1983) faunal zones found within the depth limits of the study: namely, the shelf/slope transition zone (150-450m), the archibenthal zone -- horizon A (475-740m), the archibenthal zone--horizon B (775-950 m), the upper abyssal zone (975-2250 m), and the mesoabyssal zone -- horizon C (2275-2700 m).

During Cruise I, the Central Transect was sampled, and each of the three was sampled on Cruise II. During Cruise III, the five original Central Transect stations were sampled once more and seven additional stations were sampled at depths that interdigitated those of the original station locations. The locations for the additional stations were chosen on the advice of the Science Advisory Committee (SAC) so as to collect information that would more precisely determine differences in physical, chemical, and faunal features that occur with depth.

On Cruises IV and V we sampled stations along depth contours in both the eastern and west-central Gulf to measure lateral variability in order to evaluate depth differences. Some of the stations were also paired to provide specific contrasts (e.g., seep areas versus non-seep; substrate differences, etc.). Cruise VI was only recently conducted to make observations from a submersible of chemosynthetic communities at hydrocarbon seep sites.

The field sample types collected were water column samples, box core samples of the bottom sediments, trawl samples of the megafauna, and benthic photographs of the megafauna and their environment. The box core samples were divided to provide material for identification of the biota, sediment grain size determination, hydrocarbon concentrations, and carbon isotope measurements.

RESULTS

With the exception of Cruise VI, all physical and chemical samples have been analyzed. All of the 648 meiofaunal samples have been completed. Overall, over 82% of macrofaunal samples are completed, with the major hold-up being the polychaetes. To date, some 1318 species of macrofauna have been identified, of which 530 are polychaetes. The megafaunal samples are completed, except for the dietary analysis of fishes collected on Cruises IV and V. These are nearing completion. Analysis of the 60 benthic photography transects are about 80% completed overall. Our target is to have all sample analysis completed and reported by the end of

December of this year. Actual completion may lag a month behind.

Water Masses

Physical and chemical characteristics of the water column can be used to identify specific water masses, which, in turn, may influence the composition and nature of biological communities. On the Gulf slope, three deep-water masses are present; Tropical Atlantic Central Water (~250-500 m), Antarctic Intermediate Water (~500-800 m), and Deep Gulf Water (>800 m). At least one historical, independent biological assemblage classification shows a rough correspondence between water mass distribution and the major groupings of animal communities. A Shelf/Slope Transition Zone was noted at depths of 150 to 450 m, the Archibenthal Zone was classified as lying between 475 and 950m, and the Abyssal Zone was believed to begin at about 975m. It is also at about this depth that temperature variation ceases. The vertical distribution of water masses appears rather uniform across the Gulf.

Sediments

Data from Cruises I and II provide comparative data for seasonal and regional differences. On Cruise I, bottom sediments collected at Stations C1, C2, and C3 were all comprised of clay-sized particles grading to sandy and/or silty clays at Stations C4 and C5. On Cruise II, five of the six samples collected at Station C1 were once more classified as clay, but at Stations C2 and C3 either all or most of the replicates were silty clays. Sediments taken at the deeper stations on the Central Transect (C4, C5) during Cruise II were again dominated by silty clays. Whether the differences in grain size composition observed for Stations C2 and C3 between cruises represents a seasonal affect or one of spatial variability is unknown. Based upon other data presented below, the former may be more likely.

On the Western Transect, sediments at Stations W1 and W2 graded from sand-silt-clay mixtures at W1 to sandy clays at Stations W2. Silty clay predominated at both Stations W3 and W4; but at Station W5, sediments were all sandy clay. On the Eastern Transects, sand-silt-clay mixtures were predominant at each of Stations E1 through E4. At the deepest Station, E5, two of the samples were comprised of sandy clay and one was sand-silt-clay. Sediments on both the Eastern and Western Transects, particularly the former, contained a higher proportion of sand-sized particles than was found on the Central Transect.

Levels of organic carbon in the sediments on the Central Transect were higher on Cruise II (April 1984) than on Cruise I (November 1983) with the degree of difference being least for Station C1. In general, organic carbon levels were slightly higher at the most shoreward stations along the transects, highest on the Central Transect at all sampling depths, and lowest on the East Transect at all sampling depths, except at the deepest station. The lower organic carbon levels on the East Transect were associated with higher percent sand/silt and carbonate-containing sediments.

Calcium carbonate levels in sediments at stations along the Central Transect were lower in the samples taken in November 1983 than in samples obtained from the same areas during April 1984. Central Transect levels were lowest of the three areas sampled, Western Transect levels were intermediate, and the Eastern Transect was characterized by sediments of high carbonate content.

Soft sediments predominated over most of the slope. They exhibit a high degree of biological reworking and activity. Only occasionally are megafauna observed, but burrows dot the bottom, suggesting a much higher than observed density of biota. Hard substrate is rare, but when present, unusual communities are sometimes in attendance. These will be discussed in subsequent papers.

CLOSING REMARKS

This paper was presented as a setting for the papers to follow. In summary, the deep Gulf is a dark, cold environment but perhaps not as uniform a habitat over time and space as one might expect.

Dr. B. J. Gallaway is President of LGL Ecological Research Associates, Inc. and an Adjunct Professor at Texas A&M University. Primary research interests lie in the field of population ecology and behavioral responses of fishes to environmental gradients. He is a member of the Reef Fish Scientific and Statistical Committee of the Gulf of Mexico Fishery Management Council. Dr. Gallaway holds a Ph.D. from Texas A&M University.

High Molecular Weight Hydrocarbons in Gulf of Mexico Continental Slope Sediments and Organisms

Dr. Mahlon C. Kennicutt II
Texas A&M University

Sediments on the Gulf of Mexico continental slope contain a mixture of terrigenous, petroleum, and planktonic hydrocarbons. The relative amount of these three inputs varies as a function of location, water depth, and time of sampling. The hydrocarbon concentrations measured are generally lower than those previously reported for shelf and coastal Gulf of Mexico sediments. The influence of land-derived material decreases from the central to the western to the eastern Gulf of Mexico. Low level petroleum inputs are considered to be a significant source of hydrocarbons to slope sediments. Hydrocarbon concentrations vary by 1-2 orders of magnitude along a given isobath due to changes in sediment texture and hydrocarbon inputs. Variability along an isobath is as great if not greater than that seen over a depth range of 300 to 3000 m along a single transect. In general, the highest aliphatic hydrocarbon concentrations were associated with the more clayish/organic-rich sediments. Aromatic hydrocarbons are below gas chromatographic detection limits at all sites (<5 ppb), but their presence is inferred from spectrofluorescence analyses confirming the presence of petroleum-related hydrocarbons at all sites.

Hydrocarbon levels in organisms were highly variable and were generally dominated by pristane, n-C_{17}, N-C_{15}, and n-C_{19}. This suite of compounds has a presumed source in planktonic debris. The tissues of demersal fishes contain predominantly planktonic derived hydrocarbons. Occasionally, crustaceans reflect the hydrocarbons of the sediments in which they live (terrigenous plant biowaxes) though, generally, this is dominated by the planktonic hydrocarbons. Only a few isolated cases of petroleum contamination in organism tissues were observed and these may be due to the large tar mats often recovered in the trawl samples.

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Bathymetric Distribution of Some Megafaunal Invertebrates and Fishes

Dr. Willis E. Pequegnat
LGL Ecological Research Associates, Inc.

Only a few years ago one would not have anticipated that a deep-sea study would uncover the very large numbers of benthic species that LGL investigators are now encountering. Fortunately, such discoveries have come at a time when computers are available to assist our analyses. Thus, with new and voluminous faunal data intended for use in LGL's third-year report on this project only now literally streaming off the computers, it is understandable that parts of this presentation will be tentative. Moreover, it must be evident that a study of the continental slope of the Gulf of Mexico with the broad scope of this one cannot even be capsulized in a brief presentation. Therefore, it is appropriate that I should limit my remarks to a single facet of the study, and it is understandable that the graphics will be simply rough, working documents.

The following discussion will apply only to the megafauna, including the fishes, that were collected in trawl samples. In Table 3.1, one can find reasons to appreciate the diversity of the deep-sea fauna. Here we note that we have thus far identified 537 species of invertebrates and 149 species of fishes. But two facts lend perspective to these numbers. First, this level of diversity is low compared with the macrofauna where over 530 species of polychaetes alone have thus far been identified; and second, some 170 of the 537 (32%) of megafaunal invertebrates were added to the total during Cruises IV and V in May and June of 1985. Because of the latter fact, as well as the way in which the megafaunal trawling was done, I have elected to restrict my remarks largely to the last two of the five cruises carried out by LGL.

The data derived from Cruises IV and V have provided support for our conceptions as to how faunal assemblages are distributed over the upper and middle portions of the continental slope. For the past several years, some marine scientists have debated whether or not benthic animals are arrayed on the slope in discernible bands or zones. Although there has never been an argument as to the truth of the observation that the composition of the faunal assemblage changes with increasing depth, there are those who espouse that the zones of the zonation proponents are artifacts of sampling, i.e., that the limits of the zones are simply related to the depths at which sampling was done. Nevertheless, one must point out that Haedrich et al. (1975, 1980) identified four faunal zones on the U.S. North Atlantic slope, and in 1983 Hecker et al. in an MMS report, designated five faunal zones on the same slope. In the same year, Pequegnat et al. (1983) identified five major zones on the slope and rise of the Gulf of Mexico. More recently the 1986 report on the MMS study of the U.S. North Atlantic slope carried out by Battelle, Lamont-Doherty, and Woods Hole has identified six faunal zones between depths of 242 and 1400 m. These findings, which are based both upon classification and ordination analyses, indicate that faunal replacement with depth on the slope is not uniform. Thus, we have discerned that the "rate" of replacement is not the same on all aspects of the slope. Accordingly, one may regard zones as being areas of relatively small faunal change with depth that are separated by areas of greater faunal replacement.

These separations are usually referred to as "breaks," but this is a poor term of reference because it tends to ignore the fact that few or many taxa may be shared between neighboring zones.

One is often asked to account for the factors causing faunal shifts. Naturally there are many limiting factors involved. But to my mind, two are outstanding, viz., food and pressure. We have seen that diversity is high in the deep sea, but we also know that the biomass drops except when unusual circumstances exist. When an unusual increase in food supply occurs, there will be a dramatic increase in biomass. For example, you will learn more about his phenomenon today as portrayed by faunal increases around oil and gas seeps in the central part of the slope of the northern Gulf of Mexico and elsewhere. Other factors that, undoubtedly, play some role are currents, predation, and the nature of the substratum.

Today, I propose to show how similarity measures such as NESS (Grassle and Smith 1976) give us some insights into faunal replacement. To do this, it was decided to trawl isobathymetrically on consecutively deeper isobaths along two transects, viz., on E (east) in Cruise IV and WC (west-central) in Cruise V, as shown in Figure 3.1. Note that E1, 1a, 1b, and 1c are on one isobath, whereas 2, 2a, etc., and 3a, 3b, etc. are on progressively deeper isobaths. The same depth relationships are true for the WC Transect but the trawling tended to stray off the isobath to a greater degree than on the E Transect. To save time, I shall limit my remarks largely to the decapod crustaceans and the fishes, which we have seen are the most specious groups of the megafauna (Table 3.1). Also these are characteristically mobile, which one might expect would tend to preclude their remaining within zonal limits.

In Figure 3.2, we see the results of the application of NESS to decapods taken on the E Transect during Cruise IV. Obviously there is a clear separation of the faunal clusters from one "isobath" (344 to 357 m) to the next. Lest one think that this applies to the decapods alone among invertebrates, take a look at the same clustering for all invertebrates in Figure 3.3. Essentially, the same clusters occur when the fish data are analyzed (Figure 3.4).

Next, let us turn to Cruise V and the WC Transect. Again in Figures 3.5 and 3.6 we see a tendency toward isobathic clustering in the fishes and decapods. In both cases, Station WC2, 7, 4, and 8 (in the 472-585m depth range) are most closely related. The one significant outlier in each case is WC6. The reason for this is apparent when we see that isobathic trawling was not carried out properly, there being a range of 240 m between the shallowest and deepest part of the sampling. In those cases where the relationships between stations is greatest there was about a 70 m difference (see Figure 3.2) as well as Cruises IV and V (Figure 3.7). There is very evident isobathic clustering, but Stations C9 and C10 stand apart. Reference to the cruise log for Cruise III revealed that in both cases the trawl was filled with a huge mud ball that prevented proper sampling.

In Table 3.2, we see the distribution of the dominant fish species among the isobath stations on the East Transect. The asterisks indicate where the species was found, whereas an inserted name indicates a replacement. In general, it appears that the deeper one goes, the less concordance is observed along the isobath stations. This may indicate that there is less uniformity (greater patchiness) of food supply at deeper stations.

In Figures 3.8, 3.9, and 3.10, I have plotted the occurrence of the dominant fish species found on the East Transect (numbers are shown on the ordinates, and the isobaths on the abscissa). Recall that the depth range of the E1 isobath is from 344 to 357 m, of E2 is from 613 to 631 m, and of E3 is from 783 to 871 m. There is remarkably little overlap among the isobaths, but as indicated earlier, some species have reasonably wide bathymetric ranges.

Similarly the bathymetric distributions of the dominant decapods are shown in Figures 3.11, 3.12, and 3.13. In addition to the bathymetric shifts displayed by these species, it is interesting to note in Figure 3.12 concordance between the gorgonian coral Chrysogorgia agassizii and the chirostylid anomuran Uroptychus nitidus which apparently lives among its branches. Figure 3.13 shows the close distributional relationship between the eel Synaphobranchus oregonia and the polychelid decapod Stereomastis in its stomach. There has been considerable debate as to whether or not this was a mere happenstance. The close distributional relationship between these two species as shown in Figure 3.13 supports the view that there is a good possibility of an interesting predator/prey relationship.

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Dr. Pequegnat is a marine ecologist who has studied the deep-sea Gulf of Mexico and published extensively on this area during the last 22 years. He is Professor Emeritus of Oceanography at Texas A&M University. Formerly President of TerEco Corporation Environmental Consultants, Dr. Pequegnat has a wide range of special interests, including the nature and distribution of deep-sea faunal assemblages, and the taxonomy of certain decapod crustaceans. In recent years he has become an expert on the environmental effects of dredging on which he has become a consultant to various national and international organizations.

Hydrocarbon Seepage and Seep Communities on the Louisiana Continental Slope

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The Geochemical and Environmental Research Group (GERG) undertook a trawling and coring program of R/V Gyre Cruises 86-G-1/2 for the Offshore Operators Committee (OOC) to test the hypothesis that communities based on chemosynthesis are broadly distributed on the Gulf of Mexico continental slope in seep areas that can be identified by either seismic "wipe-out" zones or bubble plumes. Although only 25 trawls were required by MMS, 39 trawls were taken in blocks that the various OOC members indicated contained seismic "wipe-out" zones. The members supplied GERG with hazard data (seafloor features and bathymetry maps), as well as, in most cases, representative shallow seismic profiles from each of these study sites. The study sites were in water depths ranging from 180 to 900 meters and spanned an area from Mississippi Canyon (4 sites) to East Breaks (2 sites). The majority of the sites were in the Green Canyon and Garden Banks lease areas (Figure 3.14).

The results of this field study have demonstrated that chemosynthetic organisms and/or their remains (either tube worms, mussels and/or clams) are found in the Green Canyon (11 sites), Garden Banks (4 sites), Ewing Bank (1 site), and East Breaks (1 site) lease areas. All of these sites contained a significant presence of seismic "wipe-out" zones. This significantly expands our previous findings that indicated these organisms were present in 10 to 20 blocks near the Green Canyon-272 and 190/234 areas. Chemosynthetic tube worms, clams, and mussels and/or their remains (shells, empty tubes) were recovered in 21, 10 and 4 trawls, respectively. The higher occurrence of tube worms in the trawls may be related to the higher catch efficiency (although still probably low) of the otter trawl of this type of chemosynthetic organism.

Carbon isotopic analysis of selected organisms from the trawling confirmed the chemosynthetic nature of the tube worms, clams, and mussels. Organisms containing isotopically light carbon isotopes indicative of chemosynthetic carbon were collected at 19 sites in the Green Canyon, Garden Banks, Ewing Bank, and East Breaks areas. All tube worms and mussels that were collected and analyzed were isotopically light. The turrids (gastropods) displayed a range of carbon isotopic values indicating that they may utilize both chemosynthetically and heterotrophically produced carbon as energy sources. Carbon isotopic compositions differentiated organisms that were methane, sulfur or heterotrophic based. The cruise collected mussels that are potentially capable of utilizing methane as their sole carbon source. This is the first demonstrated symbiosis between a methanotrophic bacterium and an animal.

The cruise was also designed to determine if chemosynthetic organisms are only found in "wipe-out" zones that are associated with oil seepage. Thus, piston cores were taken from each of the sites to determine the amount of migrated hydrocarbons present in the sediments associated with these "wipe-out zones and assemblages of vent-like organisms. Seven of the 39 pistons cores were oil-stained. All of the trawl samples recovered at locations where visibly oil-stained cores were recovered contained at least one species of chemosynthetic organism and generally represented the most abundant catches of chemosynthetic organisms. However, some tube worms were collected in areas that contain low to moderate levels of upward migrated hydrocarbons in the sediment. Subsequently, a joint cruise with LGL Ecological Research Associates dove on two sites in the Green Canyon lease area using the Johnson Sea Link. Dense communities of tube worms and mussels were observed on "Bush Hill" in the GC-185 block. Oil and gas seepage was also observed at this site.

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Spatial Distribution Patterns in Chemosynthetic Communities

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Mr. Ian Rosman, and
Mr. Joshua S. Baker
LGL Ecological Research
Associates, Inc.

INTRODUCTION

Examination of the characteristic densities, spatial distribution, and community structure of the central Gulf of Mexico autotrophs is warranted because these organisms appear to occur with significant densities in regions of potential oil and gas exploitation. Recent investigations have used the research submersible Johnson-Sea-Link I to explore chemosynthetic communities at two seep sites south of Louisiana. This presentation reviews the findings from otter-trawling and benthic photography of chemosynthetic communities in the framework of distribution at different spatial scales. Preliminary findings from the submersible investigations are presented in this context.

MESO-SCALE (100-1000 km)

Samples taken by otter-trawling and benthic photography show that seep communities occurred at numerous locations in the central Gulf of Mexico in a zone approximately 200 by 600 km at depths from 400 to 900 m. The communities appear to be restricted to active sediment surface expressions of hydrocarbons, so their occurrence within the zone is highly patchy. Comparison of results from extensive trawling effort has been useful for showing the levels of association between different chemosynthetic taxa and between individual taxa and specific environmental features associated with hydrocarbon seepage (seismic "wipe-out" zones, H_2S-rich sediments, oil-stained sediments, and gas bubbles). The only other occurrence of similar organisms reported in the Gulf of Mexico was off the Florida Escarpment (Paul et al., Science, vol. 226, pp. 965-967,1984).

COARSE-SCALE (1-10 km)

Results from individual trawls and benthic photography both indicate spatial distribution of chemosynthetic organisms at the community level. Trawls are very useful for providing voucher and laboratory specimens of chemoautotrophs; however, the success rate for trawling these organisms appears highly variable. Photographic transects have identified communities at a scale of from 10 to 1000 m and at a range of densities. Patchiness at a scale of 10-20 m is a possible interpretation of variation in density within communities. Benthic photographs have the additional advantage of revealing behavioral aspects of the communities that are not apparent from trawl samples. Uncertainty regarding precise identification of organisms in photographs requires, however, that collection of voucher specimens accompany the photography.

SUBMERSIBLE OBSERVATIONS: FINE-SCALE (10-100 m) AND MICRO-SCALE (<10 m)

The research submersible Johnson-Sea-Link I (JSL) was used to photograph and collect samples from a chemosynthetic community on a small knoll at depths of 550m. The knoll was identified as a possible site for chemosynthetic communities on the basis of oil-stained piston cores from previous cruises in the region. PDR traces of the knoll showed the absence of sub surface strata throughout the knoll. The JSL was directed on a series of dives across the top of the knoll and on adjacent areas. The usual procedure was for the JSL to steer 5 min. transects at a speed of .5 knots. At the end of each transect, the support ship would position itself over the JSL and obtain a LORAN C fix on its location. The position of the JSL within transects could be estimated from the time between fixes. A total of four dives were carried out (see Figure 3.15a). Both video and still photographs were taken on the transects. Samples were collected at the fix sites using the JSL's manipulator arm and a series of punch corers.

Examination of the video tapes showed a variety of organisms including vestimentiferan tube worms of the genera <u>Lamellibrachia</u> and <u>Escarpia</u>, a methanotrophic mussel and numerous background fauna. The structure of the community was highly complex. Transition between areas of high and low density was generally gradual in regions with soft sediment and abrupt were the substrate was composed of carbonate rock. The taxa intermingled to a high degree and extensive beds of mussels were observed in areas with continuous oil and gas seepage. A noteworthy example of dependency between taxa was the bivalve <u>Acesta</u> sp., which was always observed attached to the ends of the tube worm tubes. Specimens of <u>Lamellibrachia</u> sp. with attached <u>Acesta</u> sp. were collected and showed that both the bivalve and the tube worm were living. Spatial distribution of chemosynthetic organisms at the knoll was estimated from their location in the videotape footage taken on each transect during dives one and two (see Figure 3.15.b and Table 3.3).

Infauna samples were collected at one site off the knoll and well away from the abundant tube worm clusters, and from one site near the top of the knoll near several large tube worm clusters. Both samples were found to contain oil-stained sediments and diverse macrofauna. The macrofauna in the sample from the top of the knoll was less abundant than it was in the sample from off the knoll (Table 3.4). The sample from off the knoll was located near whitish patches on the sediment which were not observed at the site on the knoll.

A second suspected seep site at Green Canyon lease block 234 was investigated in two extended transects by the Johnson-Sea-Link. Despite previous trawl catches of chemosynthetic organisms from the area, the only evidence of seep communities were several sparse beds of Pogonophora, white patches of sediments, and a single small cluster of Lamellibrachia sp.

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Dr. Joshua S. Baker received a Ph.D. in statistics from Texas A&M University in 1985. His specialty is statistical ecology.

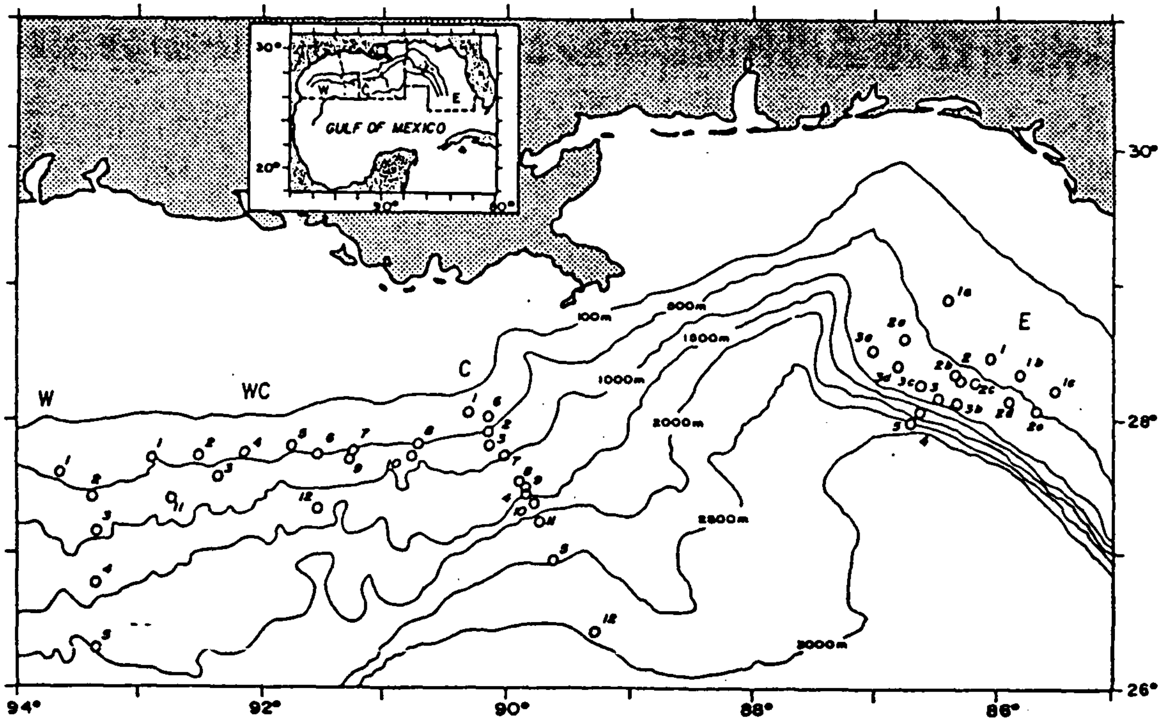

Figure 3.1.--MMS/Northern Gulf of Mexico Continental Slope (NGOMCS) station locations. Four transects are designated by the following letters: W = Western Transect; WC = West-Central Transect; C = Central Transect; E = Eastern Transect.

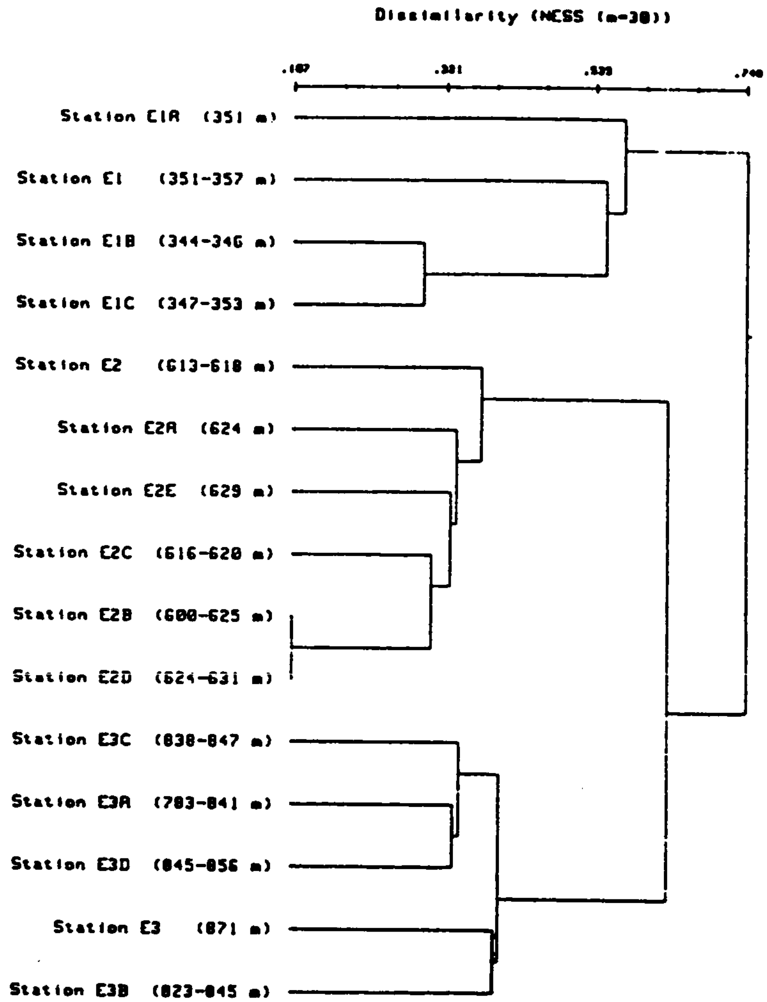

Figure 3.2.--Decapoda species on the East Transect (Cruise IV).

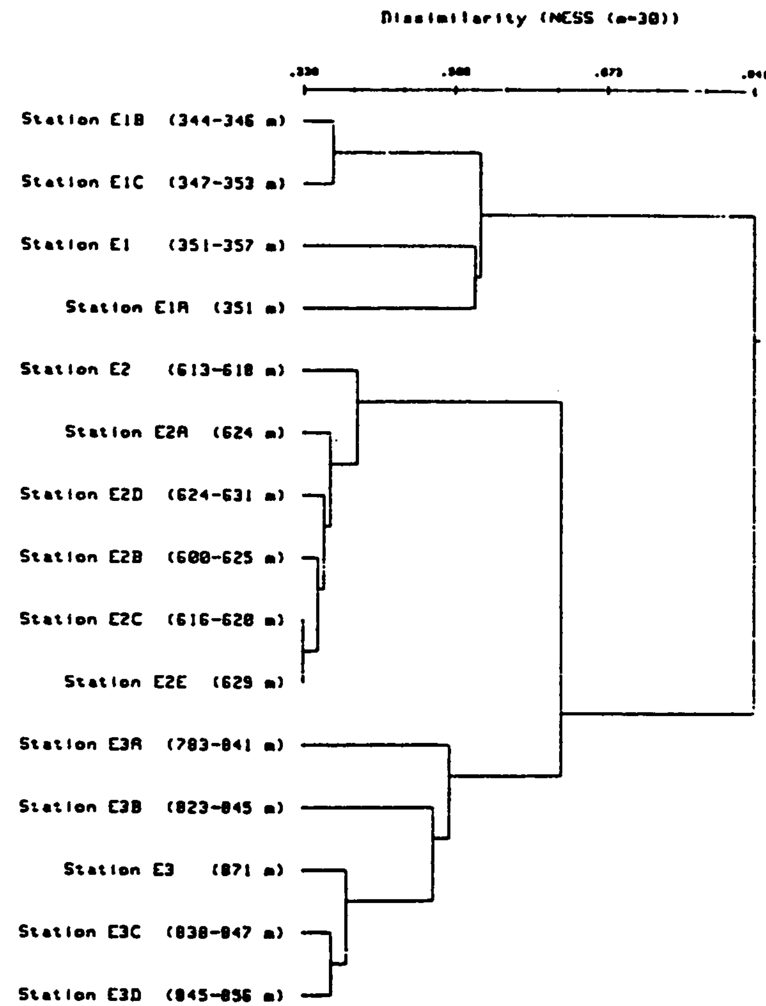

Figure 3.3.--All invertebrate species on the East Transect (Cruise IV).

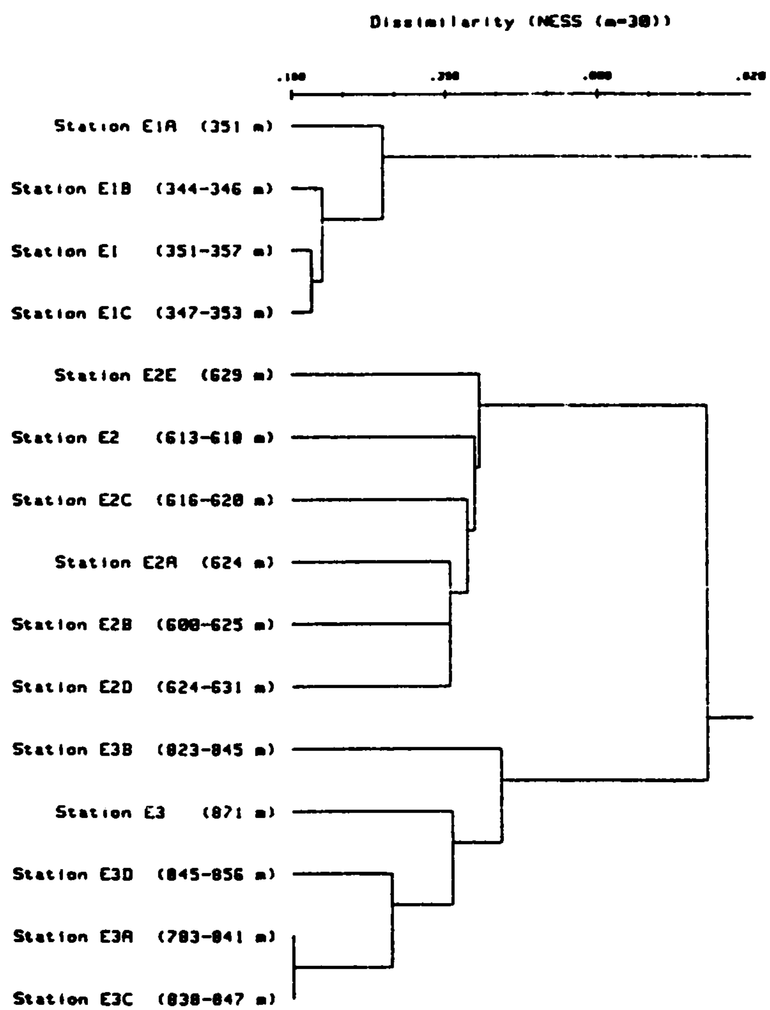

Figure 3.4.--Fish species on the East Transect (Cruise IV).

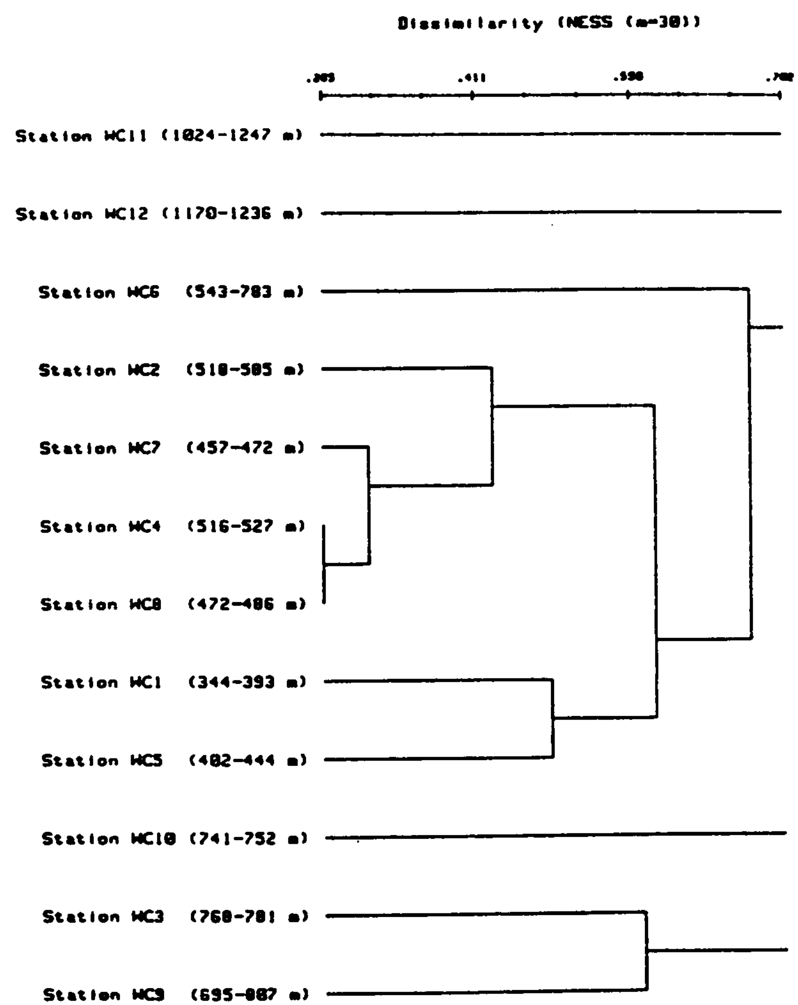

Figure 3.5.--Fish species on the West-Central Transect (Cruise V).

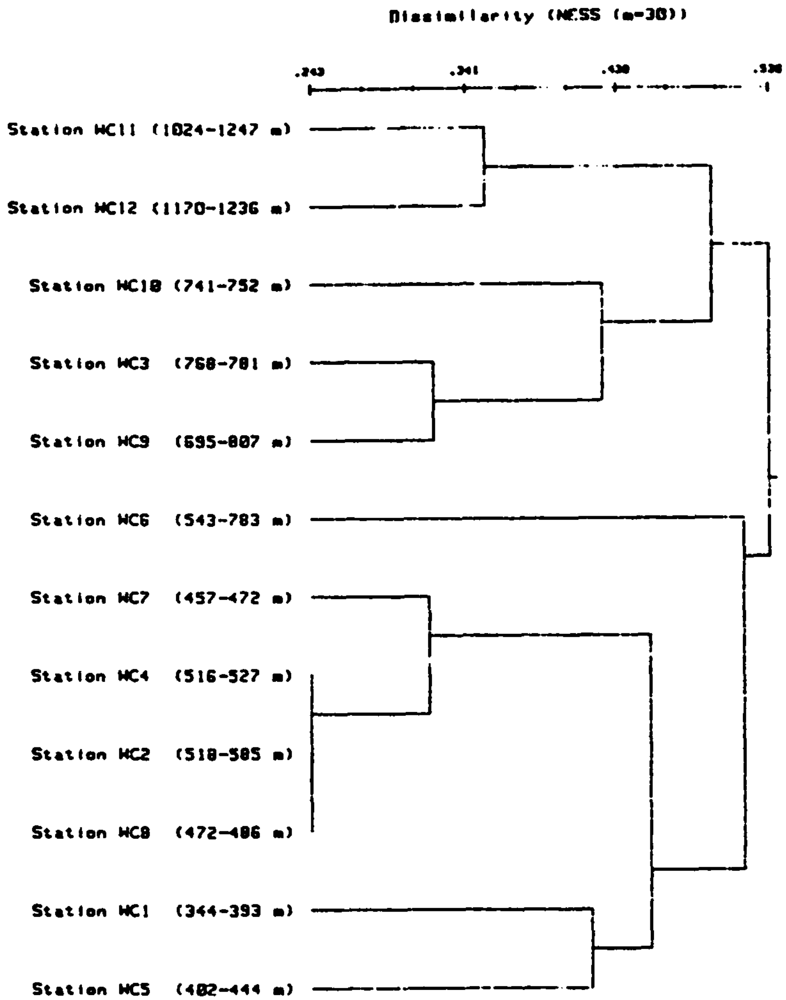

Figure 3.6.--Decapod species on the West-Central Transect (Cruise V).

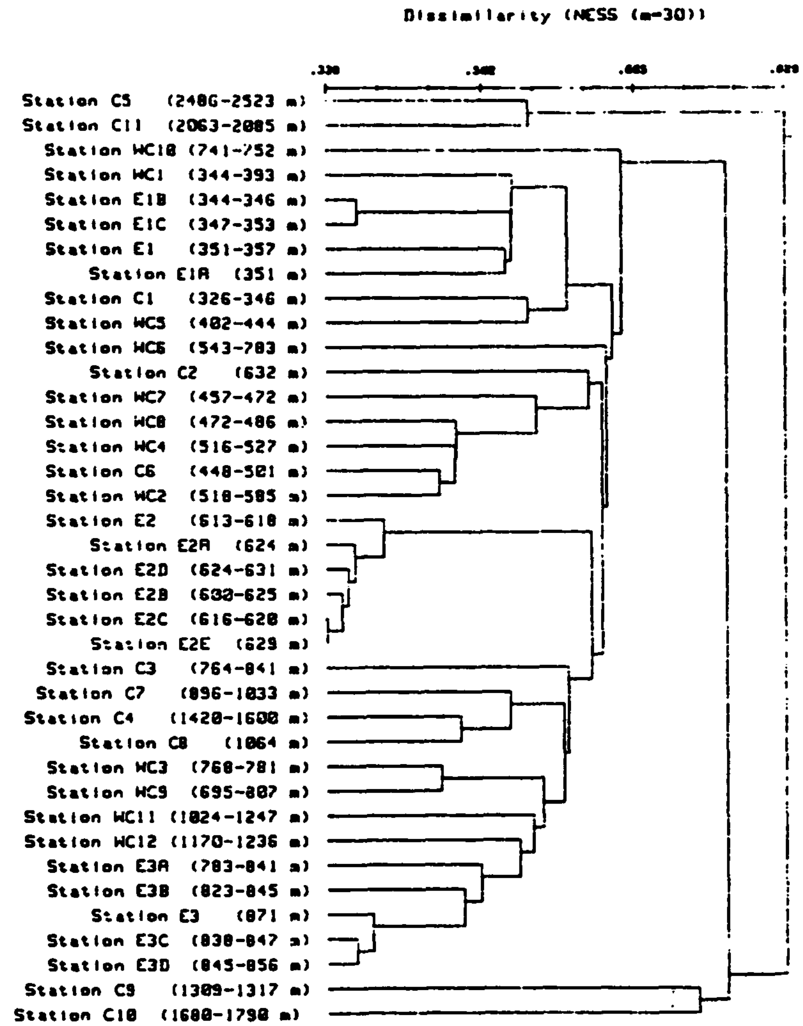

Figure 3.7.--All invertebrates from Cruises III (Central Transect), IV (East Transect), and V (West-Central Transect).

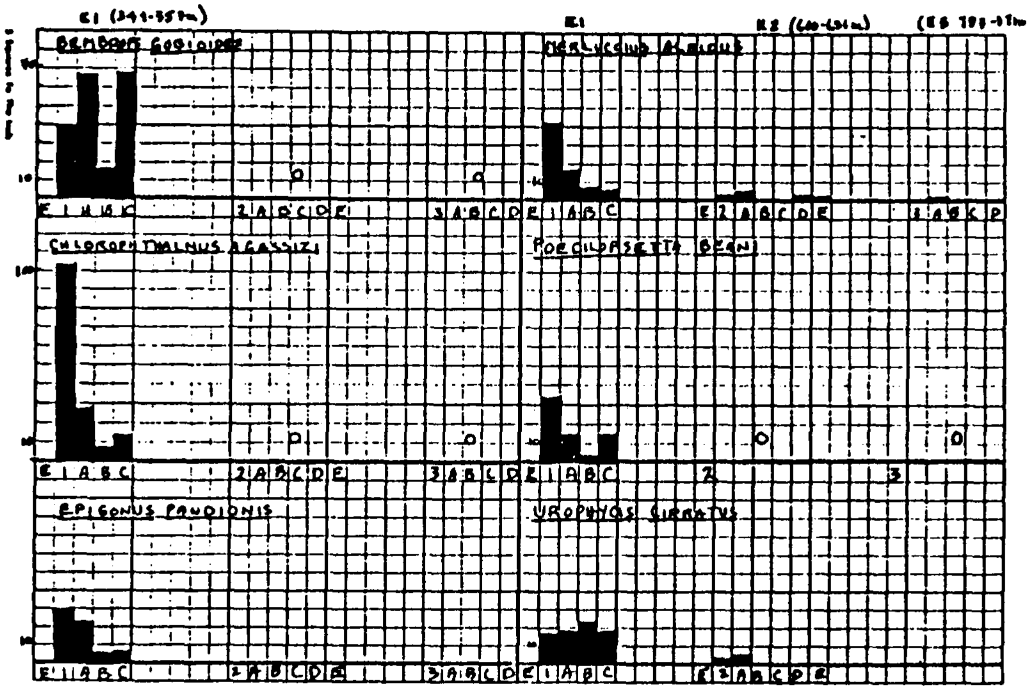

Figure 3.8.--Relative abundance of dominant fish species on the East Transect (Cruise IV).

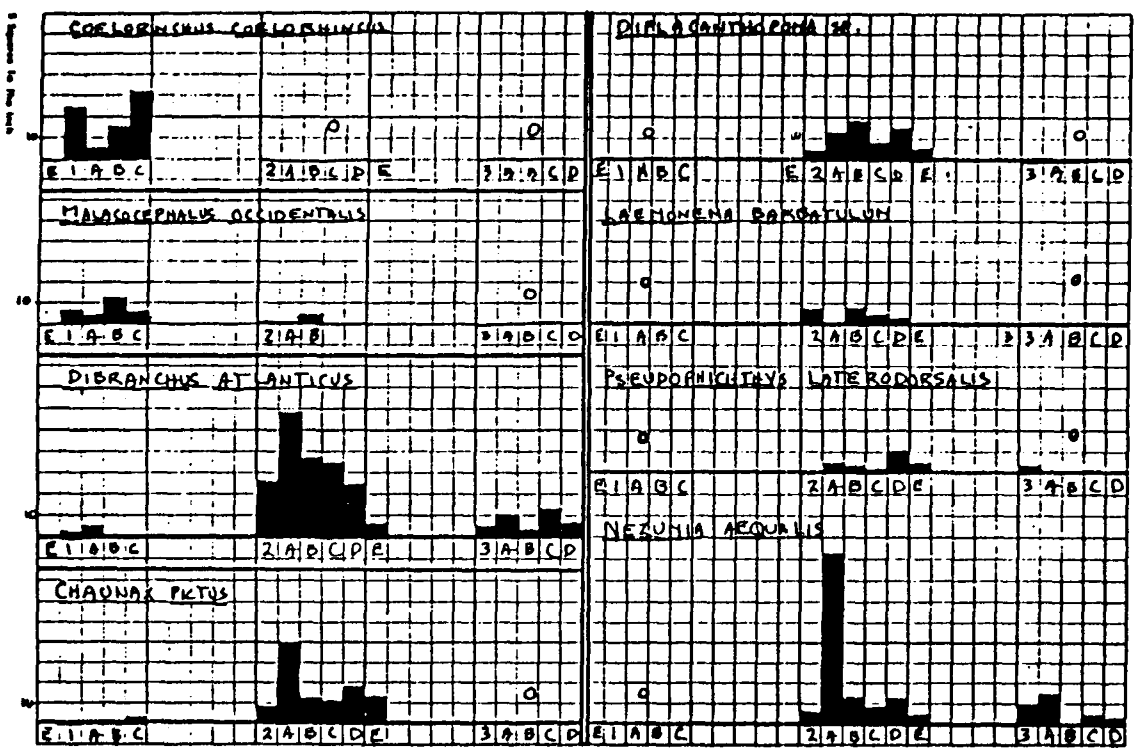

Figure 3.9.--Relative abundance of dominant fish species on the East Transect (Cruise IV).

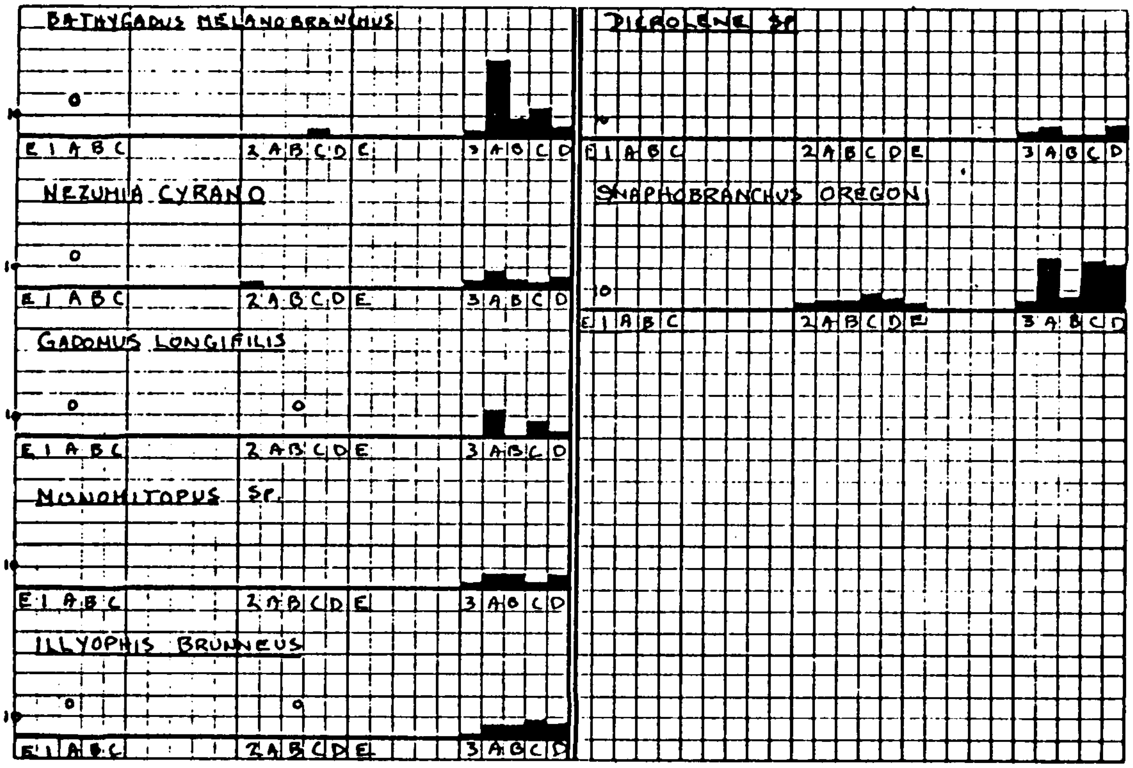

Figure 3.10.--Relative abundance of dominant fish species on the East Transect (Cruise IV).

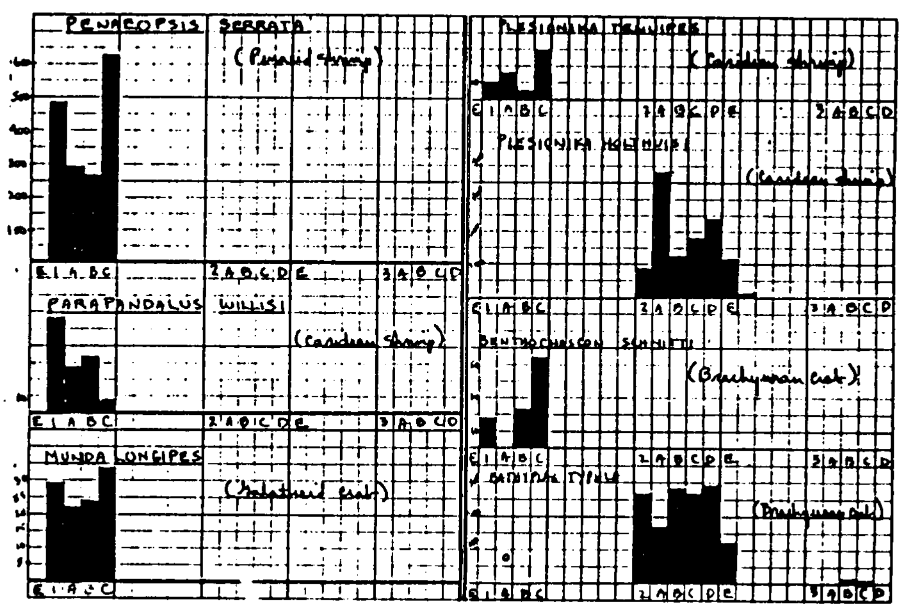

Figure 3.11.--Relative abundance of dominant decapod species on the East Transect (Cruise IV).

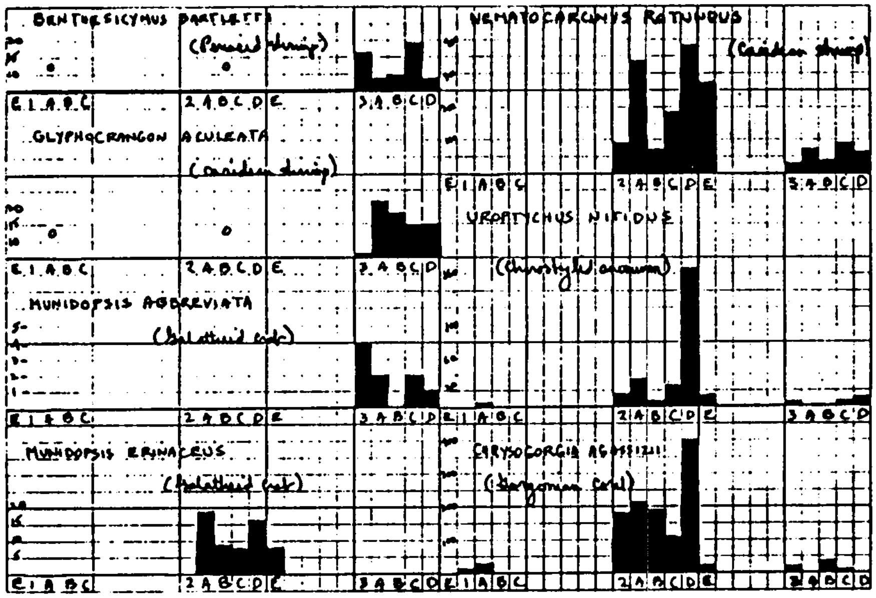

Figure 3.12.--Relative abundance of dominant decapod species on the East Transect (Cruise IV).

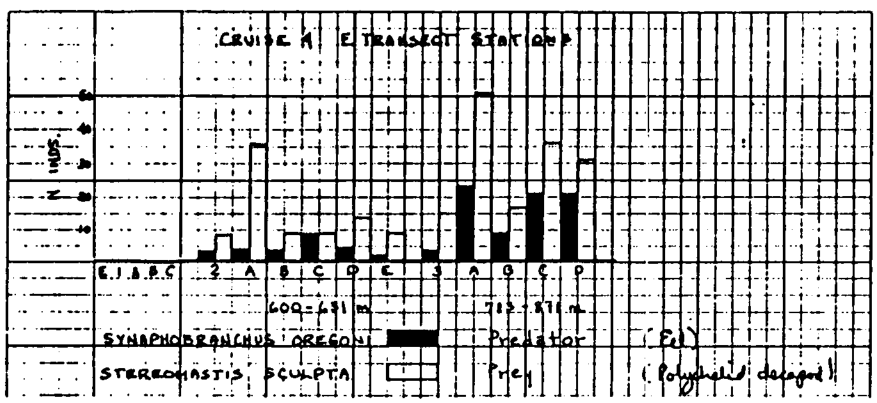

Figure 3.13.--Distributional relationship between the eel, Synaphobranchus oregoni and the polychelid decapod, Stereomastis sculpta.

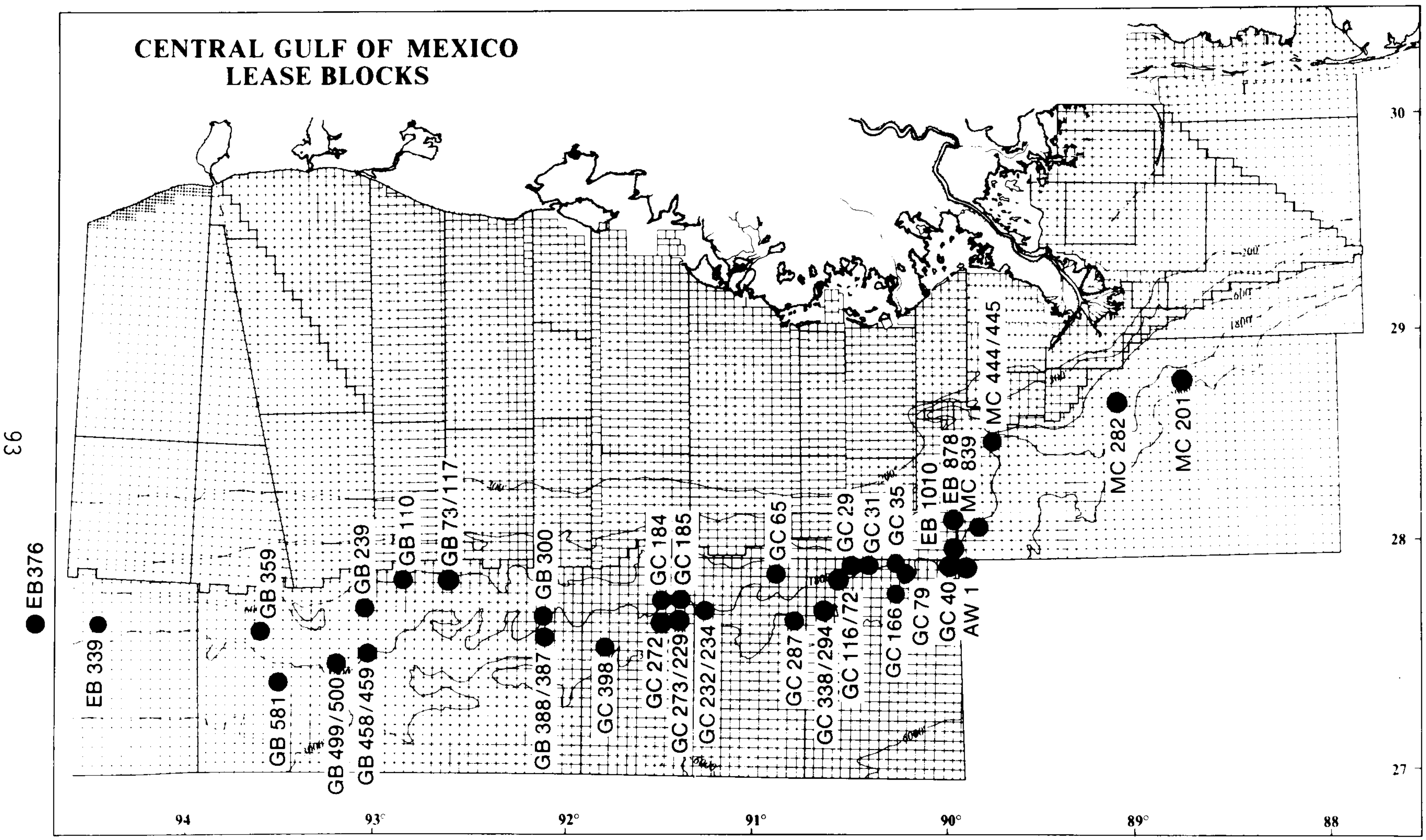

Figure 3.14.--Locations of trawl sites on the Louisiana/Upper Texas continental slope that were taken for the OOC sponsored study of chemosynthetic ecosystems.

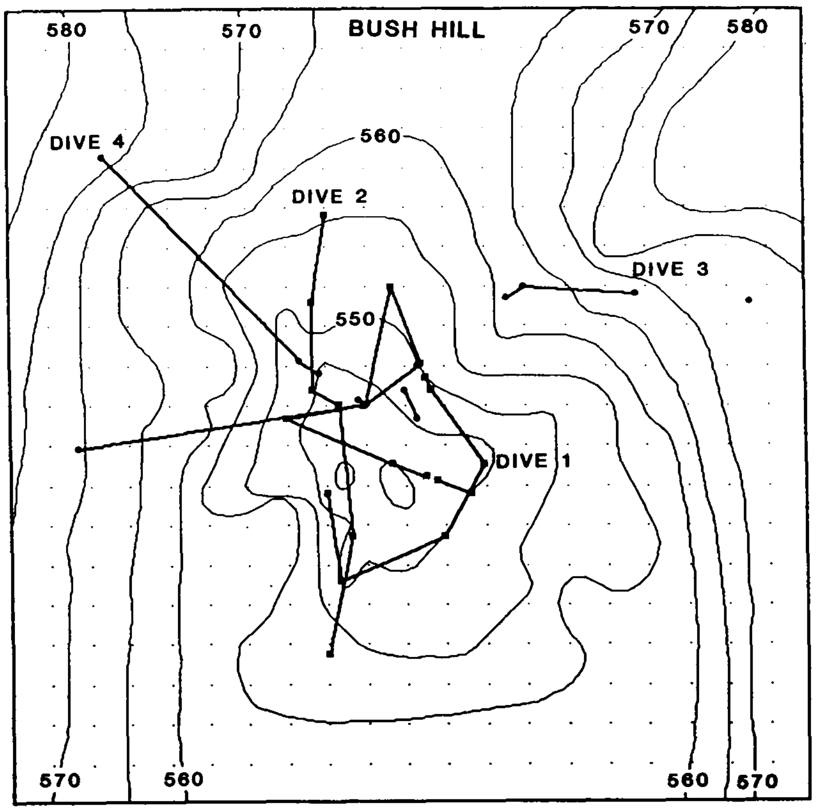

Figure 3.15a.--Chart showing continuous video records for dives 1 through 4 of MMS/NGOMCS Cruise VI with the Johnson-Sea-Link I. Points indicate position fixes at the beginning and end of video and still-photography transects. The chart width is 1000 m.

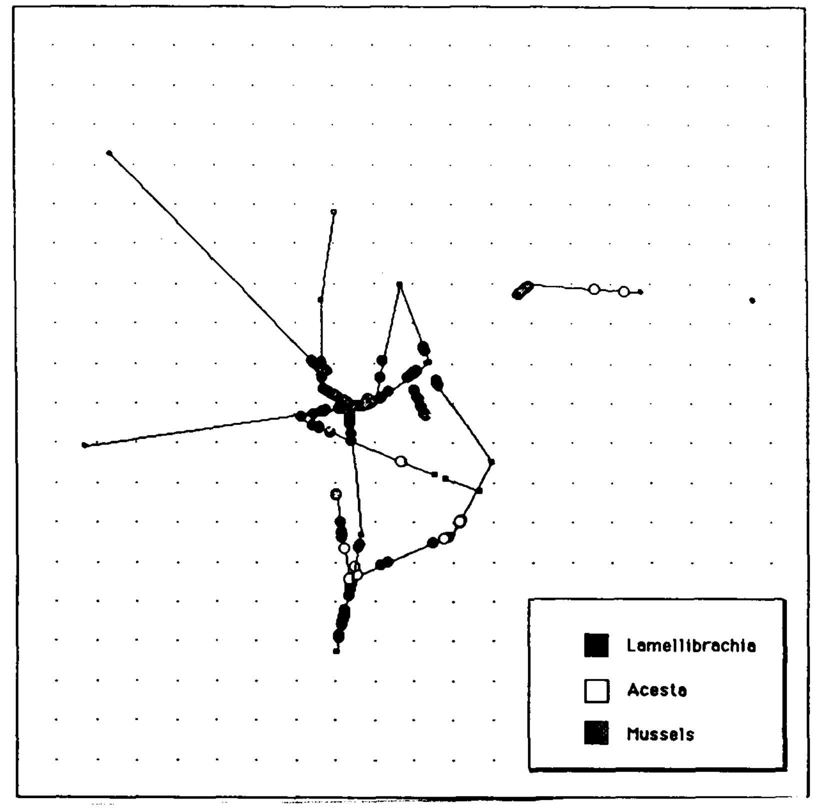

Figure 3.15b.--Chart showing encounter points of chemosynthetic organisms in the video record. The chart width is 1000 m.

TABLE 3.1

MMS/NGOMCS

No. of Taxa in Trawl Samples (Cruises I-V)

PORIFERA	24	
HYDROZOA	5	COELENTERATA = 40 TAXA
ALCYONARIA	13	
ANTINIARIA	10	
SCLERACTINIA	7	
OTHER ANTHOZOA	5	
NEMERTEA	2	
POLYCHAETA	73	
GASTROPODA	46	MOLLUSCA = 104 TAXA
BIVALVIA	37	
SCAPHOPODA	6	
CEPHALOPODA	15	
CIRRIPEDIA	17	CRUSTACEA = 160 TAXA
ISOPODA	8	
AMPHIPODA	8	
DECAPODA	127	
POGONOPHORA/VESTIMENTIFERA	2	
BRACHIOPODA	2	
ASTEROIDEA	43	ECHINODERMATA = 129 TAXA
ECHINOIDEA	13	
HOLOTHUROIDEA	21	
OPHIUROIDEA	46	
CRINOIDEA	6	
ASCIDIACEA	1	
TOTAL INVERTEBRATES =	537	
FISH =	149	

Table 3.2

Distribution of Dominant Fish Species on the East Transect (Cruise IV)

EAST TRANSECT — FISH CRUISE IV

STATIONS

344-357 m E1 E1A E1B E1C

Chlorophthalmus agassizi **

Merluccius albidus ********************** Coelorinchus ********

Bembrops gobioides **

Poecilopsetta beani ******** Urophycis cirratus P. beani

Epigonus pandionis ********************** Malacocephalus U. cirratus

600-631 m E2 E2A E2B E2C E2D E2D

Dibranchus atlanticus ***

Chaunax pictus ***

Nezumia aequalis ***

Diplacanthoma sp. ***

Synaphobranchus Oregoni ******************** Laemona barbat.********Pseudophichthys*

823-871 m E3 E3A E3B E3C E3D

Bathygadus melanobranchus **Dicrolene sp.

Nezumia aequalis ***********************Monomitopus sp. Ilyophis Monomitopus

Dibranchus atlanticus ************************Ilyophis brunneus D. atlanticus ****

Synaphobranchus oregoni ***

Nezumia cyrano *********Gadomis l. N. cyrano Gadomia l. N. cyrano

Table 3.3

Chemosynthetic Organisms Photographed in Video Tape during Dives one and two at Green Canyon 184/185.

TAXON	Total for Dives 1&2	Mean per 100 m^2	S.D.	Max per 100 m^2
Tube Worm Clusters	96	.4967	.9013	4.5
Clusters with *Acesta*	9	.0455	.1635	1
Mussel Beds	10	.0474	.1858	1.05

Table 3.4

Numbers of Specimens in Macrofauna Groups Found in Two Samples Collected by the Johnson-Sea-Link at Two Sites in Green Canyon 184/185. Each sample consisted of 5 56-mm i.d. core tubes. Parenthesis show numbers of individual polychaete taxa identified to lowest possible taxon. Identifications in both samples were hampered by high levels of oil present in the sediments. Macrofauna identification is by G. Fain Hubbard of LGL Ecological Research Associates.

Group	On knoll 27°46.94'N 91°30.34"W	Off knoll 27°47.01N 91°30.05'W
Amphipoda	1	2
Aplocophora	0	1
Bivalvia	9	1
Brachiopoda	0	1
Cumacea	4	0
Gastropoda	0	8
Harpacticoide	4	18
Isopoda	3	0
Nematoda	27	17
Oligochaeta	24	4
Ostracoda	0	5
Polychaeta	107(12)	241(16)
Tanaidacea	1	2
TOTAL	141	420

PLANNING FOR USE OF DISPERSANTS FOR OIL SPILL MITIGATION: STATUS AND ISSUES

Session:	PLANNING FOR USE OF DISPERSANTS FOR OIL SPILL MITIGATION: STATUS AND ISSUES
Co-Chairs:	Ms. Laura Gabanski Mr. Raymond Churan Mr. James H. Lee
Date:	November 4, 1986

Presentation Title	Speaker/Affiliation
Planning for Use of Dispersants for Oil Spill Mitigation: Status and Issues Session Overview	Ms. Laura Gabanski Minerals Management Service Gulf of Mexico OCS Region
Panel I: FEDERAL REGION 4	
Involvement, Status, and Issues Related to Dispersant Use	Mr. James H. Lee U.S. Department of Interior Office of Environmental Project Review
Dispersants: An EPA Region IV Perspective	Mr. Mike Norman U.S. Environmental Protection Agency, Region IV
Oil Spill Dispersant Testing	Dr. Donald R. Ekberg National Marine Fisheries Service
Oil Dispersant Use in Alabama State Waters	Mr. Gary L. Halcomb Alabama Department of Environmental Management
Mississippi's Dispersant Policy	Mr. Richard V. Ball Mississippi Bureau of Pollution Control
Dispersant Use in Oil Spill Response	Dr. John P. Fraser Shell Oil Company
Preplanning for the Use of Dispersants	Lt. Commander Tony E. Hart Seventh Coast Guard District

Session: PLANNING FOR USE OF DISPERSANTS FOR OIL SPILL MITIGATION: STATUS AND ISSUES (Cont'd)

PANEL II: FEDERAL REGION 6

U.S. Department of the Interior, Region VI, Status and Issues Related to Dispersant Use	Mr. Raymond P. Churan U.S. Department of Interior Office of Environmental Project Review
Planning for Use of Dispersants for Oil Spill Mitigation: Status and Issues	Mr. Donald Moore National Marine Fisheries Service Habitat Conservation Division
Dispersants: Can They Help Louisiana's Resources?	Mr. R. Bruce Hammatt Louisiana Department of Environmental Quality
Planning for Use of Dispersants for Oil Spill Mitigation: Status and Issues	Mr. David Barker Texas Water Commission
LOOP Toxicity Testing Program	Mr. A. J. Heikamp, Jr. Louisiana Offshore Oil Port, Inc.
Planning for Use of Dispersants for Oil Spill Mitigation: Status and Issues	Lt. Asher B. Grimes Eighth Coast Guard District Marine Environmental Protection Branch

Planning for Use of Dispersants for Oil Spill Mitigation: Status and Issues Session Overview

Ms. Laura Gabanski
Minerals Management Service

The purpose of the session was to learn about planning for dispersant use for the Gulf of Mexico and to discuss issues concerning dispersant use. The session was divided into two panels; one representing the Federal Region 4 Regional Response Team (RRT) which includes the States of Mississippi, Alabama, and Florida and the other representing the Federal Region 6 RRT which includes the States of Texas and Louisiana. Planning for dispersant use is the responsibility of the RRT's.

PANEL I: FEDERAL REGION 4

The Department of the Interior is a member of the Dispersant Working Group, but was not involved in the development of the Florida Letter of Agreement. This agreement was made between the Environmental Protection Agency (EPA), State of Florida, and U.S. Coast Guard and allows for pre-approval of dispersant use in specified areas. Interior's representative to the RRT needs to be involved in the decision-making process. The Department's position is that dispersants are a valid tool and should be considered on a case-by-case basis.

Mr. Norman indicated that in some cases dispersants may provide the best cleanup option. More pre-approval policy agreements should be reached with other states in the region pursuant to Subpart H of the National Contingency Plan.

Dr. Ekberg objected to the use of the EPA's Dispersant Product Schedule toxicity data in making dispersant use decisions by the on-scene coordinator (OSC). He recommended toxicity testing of major Gulf species and field monitoring of dispersant tests.

Mr. Halcomb said that Alabama is in the formative stages of planning for dispersant use. Application of dispersants would be recommended for offshore spills that threaten to enter Mobile Bay or make landfall. The State needs to coordinate its planning closely with the States of Mississippi and Florida.

Mr. Ball stated that Mississippi does not approve the use of dispersants due to concern with toxicity. Dispersants may be a useful tool; however, more research is needed on toxicity to important marine species of Mississippi.

Dr. Fraser stated that dispersants may be a preferred cleanup option when mechanical methods are ineffective. A method for dispersant use decisionmaking based on environmental concerns is being developed for the Gulf of Mexico by the Marine Industry Group (MIRG) with involvement of state and federal regulatory agencies. The goal of the project is to expedite decisionmaking.

Lt. Commander Hart stated that dispersants should be given serious consideration as an oil spill cleanup tool. Agreements between the States, EPA, and Coast Guard which pre-authorize the OSC to use dispersants in some areas, and may require concurrence in other areas, are necessary to expedite the decisionmaking process and, therefore, make dispersants a viable tool.

The discussion which followed provided some interesting information. Lt. Commander Hart stated that the Florida Letter of Agreement has not been reviewed since it became effective in September 1984 and will be revised to incorporate ideas from other such agreements and changes in the National Contingency Plan. Additionally, industry can be advised of these agreements or dispersant contingency plans through the RRTs. Mr. Lee indicated that national parks and wildlife refuges individually develop oil spill contingency plans and not all parks and refuges have them. Finally, Alabama is addressing its data needs for dispersant planning by collecting marine weather data for more accurate prediction of oil slick trajectories.

PANEL II: FEDERAL REGION 6

The Department of the Interior has a responsibility to protect the resources for which it is a trustee, e.g., national parks, seashores, and wildlife refuges, and threatened and endangered species and/or their habitat. The Department believes that there is inadequate toxicity data on species indigenous to the Gulf of Mexico. Mr. Churan stated that Interior should participate in the dispersant decisionmaking process. Interior's position on dispersants is that they should be considered as a tool for oil spill cleanup on a case-by-case basis after mechanical methods have been considered.

Mr. Moore reported that the National Marine Fisheries Service (NMFS) has been involved with assessing the impact of oil versus dispersed oil on marine resources as a member of the Region 6 Dispersant Working Group (DWG). NMFS has noted the lack of toxicity data on early life stages (eggs and larvae) of Gulf of Mexico fisheries species, particularly shrimp and menhaden. As a result of this, NMFS has recommended not to pre-authorize dispersant use in the northwestern Gulf. The Service will continue to work with the DWG to develop a Regional dispersant contingency plan so the OSC can make a rapid, well-informed, and well-founded decision on dispersant use.

Mr. Hammatt advised that Louisiana has been actively involved in pre-planning for dispersant use as a member of the DWG and a participant in the development of the MIRG dispersant decisionmaking method. A main concern of Louisiana is that a timely decision is made concerning the use of dispersants. A problem that has been identified is jurisdiction disputes among states over whether or not to use dispersants. Finally, Mr. Hammett indicated that dispersant spill drills would be helpful for improving efficiency of dispersant application and monitoring.

Mr. Barker stated that dispersed oil appears to be more toxic than dispersant or oil alone and that toxicity data are lacking for commercially important Gulf species. Texas bays and estuaries are protected by barrier islands which have a low sensitivity to oil. Mr. Barker indicated that, based on this, Texas should deny any request for dispersant use unless the spill is offshore and trajectories show it threatens to enter a pass in the barrier island.

Mr. Heikamp stated that LOOP, Inc., is interested in using dipersants as an oil spill mitigation tool, but is concerned about the lack of toxicity data on commercially important species. To address this, LOOP, Inc., is conducting toxicity tests (static and flow-through 96-hour LC50 test and 30-day life cycle studies) on juveniles and/or postlarvae of brown and white shrimp, blue crab, oyster, and red drum. The study is scheduled to be completed in the fall of 1987.

Lt. Asher B. Grimes presented the Eighth Coast Guard District's position that dispersants may be a tool for oil spill mitigation.

However, mechanical cleanup is the preferred method. The EPA and states must decide on whether it is advantageous to use dispersants. The OSC requires that concurrence be made within six hours. The Coast Guard as the DWG Co-Chair, is participating in the development of subpart H of the Regional Contingency Plan which will contain dispersant-use decision procedures and policy.

The main concerns raised in the panel presentations and discussion were contingency planning and dispersant toxicity. A Region 6 dispersant contingency plan is being developed and completion may be expected by the summer of 1987. A dispersant decisionmaking method based on impacts on natural resources is being developed for the Gulf of Mexico by MIRG in cooperation with the States. At this point, the decision to use dispersants is being made on a case-by-case basis, and indications are there will be no pre-authorization agreements.

The toxicity issue is being addressed by LOOP, Inc., and most probably by the Minerals Management Service (MMS). LOOP, Inc., however, is studying toxicity to juveniles and postlarvae of important Gulf species. The proposed MMS study will examine toxicity to the more sensitive eggs and larvae of fishery species and other sensitive organisms, e.g. corals, seagrasses, and turtles.

Ms. Laura Gabanski is an oceanographer with the Environmental Assessment Section of the MMS Gulf of Mexico OCS Region. She has investigated the dispersant issue and has been a member of the Region 6 DWG for the last two years. Ms. Gabanski received her BA degree in biology from Lake Forest College and MS degree in oceanography from Old Dominion University.

Involvement, Status and Issues Related to Dispersant Use

Mr. James H. Lee
U.S. Department of the Interior

This presentation relates to the involvement of the representative and the alternate representative to the Regional Response Team (RRT) with dispersants.

Past Involvement

1981 - DOI RRT Representative, also a member of the American Society of Testing Materials (ASTM), began working on the Dispersants Use Group of the Committee on Oil and Hazardous Materials Spills and Sites to develop standards for evaluating dispersant use.

1983 - DOI RRT representative attended a dispersants workshop hosted by Coast Guard (CG) in Portsmouth, VA. Basically, an introduction to dispersants.

1984 - A dispersants work group formed within RRT in Region IV. First meeting was for some basic training, evaluation of scenarios and to discuss how to proceed in the future. States, DOI, CG, NOAA, and EPA are members.

RRT rep attended Exxon Dispersants Workshop.

1985 - A letter of agreement resulting from the Region IV Dispersants workgroup with State of FL, EPA, CG. DOI did not participate.

1986 - Letter of agreement for dispersants use with Puerto Rico. DOI participated by reviewing document and providing comments.

Dispersants workshop held in St. Thomas, VI. Letter of Agreement drafted. DOI participated in drafting letter and later signed letter. DOI is to be consulted now by OSC and would be notified when dispersants are to be used.

Alternate representative to RRT attended MIRG dispersants workshop in Tallahassee.

Region IV RRT dispersants workgroup is to meet in December 1986 to discuss monitoring dispersant use.

Issues

Natural Resources

The Department has special responsibilities regarding certain natural resources. Those particularly susceptible to spills in offshore waters include our trust resources of land, endangered species, and marine mammals. Spills would affect land such as national parks, seashores, and wildlife refuges, and also endangered and threatened species and/or habitat. We see difficulty if we had to set priorities on these natural resources, especially if we were given the choice of saving one while damaging another.

Toxicity

The Department has continually been concerned with toxicity of dispersants and with the toxicity of oil mixed with dispersants, and how this may affect our resources. We realize that dispersants are now not nearly as toxic as they were a few years ago.

Decision-Making Process

The Department has need of being part of the decision-making process for use of dispersants. RRT's around the country have developed various kinds of decision trees and other means of deciding when to use dispersants. We believe we should be part of that process because of our natural resource responsibilities. In some areas, we are part of the process. In other areas, we are not.

Position

Dispersants are a valid tool that should now be considered on its own merits and considered along with other mechanical methods of cleanup. It is difficult to make a blanket statement concerning use of dispersants, and we feel they should be considered on a case-by-case basis.

Mr. James H. Lee is the Regional Environmental Officer (Southeast Region) for the Office of the Secretary, U.S. Department of the Interior.

The region includes eight (8) southeastern states, Puerto Rico and the Virgin Islands. He represents the Department on the Region IV and Caribbean Regional Response Teams (RRT) for oil and chemical spills; and the Regional Assistance Committee (RAC) for nuclear plant incidents, flood hazard mitigation teams, and emergency preparedness. He also has Environmental Policy Act (NEPA) responsibilities.

Dispersants: An EPA Region IV Perspective

Mr. Mike Norman
U.S. Environmental Protection Agency

Recent developments, including the emergence of less toxic third generation dispersants and revisions to the National Contingency Plan (NCP), have allowed EPA to take a more objective look at dispersants, realizing that in some situations, mechanical cleanup is not feasible and that dispersants may indeed provide the best cleanup option. Subpart H of the NCP allows the Regional Response Teams (RRT) to consider advance planning for dispersants use authorization in the event of an oil spill. Through the RRT, which brings various state and Federal agencies together, advance planning for dispersants use can be considered in a coordinated, organized manner. By exchanging information, ideas, and opinions in RRT meetings, we may reach acceptable dispersants pre-approval policy agreements with the states of Region IV, as allowed by the NCP.

Mr. Mike Norman is an Environmental Engineer with the U.S. EPA's Region IV Office in Atlanta, GA. He serves as a Federal On-Scene Coordinator providing emergency response to oil and chemical spills and directing removal activities at hazardous waste sites. Mr. Norman received his bachelor of civil engineering degree from Georgia Tech.

Oil Spill Dispersant Testing

Dr. Donald R. Ekberg
National Marine Fisheries Services

The use of dispersants, surface collecting agents and biological additives on oil discharges by the On-Scene Coordinator (OSC) is permitted, provided there is concurrence of the EPA representative to the Regional Response Team (RRT) and concurrence of the state involved (40 CFR Part 300 July 18, 1984). These surface active agents and biological additives must also be on the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) Product Schedule. Those items on the schedule must have been tested for toxicity using Fundulus and Artemia (40 CFR Part 300).

In discussing toxicity and effectiveness tests in 40 CFR Part 300, EPA states "EPA acknowledges that these species may not be present in all environments in which dispersants or surface collecting agents may be used in response to an oil discharge, but EPA believes that the toxicity data provided by the test are useful to the OSC in judging whether to use a product on the NCP Product Schedule". EPA cannot be expected to require testing of all major species from all areas (the testing is done by the manufacturer and submitted to EPA), but some testing should be done using major species such as penaeid shrimp and menhaden.

Table 4.1 lists the dispersants, collecting agents, and miscellaneous control agent toxicities that appear in the NCP Product Schedule. There is not only a wide range of toxicity levels, but in all cases, the material tested is more toxic than the oil itself, and, in several cases, the oil dispersant mixture is listed as more toxic than the dispersant alone. Bioassays performed at various times and places on different stocks of organisms may be expected to yield a wide range of results, but three orders of magnitude is excessive (See Table 4.2). In Table 4.2, number 2 fuel oil toxicity is compared, as tested by several product manufacturers. Since number 2 fuel oil toxicities are reported with such a wide range, the usefulness of the data given for dispersants, and dispersants plus oil toxicities are questionable.

Further testing such as that proposed by Heikamp (see A.J. Heikamp report for Federal Region 6 - this meeting) using brown and white shrimp, red drum, blue crab, and eastern oyster should give data useful to on-scene coordinators in planning for the use of dispersants. Field testing of dispersants in which biological, chemical, and physical parameters are measured is also recommended, since laboratory testing alone may not include assessment of the several variables that can alter the effectiveness of oil spill dispersants (see Table 4.3).

Dr. Donald R. Ekberg received the Ph.D. degree in physiology from the University of Illinois in 1957. He is currently the Regional Scientific Coordinator for the NOAA/NMFS Southeast Region and the Department of Commerce Regional Response Team (RRT) member for Region IV.

Oil Dispersant Use in Alabama State Waters

Mr. Gary L. Halcomb
Alabama Department of
Environmental Management

The Alabama Department of Environmental Management (ADEM) is studying the use of chemical oil dispersants as a means of protecting Alabama's coastal resources in the event of an oil spill in area waters.

Although no regulations have been promulgated by the State of Alabama for the use of chemical dispersants, a tentative plan is as follows: Large scale area applications of chemical dispersants may be useful for some oil spills in the Northern Gulf of Mexico. A possible scenario favoring use of chemical dispersants would be that of southerly winds blowing floating oil from a tanker accident or well blowout towards the Alabama Coast. Dispersal may cause Gulf currents to transport oil away from State waters.

Dispersants may also be useful in small scale applications in Mobile Bay and the Mississippi Sound. These efforts would be directed towards preventing oil from entering salt marshes and productive hard bottom areas. However, ADEM and the Alabama Department of Conservation and Natural Resources still prefer mechanical containment and clean-up for oil in quiescent backwaters, small bays, marshes, and tidal flats. There are concerns of both ADEM and Alabama Department of Conservation and Natural Resources that large scale use of chemical dispersants in these shallow water environments would introduce petroleum hydrocarbons into the water column in concentrations sufficient to cause significant loss of fisheries resources.

Mr. Gary L. Halcomb is with the Mobile Office of the ADEM. His responsibilities include monitoring sediments of offshore oil and gas drilling sites for compliance with State regulations prohibiting discharge of drilling wastes. Other responsibilities include response to oil spills and inspection of natural gas processing plants. Mr. Halcomb was previously employed by Barry A. Vittor and Associates where he participated in water quality and biological resource surveys. Mr. Halcomb received a M.S. in aquatic ecology and a B.S. in biology from the University of Alabama.

Mississippi's Dispersant Policy

Mr. Richard V. Ball
Mississippi Bureau
of Pollution Control

The Mississippi Bureau of Pollution Control is responsible for oil and chemical spill response. The Bureau of Marine Resources, which provides scientific support, has prepared an oil spill contingency guide for coastal protection. The State's goal in spill response is protection of sensitive environments by diversion of oil to less sensitive areas for removal. Dispersants are not approved for use in State waters due to concerns with toxicity and effectiveness. Dispersants may be a useful tool but, until toxicity data on Mississippi coastal marine species are available, dispersants will not be approved for use.

Mr. Richard V. Ball is an on-scene coordinator for oil spills with the Mississippi Bureau of Pollution Control. He received a B.S in marine biology from the University of South Alabama.

Dispersant Use in Oil Spill Response

Dr. John P. Fraser
Shell Oil Company

There are four major countermeasure options available for oil spill response:

- Mechanical Removal
- Chemical Dispersion
- Shoreline cleanup
- Natural removal (i.e., by evaporation, biodegradation, photooxidation, solution, etc.)

The choice of which countermeasure(s) to use in any given spill event will depend on a variety of factors, such as the size of the spill, what product has been spilled, where it was spilled, meteorological and hydrographic conditions at the time of the spill, sensitivity of the environment to spilled oil, and availability of equipment and supplies. One of the primary purposes of this presentation is to indicate when dispersant use may be one of the preferred options, based on operational considerations. Other considerations which will be discussed include 1) would dispersant use be effective, 2) would use of dispersants be environmentally acceptable, and 3) would use be allowed by regulation?

This presentation will also outline a project which is now underway to develop a method for oil spill dispersant use decision-making. The method is based on a quantitative comparison of the environmental impacts which would be caused by dispersed oil vs. the environmental impacts of untreated oil. Although development of the method is being funded by industry, affected federal and state regulatory agencies are heavily involved in this project. If the project is successful, it should provide a means to expedite decision-making at the time of a spill, by indicating clearly those areas and conditions (e.g., season of the year) in the Gulf of Mexico in which dispersant use normally should be considered favorably.

Dr. John P. Fraser is a Senior Staff Engineer with Shell Oil Company, with responsibility for oil spill countermeasures planning and response. He has been involved in oil spill research and development, and operations since 1969. His present activities include participation with the API Spill Response Task Force and with the Committee on Oil Spill Dispersant Effectiveness of the National Research Council. He is also involved with the Dispersant Working Groups of the Regional Response Teams of Federal Regions 4 and 6. His educational background includes the bachelor of chemical engineering degree and the Ph.D. in metallurgy, both from Cornell University.

Preplanning for the Use of Dispersants

Lt. Commander Tony E. Hart
Seventh Coast Guard District

Subpart H to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) authorizes the On-Scene Coordinator (OSC) to use dispersants on oil discharges if certain conditions have been met. Primary among these is the requirement that the EPA representative to the Regional Response Team (RRT) and the affected State both concur with the dispersant use. Since the effectiveness of dispersants is time critical, the sooner the OSC can obtain concurrence and the dispersant applied, the more effective the application should be. However, obtaining concurrence after a spill can be so time consuming that optimal use is no longer possible. Preplanning for dispersant use will afford the OSC a greater range of options for response, and if dispersant use appears to be desirable, this can significantly increase its performance.

In the Seventh District, we believe that there is a place for dispersant use and that because of the size of a spill, its location or difficulties that might be encountered with physical recovery serious consideration will have to be given to dispersant application. At such time, one way to expedite the decision-making process is in the way of agreements which pre-authorize the OSC to use dispersants. The NCP encourages RRTs to plan for such use and to have pre-authorizations in place. In September 1984, the Region IV RRT developed an agreement for the use of dispersants for the part of Florida that is within the Seventh Coast Guard District. This agreement signed by the Coast Guard, Region IV EPA, and the State of Florida authorizes the Coast Guard On-Scene Coordinators to use dispersants with certain constraints without the need for further concurrence. Key elements of the agreement include:

- Physical or mechanical removal is still the preferred recovery method.
- Dispersants may be used in areas greater than 3 miles from shore where the water depth is greater than 20 meters.
- Dispersants shall not be used in shellfish propagation areas, over reefs, marshes, aquatic preserves, in mangroves or inside 3 miles of the shoreline without further concurrence of the State and EPA.

Although in effect for two years, no dispersant application under the agreement has been necessary. However, at least on two occasions, involving spills off the Florida Keys, the OSC has considered dispersant use. In both of these instances, currents kept the oil offshore where it naturally dispersed.

Two similar agreements have been developed by the Seventh District and the Caribbean RRT for Puerto Rico and the U.S. Virgin Islands. While none of these agreements allow for the unrestricted use of dispersants, each does provide specific areas where the OSC has been given the required concurrence to use them and areas where they cannot be used without further discussion with EPA and the State.

The key to an effective and successful response is having an organization and contingency plan in place. The agreements are an integral part of the Region IV and Caribbean RRT's contingency plans and when used in conjunction with other elements of the response plan these agreements will result in a more timely and informed decision as to whether dispersants should be used.

Lt. Commander Tony E. Hart is currently serving as Chief of the Marine Environmental Protection Branch, Seventh Coast Guard District, in Miami, Florida. His duties entail administration of the Coast Guard's enforcement of pollution regulations in the Seventh District, maintaining the regional contingency plan for the coastal areas, and logistical support for the Coast Guard pre-designated OSC.

Lt. Commander Hart received his BS from the U.S. Coast Guard Academy and an MS in transportation engineering from Seattle University.

U.S. Department of the Interior, Region VI Status and Issues Related to Dispersant Use

Mr. Raymond P. Churan
U.S. Department of the Interior

This presentation summarizes the responsibilities of the Department of the Interior for trustee resources in the Gulf of Mexico and coastal areas along Texas and Louisiana which are of concern in making dispersant-use decisions.

The Department serves as Federal trustee for lands designated as National Wildlife Refuges, National Seashores, National Parks, and for the lands included in the Federal Outer Continental Shelf (OCS) area. Also, the Department serves as Federal trustee for migratory birds and threatened and endangered species.

In the coastal area of Louisiana, the Department manages 2 refuges which include about 100 miles of coastal shoreline, several species of threatened and endangered species and significant numbers of migratory birds which can be impacted by offshore oil spills.

In addition, the Department has leasing responsibility for OCS lands in the Gulf and has permitted over 4,000 exploration or production structures offshore of both Texas and Louisiana which can be potential sources of an oil spill for which dispersants could be used for spill abatement purposes.

Issues

Natural Resources

The Department has special responsibilities regarding trustee resources. Spills can affect lands such as national Parks, seashores, wildlife refuges and also threatened and endangered species and/or their habitat. It is difficult to set priorities on these resources, especially if given the choice of impacting one at the expense of another.

Toxicity

The Department is concerned with toxicity of dispersants and with the toxicity of oil mixed with dispersants, and how this may affect trust resources. Dispersants are not nearly as toxic as they were a few years ago. However, there is inadequate data on toxicity of chemical dispersants and dispersed oil on Gulf of Mexico species.

Decision-Making Process

The Department should participate in the decision-making process for use of dispersants. RRT's around the country have developed various kinds of decision trees and other means of deciding when to use dispersants. We believe we should be part of that process because of our natural resource responsibilities. In some areas, we are part of the process. In other areas, we are not.

Department Position Concerning Dispersants

A tool we want to have available. If a major spill occurs, we first use mechanical means, then supplement with dispersants if warranted in order to minimize impacts to important resources. Dispersants should be considered on a case-by-case basis.

Mr. Raymond P. Churan is the Regional Environmental Officer (Southwest Region) for the Office of the Secretary, U.S. Department of the Interior.

The region includes five (5) southwestern states (NM, OK, AR, TX and LA). He represents the Department on the Region VI Regional Response Team for oil and hazardous materials spills, the Regional Assistance Committee for radiological incidents, the Flood Hazard Mitigation Team for major floods and for regional emergency planning preparedness. He also has National Environmental Policy Act responsibilities for the Department in this region.

Planning for Use of Dispersants for Oil Spill Mitigation: Status and Issues

Mr. Donald Moore
National Marine Fisheries Service

The Department of Commerce (DOC), named as a participating agency in the National Oil and Hazardous Substances Contingency Plan (NCP), is represented on the National and Regional Response Teams by the National Oceanic and Atmospheric Administration (NOAA). Under the NCP, NOAA also provides, upon request, Scientific Support Coordinators (SSC) to assist On-Scene Coordinators (OSC) on the scientific aspects of responses to releases of oil and hazardous substances in coastal and marine areas. The DOC/NOAA is also designated in the NCP as a federal trustee for natural resources under its management or protection that may be destroyed or damaged by releases of oil or hazardous substances.

Because the SSC serves under the direction of the OSC and is responsible for coordinating all scientific advice on response operations, that person does not represent the policy views of any single agency, including DOC/NOAA. The SSC's specific duties include (1) providing liaison between natural resource, chemical, medical, and other scientific experts and the OSC (2) modeling trajectories of released materials to predict movement of the contaminant, and drawing on appropriate modeling capabilities within NOAA and elsewhere; (3) assessing the nature, behavior, and fate of pollutants; (4) advising on safety precautions for response personnel; (5) identifying areas of special biological importance requiring protection; (6) helping the OSC respond to requests from local, state, and federal agencies for assistance in scientific studies and environmental assessments; and (7) assisting the OSC's public relation efforts on scientific issues. During non-response periods, the SSC assist the OSC and the RRT by obtaining scientific data to improve regional and local contingency planning. These data include: 1) forecasting pollutant trajectories with respect to specific areas or biologically important environments; 2) identifying environmentally sensitive regions; 3) obtaining background data on the behavior of various pollutants under a range of environmental conditions; and 4) predicting the environmental impact of alternative cleanup strategies.

The NMFS Southeast Regional Office provides DOC/NOAA RRT representatives for Standard Federal Regions IV and VI. They are assisted as appropriate by regional staff of other NOAA elements. The DOC/NOAA representatives assist the RRT and OSC in obtaining NOAA data and resources to support a response, including (1) charts and maps; (2) tide and circulation information; (3) satellite imagery; (4) meteorological, hydrologic, and oceanographic data for marine, coastal, and certain inland waters; (5) information on marine fisheries, marine mammals, and certain endangered species; (6) use of the National Weather Service (NWS) communications network, (7) special-purpose NOAA aircraft and/or vessels, if these are needed, and (8) advice on the use of oil dispersants, provided in consultation with NMFS fishery research center staff. With regard to the use of dispersants, we are asked first to determine, among other things, whether the damages to habitats and resources resulting from chemical dispersion will be less than those without chemical dispersion.

Since the Region 6 RRT Dispersant Workgroup was formed in 1985, we have been exploring what living marine resources may be at risk to dispersed oil in various seasons and locations. We have also been examining available long and short term toxicity information concerning dispersed oil on marine organisms. The SSC is having a nearly completed search and synthesis conducted of the literature bearing on that subject. So far we have found little to no information on dispersed oil toxicity and sublethal impacts on early life stages of major Gulf fish and shellfish, such as menhaden and shrimp.

To have a dispersant placed on the Environmental Protection Agency's (EPA) NCP Product Schedule, the producer is required to submit results of toxicity bioassays that use only killifish, Fundulus, and brine shrimp, Artemia, both of which are hardy enough to have relative low rates of natural mortality. Also, the test organisms are usually offspring of many generations of laboratory reared organisms and thus may be even more resilient than wild stock. An examination of bioassays performed on No. 2 fuel oil alone by several dispersant producers reveals some great variability of test results (see Table 4.2, Ekberg, this session). No. 2 fuel oil LC 50 toxicity appeared to vary from > 1,000 ppm to 67,000 ppm for Fundulus (96 hr.) and from 43 ppm to 44,000 ppm for Artemia (48 hr.). Since each dispersant would be expected to have different toxicities, we have not been able to determine whether there were similar large variabilities in the results of dispersed oil bioassays.

Since shrimp and menhaden lead in total value and weight, respectively, of commercial landings in the northwestern Gulf and since both resources spend their early life stages offshore, we examined the few instances in which abundance of those stages were already mapped throughout the part of the Gulf. Examination of the distribution of planktonic stages of penaeid shrimp, Penaeus spp., revealed levels of abundance over much of the continental shelf that varied greatly between seasons and years (Figures 4.1-7) (Temple, et al, 1964; Temple and Fischer, 1965a and 1967; and Fischer, 1966 and 1967). They were distributed throughout the water column (Figure 4.8) (Temple and Fischer, 1965b). Gulf menhaden spawning areas, as determined by the occurrence of eggs, were also found over much of the continental shelf from October through March (Figures 4.9, 4.10, and 4.11) (Fore, 1970; (Christmas and Waller 1975).

In view of (1) our not being aware of any dispersed oil bioassay results on early stages of major Gulf fishery species, (2) extremely great variability of bioassay results in the same medium, (3) the abundance of these early life stages over much of the continental shelf and(4) great seasonal and annual variation in the distribution and abundance of these organisms, we have been recommending that dispersants use not be preauthorized in the northwestern Gulf. However, we will reevaluate this recommendation in light of new information that may be developed, such as future bioassays determining that dispersed oil in the water column will not significantly impact these resources. In the meantime, we have been working with other RRT members on the Region 6 Dispersant Workgroup, as well as with the Marine Industry Group, to develop a regional contingency plan to enable OSC's, who wish to consider dispersant use for a specific oil spill, to reach a rapid, well-informed decision.

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Mr. Donald Moore, Area Supervisor of Habitat Conservation (formerly Environmental Assessment), NOAA National Marine Fisheries Service from 1970 to present; the Supervisory Fishery Biologist (Ecologist), supervising the Service's evaluation of proposed federal, and federally permitted, construction and discharges in the coastal zone of, and outer continental shelf off, Louisiana and Texas. Evaluations are for the activities' impacts on marine fishery resources and their habitats with recommendations toward eliminating adverse impacts. The NOAA representative on the Gulf of Mexico Regional Technical Working Group for the Outer Continental Shelf, since 1979.

Mr. Moore is the Department of Commerce representative on the Federal Region 6 Regional Response Team for discharges of oil and releases of hazardous substances, since 1985.

Dispersants: Can They Help Louisiana's Resources?

Mr. R. Bruce Hammatt
Louisiana Department of Environmental Quality

Louisiana's economy is based to a significant degree on the production and transportation of petroleum products on our waterways, and for this reason, we have the potential for major accidental spills along our coast. The Louisiana Offshore Oil Port also handles a large percentage of the supertanker transports for the United States and has an average design capacity of 1.4 million barrels of throughput per day. New Orleans and Baton Rouge are, respectively, the largest and fifth largest ports in the nation with a major portion of the commerce through these ports being related to petroleum products.

Of primary concern in Louisiana is the protection of the great renewable resources that exist in our coastal region. Approximately forty percent of the coastal wetlands of the contiguous forty-eight states are contained in Louisiana. The integrity and protection of these wetlands and offshore resources is of paramount importance to the maintenance of current levels of fisheries production.

The approval for the use of oil spill dispersants, surface collecting agents, and biological additives (collectively termed dispersants) on oil discharges by the Federal On-Scene Coordinator is permitted, provided there is concurrence of the Environmental Protection Agency and the affected state representative to the Regional Response Team (RRT). To protect our coastal resources, the Department of Environmental Quality (DEQ), as the state representative on the RRT, along with other state and federal agencies, has been actively reviewing the available information relative to the use of oil spill dispersants since the fourth quarter of 1984. It is DEQ's firm opinion that oil spill dispersants must be considered as one of the primary "tools" which can be used to mitigate the effects of a major oil spill event.

The DEQ has been participating on the Region VI RRT Dispersant Use Task Force which was asked to identify where, and under what conditions, should dispersants be used to reduce the damages resulting from a major oil spill in the northern Gulf of Mexico. One of our major concerns is that the necessary decisions by the agencies involved be made as rapidly as possible at the time of a spill. To accomplish this in a timely manner, we believe that adequate preplanning is the most essential ingredient to the proper handling of an oil spill.

We have requested the advice and support of other federal and state agencies along with private industry to assist us in identifying specific areas of concern regarding dispersants usage and their possible solutions. This cooperation is necessary to make the case-by-case decisions regarding dispersant usage within an appropriate time period after our initial notification of the oil spill.

Recently, the U.S. Department of the Interior and Commerce have requested they be included in the final decision process as <u>concurring</u> agencies. We agree there is a need for these agencies to have input into the dispersant use/non-use decision process; however, we feel their input could be primarily handled in the preplanning stage. The major concept these agencies are presenting, that they are trustees of resources in the area of concern, could just as equally be applied to other state agencies as well as local government.

Each of these agencies should be consulted whenever practicable regarding the specifics concerning a major spill which may affect resources under their jurisdiction prior to making a final decision. However, we feel it is incumbent on the RRT to keep the concurring agencies in the decision process down to as few as practicable while still being consistent with Subpart H of the National Contingency Plan.

Although most of the discussions regarding dispersant usage in Louisiana to date have dealt primarily with the decision process, we also recognize the proper application of the dispersants on the spilled oil is another step that needs to be reviewed and better understood. There is not enough expertise within any of the member agencies of the RRT to verify that dispersants would be applied in the most environmentally sound and cost effective method. To obtain this expertise among the federal and state agency personnel, we believe the RRT should actively encourage and promote open-Gulf field testing of the dispersants on some of the more predominant oils produced and transported in the Gulf. This process of controlled testing, evaluating, and retesting the various dispersants and oil mixtures would be invaluable in determining the overall effectiveness and efficiency associated with their use.

These tests could also be used to greatly enhance our knowledge regarding the effects the dispersants and dispersed oils have on some of the more important species in the Gulf. The DEQ would like to see these tests conducted in an area along our coast where sufficient information on the biological communities already exists so that we can qualitatively and quantitatively identify any adverse effects resulting from the various dispersants and oil mixtures used in the test. Obviously, this testing would have to be a cooperative effort with federal and state agencies working closely with private industry.

Although we have identified several unresolved issues regarding the proper use of oil spill dispersants, the DEQ has concluded there are some potential oil spill situations in which dispersant use would be the preferred countermeasure option.

Mr. R. Bruce Hammatt is the Statewide Emergency Response Coordinator for the Office of Water Resources, Louisiana Department of Environmental Quality. He has been designated as the alternate state representative to the EPA Region VI RRT and is also the state representative on the Regional VI RRT Dispersant Use Task Force.

Mr. Hammatt received his B.S. in forestry and wildlife management and his M.S. in wildlife from Louisiana State University, Baton Rouge, Louisiana.

Planning for Use of Dispersants for Oil Spill Mitigation: Status and Issues

Mr. David Barker
Texas Water Commission

BRIEF PROJECT HISTORY

By State law, the Texas Water Commission (TWC) is designated as the State's lead agency in spill response. The TWC provides the State's primary member to the Federal Region VI Regional Response Team (RRT). The State's Oil and Hazardous Substances Spill Contingency Plan is published and maintained by the TWC. Through this authority and this process, the TWC attempts to exercise the State's stated policy in the law to prevent a spill or discharge of hazardous substances into the waters in the State and to cause the removal of any spills and discharges without undue delay.

Due to the RRT's interest in improving response to oil spills in the Gulf of Mexico and perception that dispersants and dispersant use technology has improved through the years, a dispersant work group was established during the RRT's meeting of March 7, 1985. The work group's mission was to examine the issue of dispersants and to develop an approved RRT checklist for dispersant use.

The TWC elected to volunteer to participate in the activities of this work group because of its legislative directives and federally mandated role in dispersants use decision-making under the National Contingency Plan. The TWC cooperates with all involved and/or interested State agencies. Two other State agencies, the Texas Parks and Wildlife Department and the Texas Department of Health, have an intimate interest in the issues surrounding the use of dispersants in the Gulf of Mexico.

ACCOMPLISHMENTS

As a result of the work group's efforts, the following has been achieved or developed at the present:

1. Oils transported and produced in the Gulf of Mexico have been identified along with the properties or specifications for each one.
2. A Federal Region VI "Dispersant Checklist" has been developed and approved by the RRT. All OSC's in the Region have been provided a copy of the checklist for use as deemed necessary.
3. Readily available dispersant stockpiles and application equipment have been identified for the Gulf of Mexico.
4. An information search regardingthe fate and effects of dispersants and dispersant/oil mixtures is continuing.
5. Environmental/logistical response maps have been identified and adopted by the RRT for consistent review in dispersant use decision-making. The environmental atlas designated for Texas is the Coastal Spill Response Map Series maintained by the TWC.
6. The "Dispersant Work Group" identified six issues which have been adopted by the RRT along with recommendations as follows:

   a. Issue: There is a lack of information on the fate and effect of dispersants and oil mixtures in the Gulf of Mexico.

   Recommendation: Develop a joint funding effort among the Federal and State governments and private industry to address the existing data gap in a timely manner.

   b. Issue: There is a need for a checklist for obtaining technical data to address requests for the use of dispersants.

   Recommendation: Use the Region 6 dispersant use checklist as a tool to assist the On-Scene Coordinator (OSC) and the RRT in making a decision concerning the use of dispersants.

   c. Issue: There is a need for common reference maps for use by RRT members during the dispersant decision-making process.

Recommendation: Use the following maps: Texas Water Commission's Spill Response Maps; National Oceanic and Atmospheric Administration's (NOAA) 1:80,000 scale coastal charts; the Minerals Management Service's (MMS) West and Central Gulf block charts.

d. Issue: There is a need for quality assurance/quality control (QA/QC) during dispersant application and a need for qualified personnel to perform QA/QC during dispersant application.

Recommendation: Establish criteria for identifying qualified personnel and identify personnel from Federal and State government and private industry to perform QA/QC during dispersant application.

e. Issue: There is a need for environmental monitoring during and after dispersant application.

Recommendation: Develop an environmental monitoring program which may include pre-monitoring agreements among Federal and State government and private industry on a case-by-case basis.

f. Issue: There is a need for developing rapid transmission for timely communication of information among RRT members.

Recommendation: Establish an RRT "Communications Work Group" to address rapid communications needs in general.

SIGNIFICANT FINDINGS

1. It appears that dispersant/oil mixtures are more toxic than either oil or the dispersant alone. The most effective dispersants seem to be the most toxic. With respect to toxicity, data are lacking for the commercially important Gulf specific organisms and the readily available dispersant stockpiles.
2. Texas has a unique coastline in that its bays and estuaries are protected by barrier islands which have a sand/shell substrate with a low sensitivity to oil spills. For substantial reaches, the beach is used for recreational purposes. Local, State and Federal authorities have demonstrated a belief in removal of oil from the beach following a spill. Other than the loss in recreation and tourism, the oiling of a beach and cleanup seem to impact the beach sand budget and the party assuming responsibility for the cleanup. These impacts may be documented, whereas impacts to the commercial fisheries and other biota are more difficult if not impossible to assess with existing data and current limitations.
3. For many reasons, a dispersant will not be 100 percent effective under field conditions. Shoreline impacts will continue to occur. Shallow water impacts may be greater.

RECOMMENDATION

With consideration given to all these issues and the state of dispersant use technology, Texas should probably deny any request for use of a dispersant unless the application will occur many miles from shore and the trajectory for the untreated spill indicates a major impact through a pass in the barrier island.

Mr. David Baker is the Texas Member of the Regional Response Team. He works for the Texas Water Commission. He has developed the State's contingency plan and spill response maps which are valuable for deployment of cleanup resources and strategies.

Mr. Barker received his BS and MS from Southwest Texas State University. His major and minor courses of study were biology and chemistry, respectively.

LOOP Toxicity Testing Program

Mr. A. J. Heikamp, Jr.
Louisiana Offshore Oil Port, Inc.

Louisiana Offshore Oil Port, Inc. (LOOP) first became interested in the use of dispersants in the Gulf of Mexico after attending an Exxon sponsored dispersant seminar in Houston, Texas in February of 1984. LOOP then proceeded to help arrange two dispersant seminars in Baton Rouge, Louisiana, in September of 1984 and January of 1985. At both seminars, it became apparent that there was concern over the lack of toxicity data on commercially important species indigenous to the Gulf of Mexico. This concern was again prevalent at an industry-sponsored dispersant planning seminar in April of 1986.

As a result, LOOP has agreed to conduct toxicity tests on the following Gulf species: brown shrimp (Penaeus aztecus), white shrimp (Penaeus setiferus), blue crab (Callinetes sapidus), eastern oyster (Crassostrea virginica), and the red fish. Three types of tests will be performed: (1) Static 96-hour LC50 test; (2) Flow through 96-hour LC50 test; and (3) 30-day life cycle study. The crude oil to be tested is Mayan crude from Mexico and the dispersant to be tested is Exxon's Corexit 9527. The static 96-hour LC50 test will be performed on the white shrimp and redfish. The flow-through, 96-hour LC50 test will be performed on all five previously mentioned species. The 30-day life cycle study will be performed on the white shrimp. The redfish and eastern oysters will be tested in December of 1986. The brown shrimp and blue crabs will be tested in the spring of 1987 with the white shrimp test scheduled for the summer of 1987.

Mr. A. J. Heikamp, Jr. is the Superintendent of the Environmental Affairs and Safety Department at LOOP, Inc. He received his BS in civil engineering and MS in environmental engineering from Tulane University. He is a registered Professional Engineer in Civil Engineering in Louisiana.

Planning for Use of Dispersants for Oil Spill Mitigation: Status and Issues

Lt. Asher B. Grimes
Eighth Coast Guard District

The Coast Guard position in the Eighth District is that dispersants may be a tool that the On-Scene Coordinators (OSC) may want to use to minimize the environmental effects of an oil spill. The preferred method is still mechanical cleanup, but there may be instances where dispersants could be used. The Coast Guard would like the OSC to have dispersants available as another tool to mitigate oil spill impacts in situations where their use is appropriate.

In a non-emergency, non-life threatening spill situation, the Coast Guard OSC's would ask for EPA and state concurrence if the spill would impact environmentally sensitive areas and if the oil was dispersible. If the spill would impact resources managed by the

Department of Interior or Commerce, those agencies would be consulted. The EPA and states will have to decide if the benefits of dispersant use outweigh the disadvantages. The concurrence is needed within 6 hours so the OSC may make a timely decision. Dispersant effectiveness diminishes as the spill weathers.

In the spring of 1985, the Regional Response Team formed a Dispersant Work Group to develop dispersant use decision procedures and policy. The group is in the process of developing subpart H to the Regional Contingency Plan which will contain comprehensive guidance on dispersant use in Region 6. The following is an outline of the plan:

A. Notifications by OSC of concerned agencies
B. Checklist information on the spill
C. Decision Matrix decision method used by each state or agency
D. List of Oils
   1. Transported in the Gulf
   2. Produced in the Gulf
   3. Dispersibility of oils
E. Dispersants and equipment available in area
F. Resource chart
   1. Texas
   2. Louisiana
   3. Department of the Interior
G. Toxicity data
H. Quality control and assurance
I. Environmental Monitoring agreements, baseline data.
J. MMS Policy
K. Dispersant Field Tests when oil dispersability is unknown.

Lt. Asher B. Grimes is with the Marine Environmental Protection Branch of the Eight Coast Guard District. His duties include contingency planning and review, and monitoring U.S. Coast Guard responses to oil and chemical spills. He has been involved with pollution response and marine safety for seven years. Currently, he serves as co-chair of the Region 6 Regional Response Team Dispersant Working Group.

Lt. Grimes is a graduate of the U.S. Coast Guard Academy.

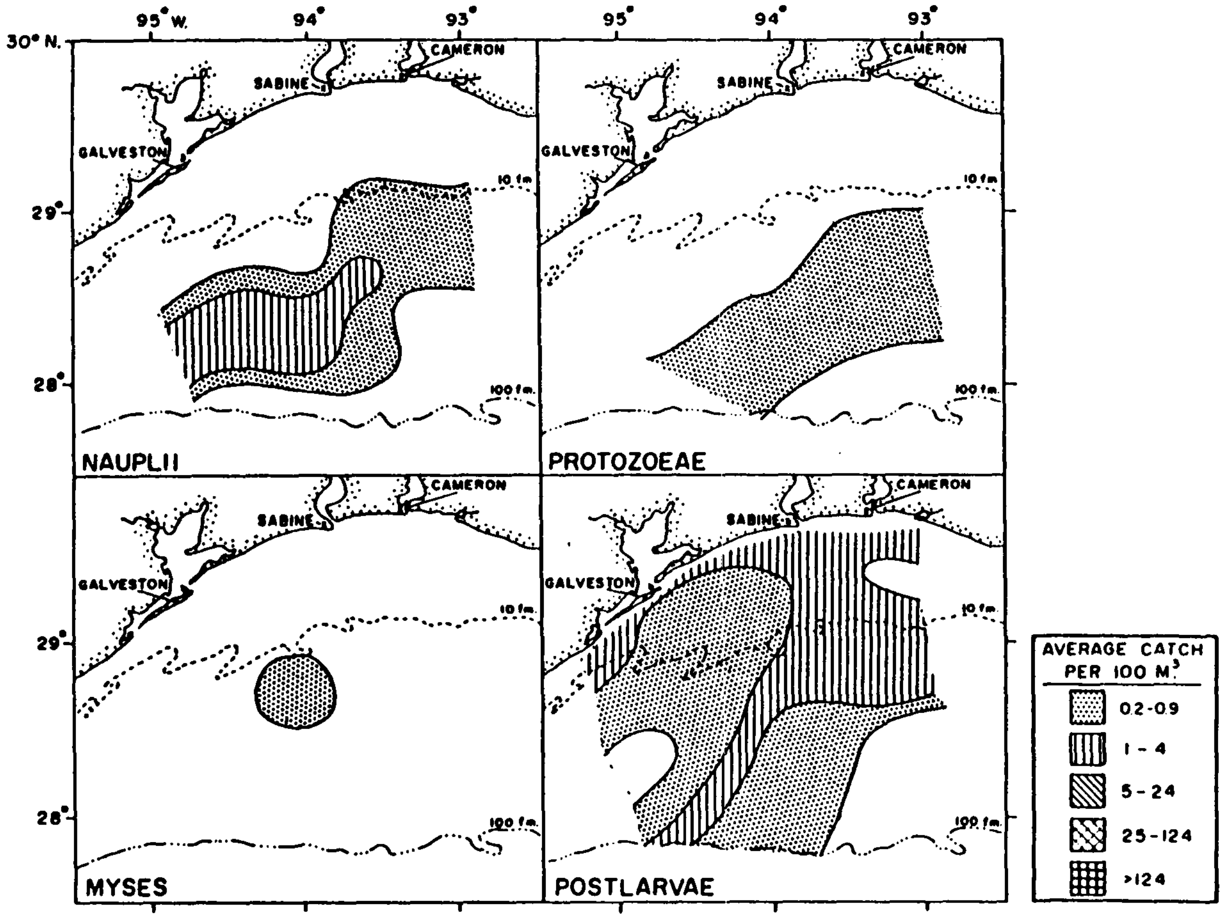

Figure 4.1.--Relative abundance and distribution of planktonic-stage Penaeus spp., January to March 1961. (from Temple and Fischer, 1967).

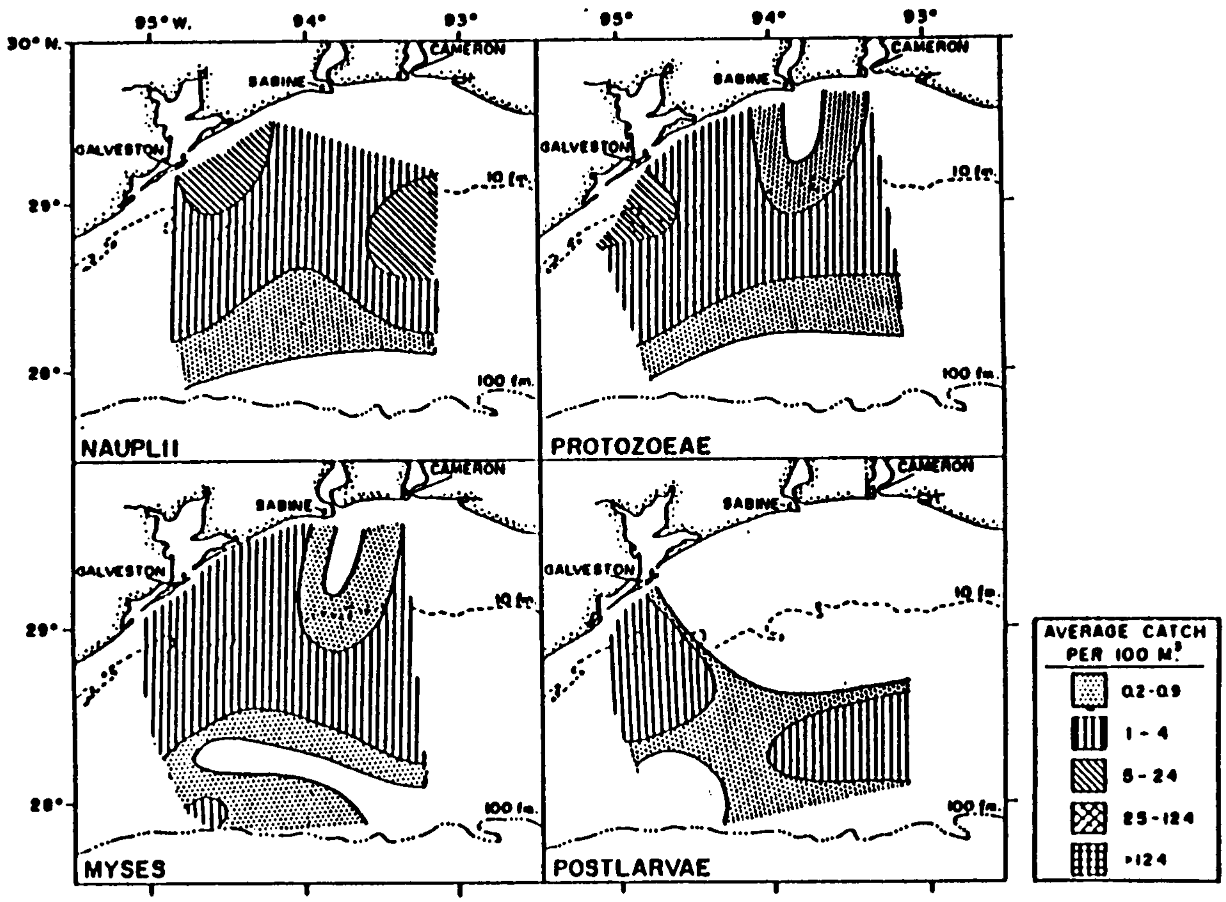

Figure 4.2.--Relative abundance and distribution of planktonic-stage Penaeus spp., April to August 1961. (from Temple and Fischer, 1967).

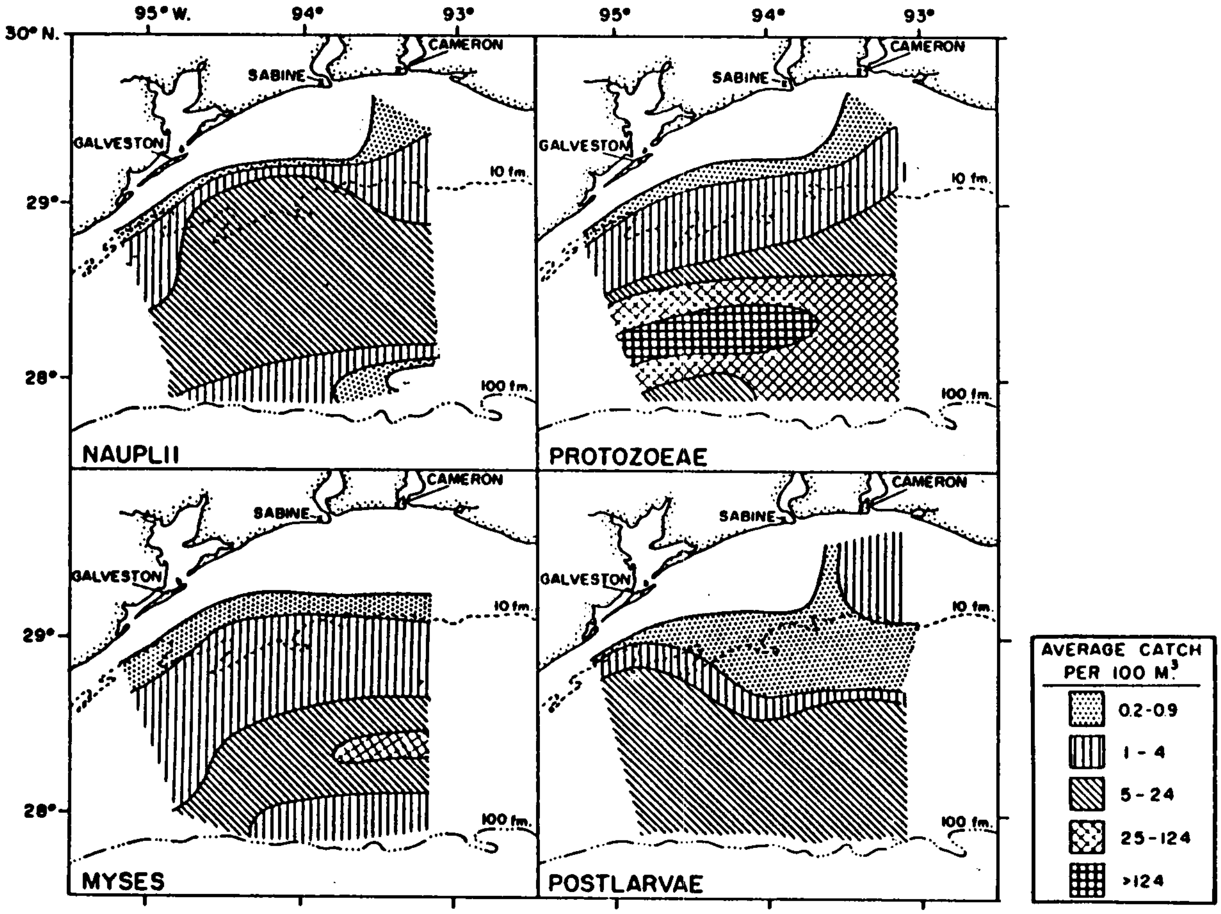

Figure 4.3.--Relative abundance and distribution of planktonic-stage <u>Penaeus</u> spp., September to December 1961. (from Temple and Fischer, 1967).

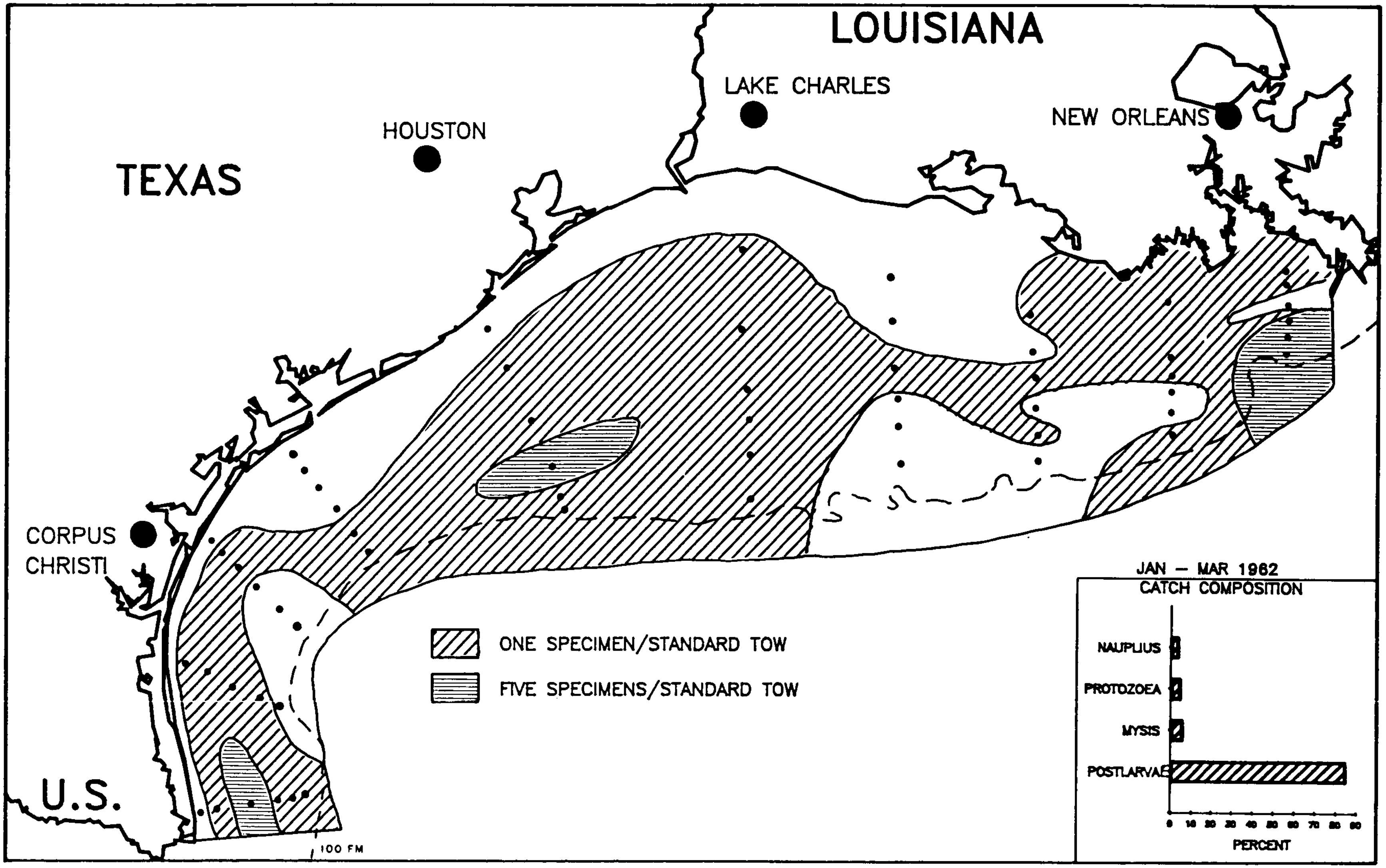

Figure 4.4a.--Distribution of planktonic stages of Penaeus spp. in the northern Gulf of Mexico during the period January-March 1962. (re-drawn from Temple et al., 1964).

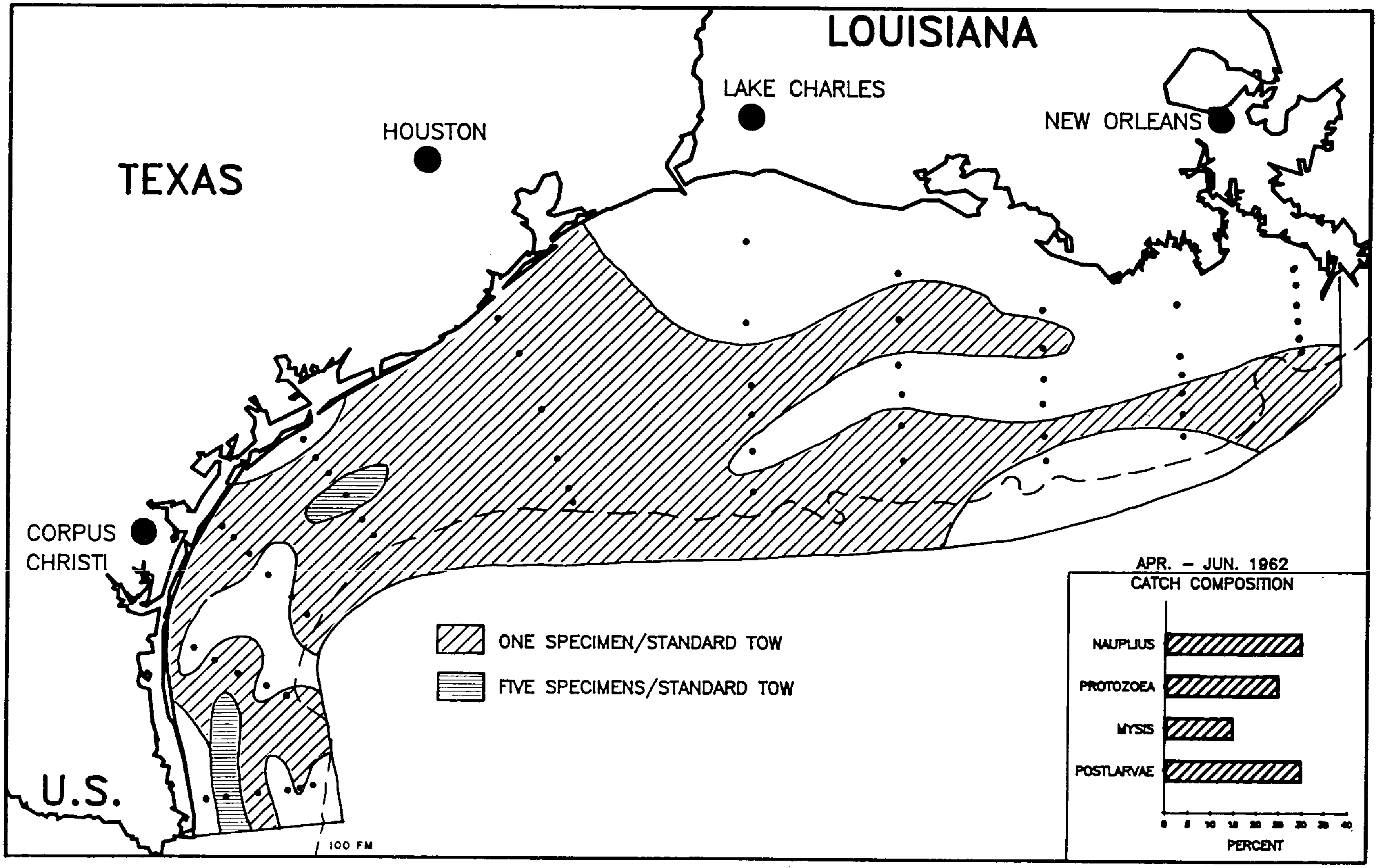

Figure 4.4b.--Distribution of planktonic stages of Penaeus spp. in the northern Gulf of Mexico during the period April-June 1962. (re-drawn from Temple et al., 1964).

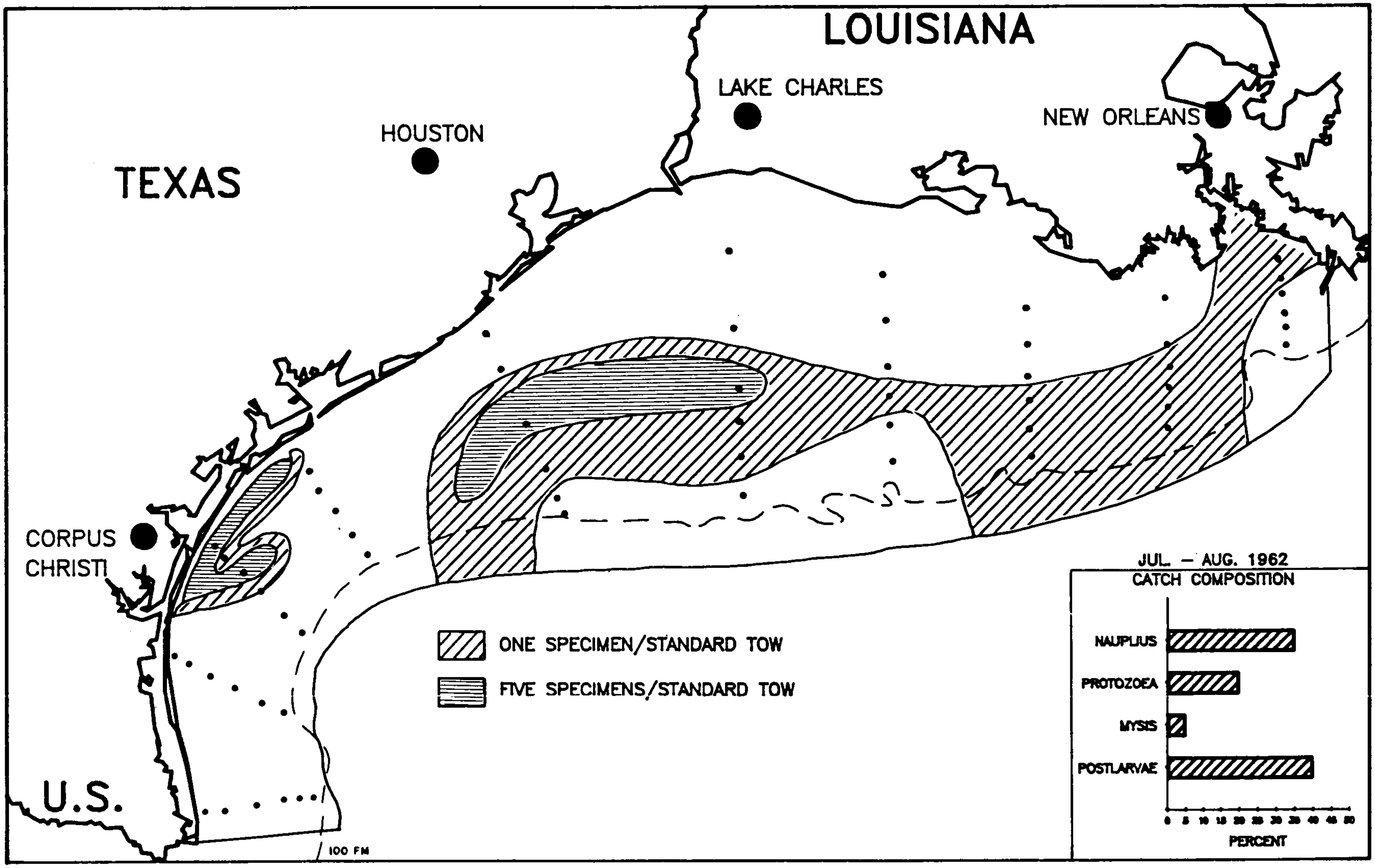

Figure 4.4c.--Distribution of planktonic stages of <u>Penaeus</u> spp. in the northern Gulf of Mexico during the period July-August 1962. (re-drawn from Temple et al., 1964).

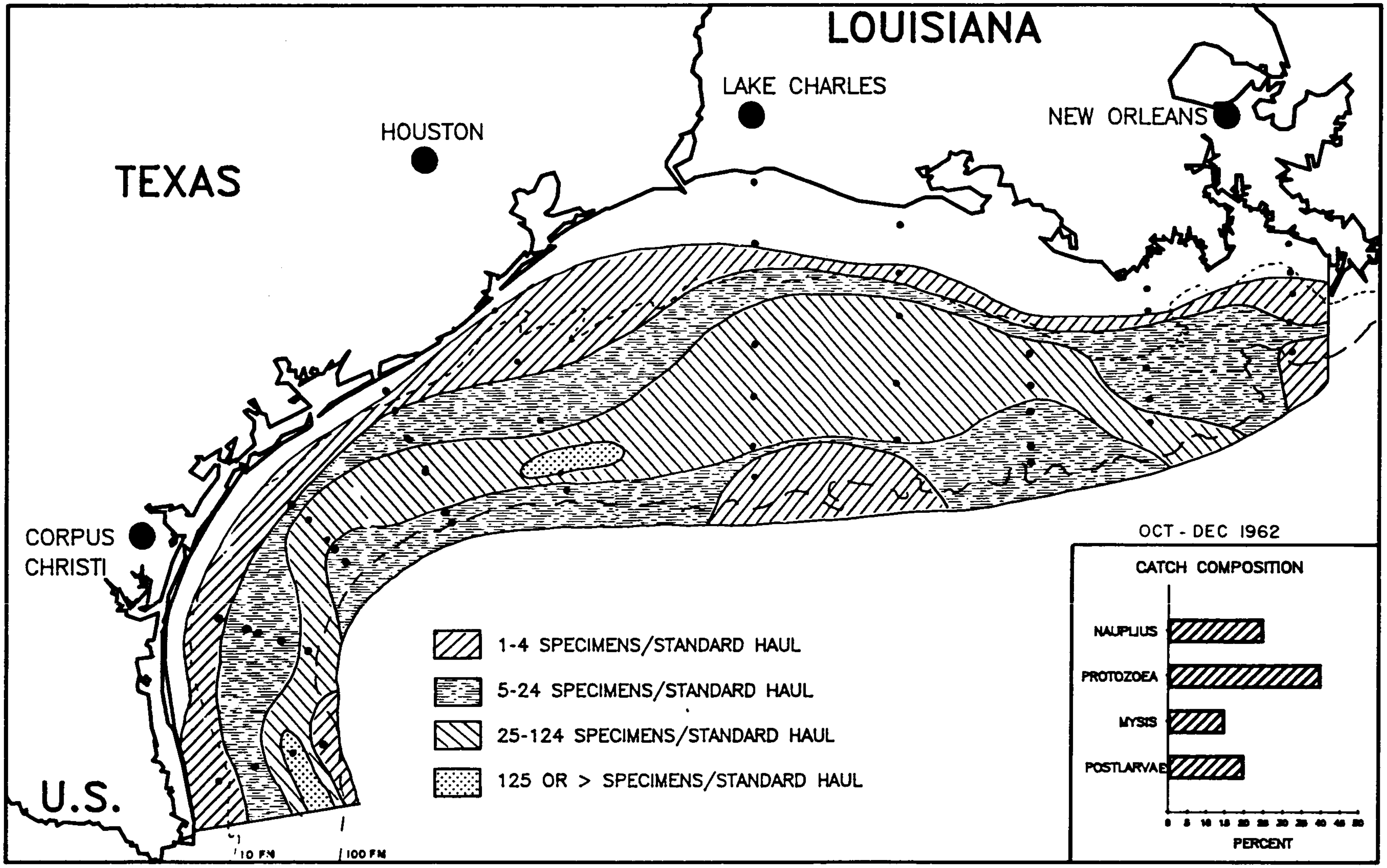

Figure 4.5a.--Distribution of planktonic-stage Penaeus spp. in the northwestern Gulf of Mexico during the period July-September 1962. (re-drawn from Temple and Fischer, 1965a).

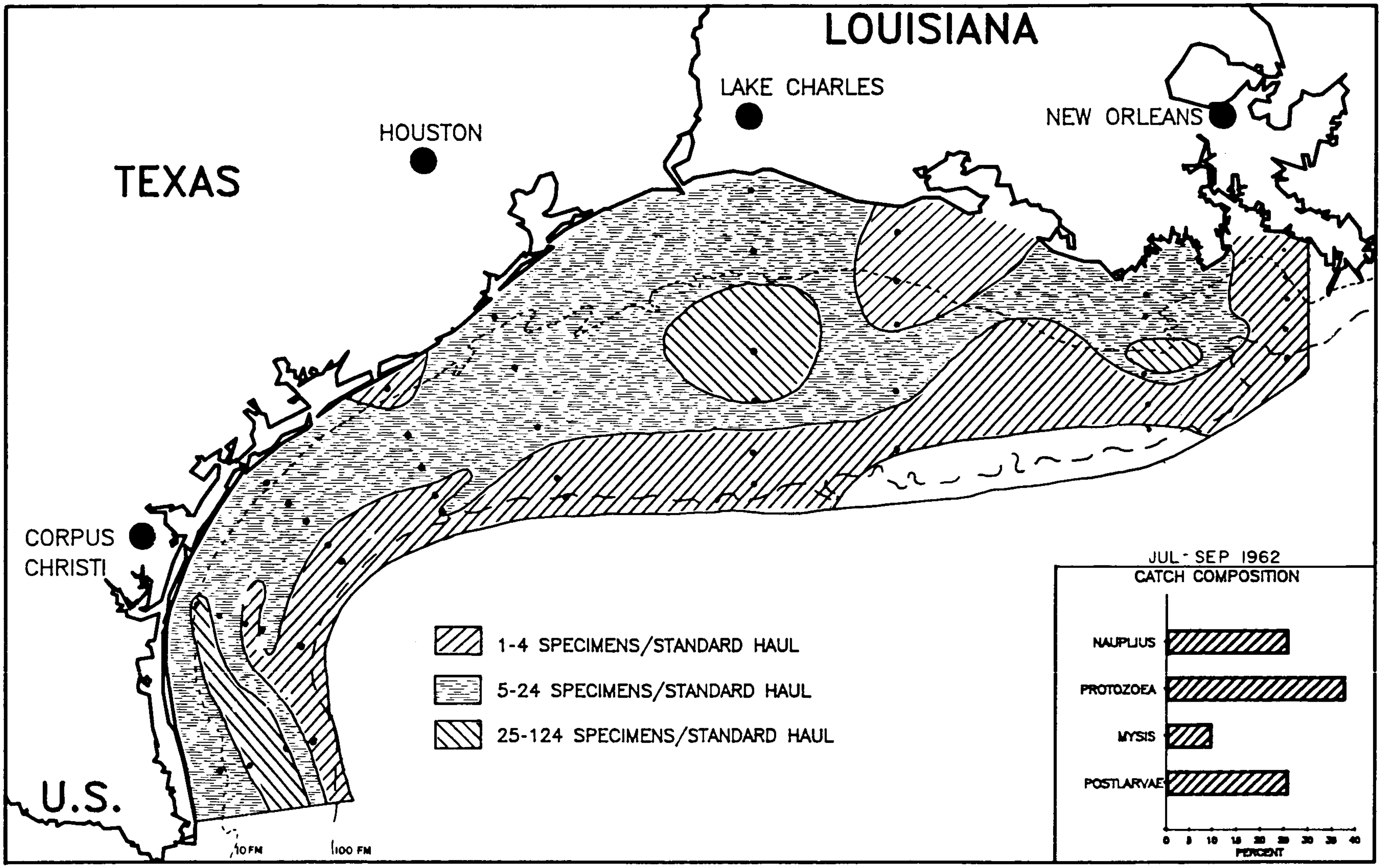

Figure 4.5b.--Distribution of planktonic-stage *Penaeus* spp. in the northwestern Gulf of Mexico during the period October-December 1962. (re-drawn from Temple and Fischer, 1965a).

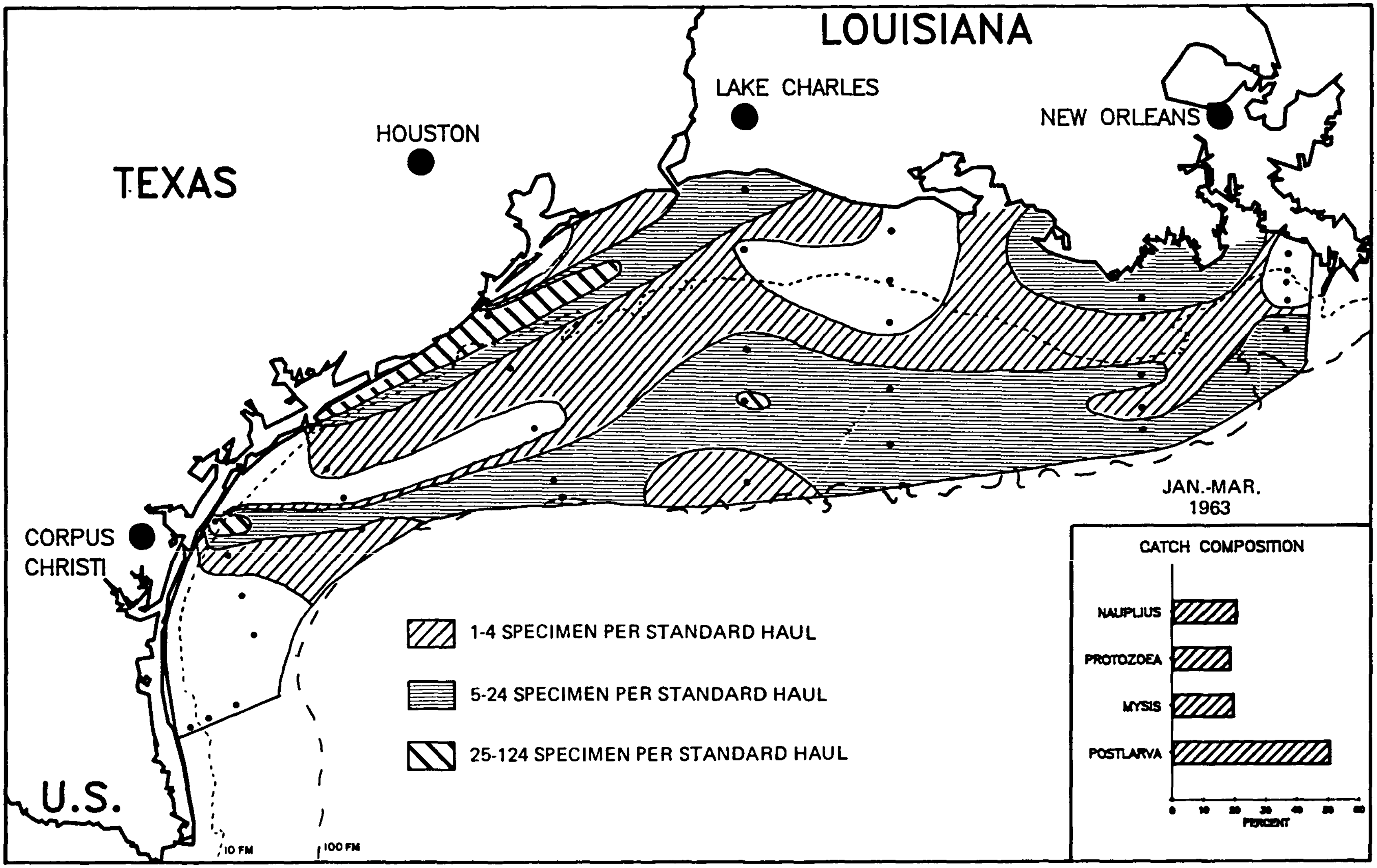

Figure 4.6.--Distribution of planktonic states of species of *Penaeus* in the northwestern Gulf of Mexico, January-March 1963. (re-drawn from Fischer, 1966).

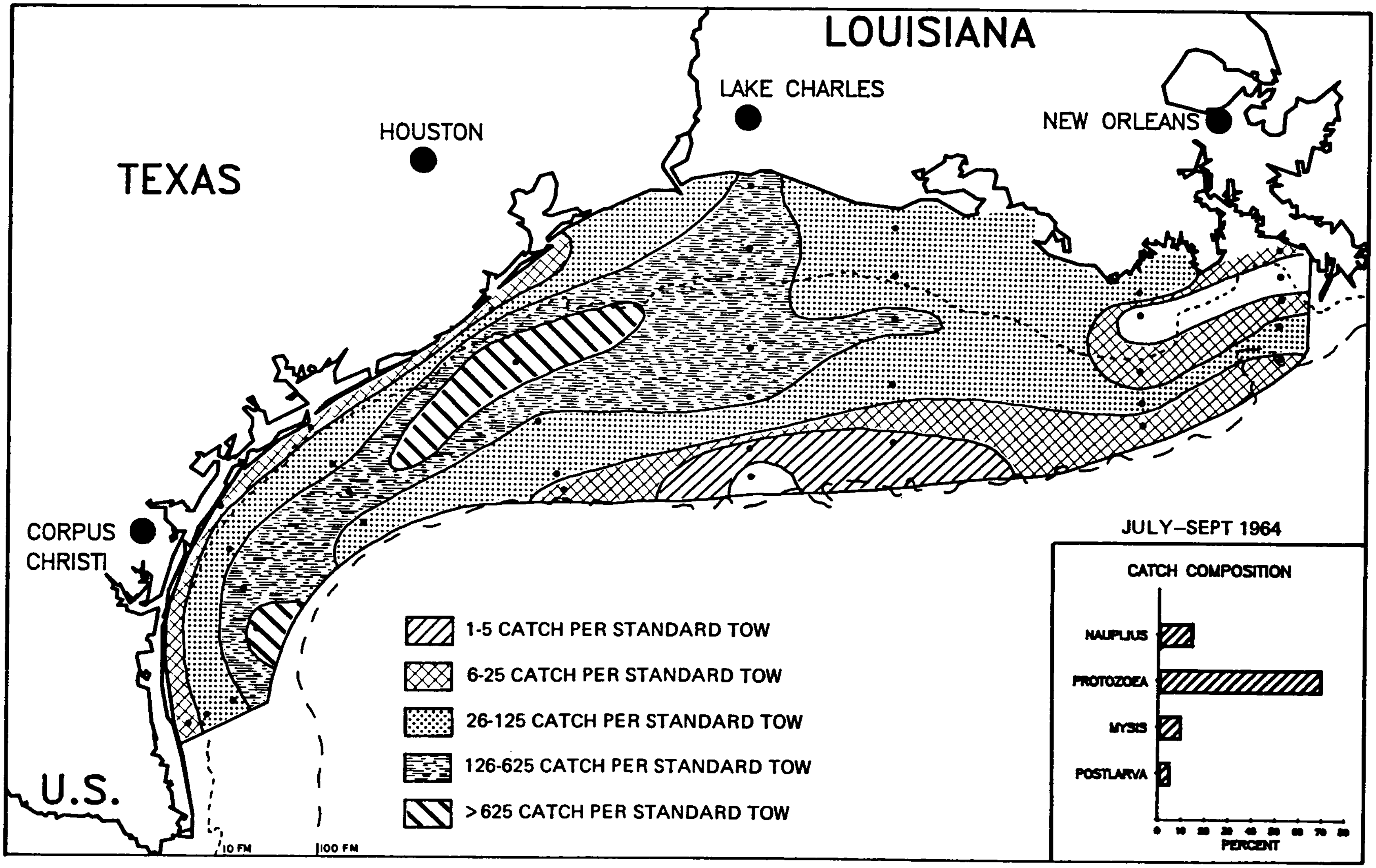

Figure 4.7.--Distribution of planktonic stages of <u>Penaeus</u> spp. in the northwestern Gulf of Mexico, July-September 1964. (re-drawn from Fischer, 1967).

Vertical Distribution of Planktonic Shrimp

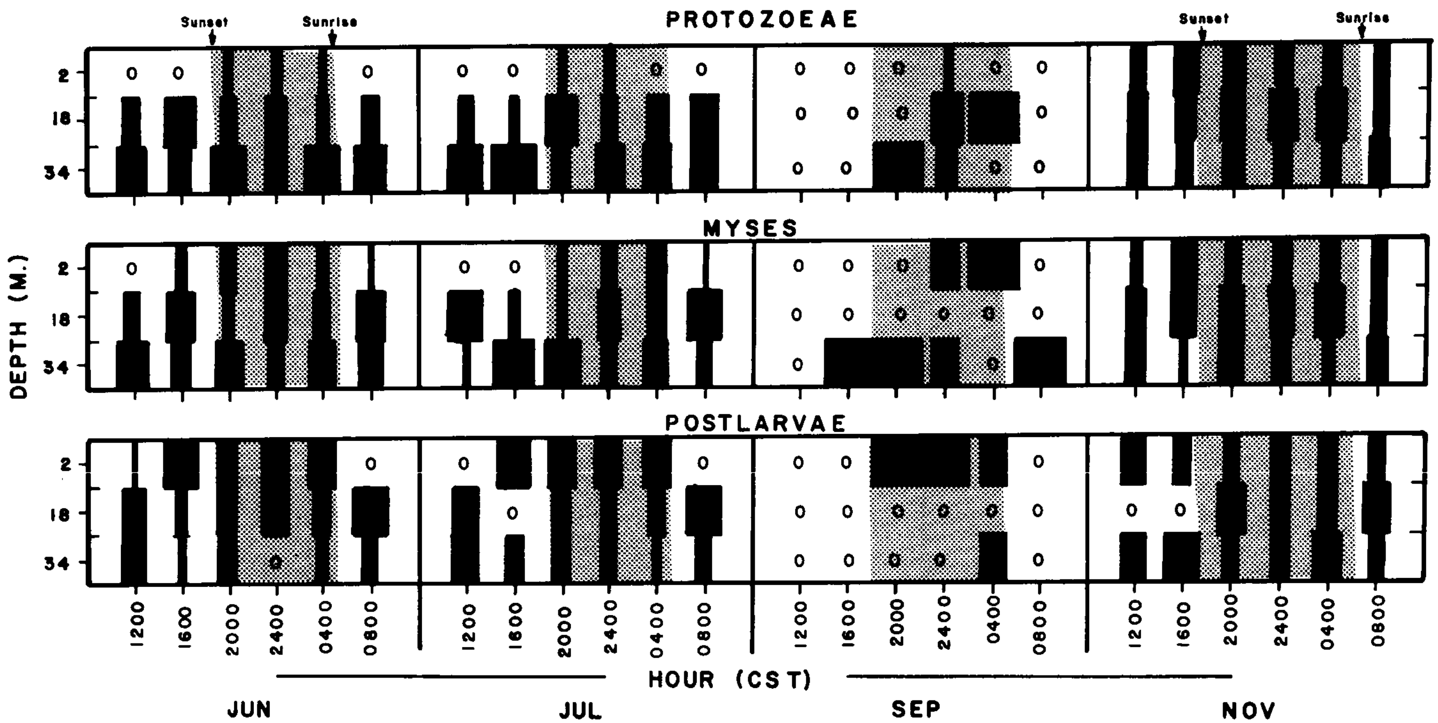

Figure 4.8.--Variations in the vertical distribution of immature (planktonic) penaeids over a 24-hour period (from Temple and Fischer, 1965b).

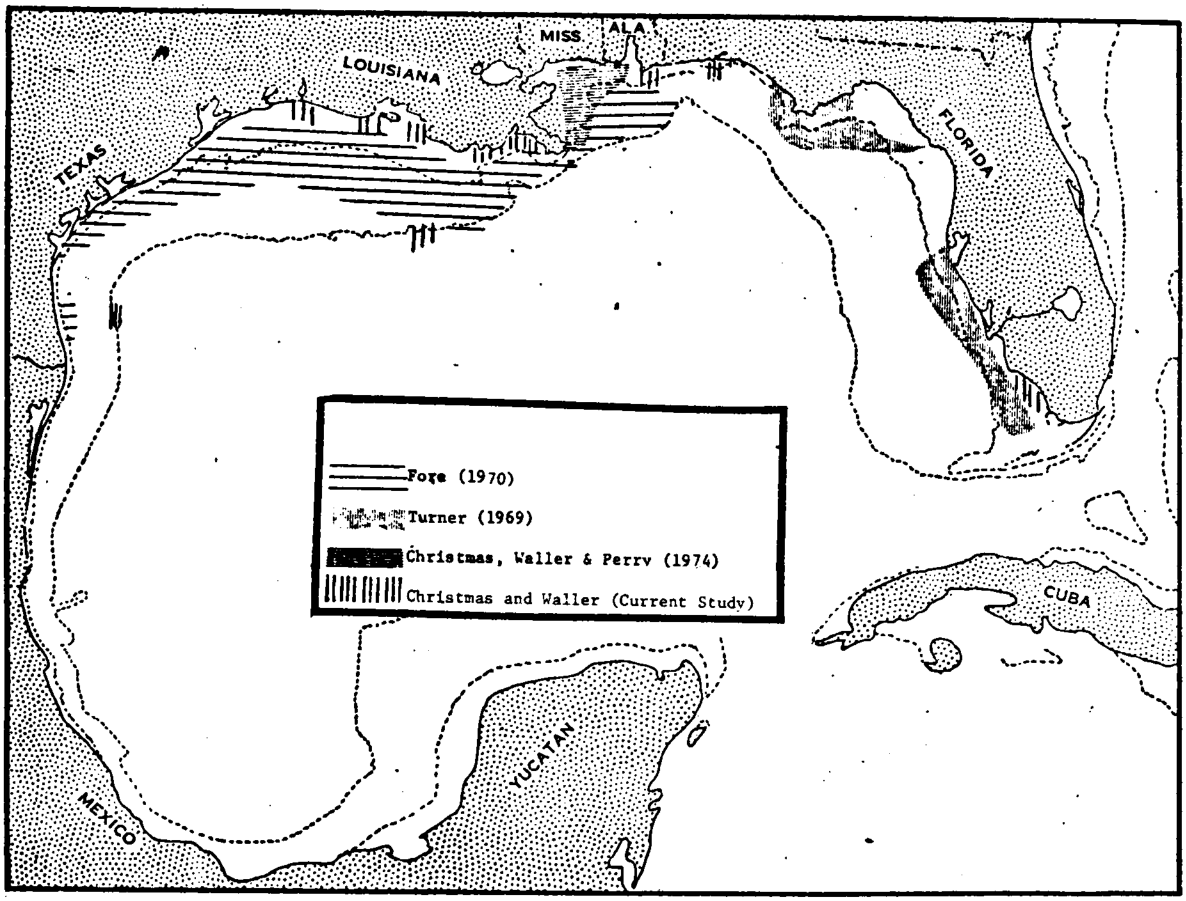

Figure 4.9.--Approximate spawning areas of menhaden identified by the occurrence of eggs. (from Christmas and Waller, 1975).

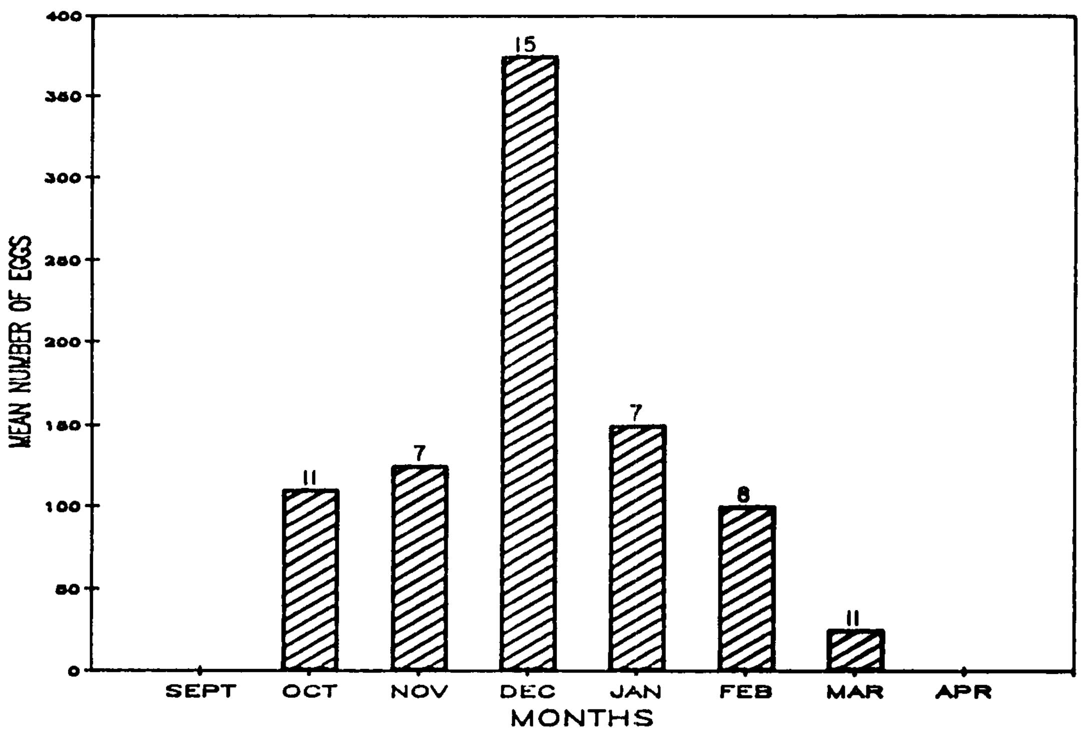

Figure 4.10.--Distribution of menhaden eggs in the northern and western Gulf of Mexico, 1963. The numerals represent the number of collections containing eggs (from Fore, 1970).

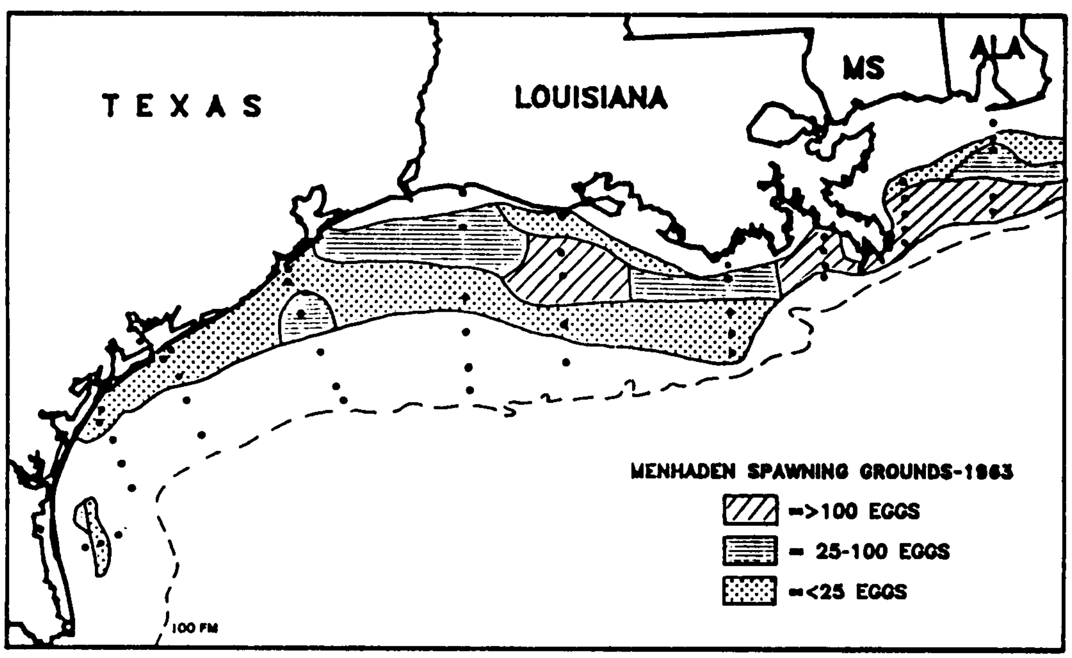

Figure 4.11.--The winter spawning grounds of the Gulf menhaden (from Fore, 1970).

Table 4.1

Dispersant, Collecting Agent and Miscellaneous Oil Control Agent Toxicities

MATERIAL TESTED	LC50 (ppm)	
	Fundulus (96 hr.)	Artemia (48 hr.)
BP-1100X	10,000	8
" + fuel oil (1:10)	2,400	230
COLD CLEAN 500	142	210
" + fuel oil	240	12
CONCO DISPERSANT K	18	300
" + fuel oil	125	52
COREXIT 7664	1,150	99,500
No. 2 Fuel Oil	4,280	44,000
COREXIT + fuel oil	1,670	582
COREXIT 8667	54,500	1.7
No. 2 Fuel Oil	4,280	44,000
COREXIT + fuel oil	1,144	25
COREXIT 9527	100	50
No. 2 Fuel Oil	4,280	44,000
COREXIT + fuel oil	4	40
EC.O ATLAN'TOL AT7	29	11
" + fuel oil	264	67
FINASOL OSR-7	1,200	320
" + fuel oil	2,000	35
GOLD CREW DISPERSANT	115	630
" + fuel oil	71	0.46
MAGNOTOX	32	65
" + fuel oil	510	32
OFC™ D-609	126	240
" + fuel oil	1,230	470
OIL SPILL ELIMINATOR N/T No. 4	480	46
" + fuel oil	67	162
OSD/LT™	28,000	5.5
" + fuel oil	460	200
PETRO-GREEN ADP-7	15.5	61
No. 2 Fuel Oil	>1,000	>1,000
PETRO-GREEN + fuel oil	140	185

Table 4.1 (cont'd)

Dispersant, Collecting Agent and Miscellaneous Oil Control Agent Toxicities

MATERIAL TESTED	LC50 (ppm) Fundulus (96 hr.)	LC50 (ppm) Artemia (48 hr.)
PETROMEND, MP-900-W	15.5	61
No. 2 Fuel Oil	>1,000	>1,000
PETROMEND + fuel oil	140	185
PROFORM-POLLUTION CONTROL AGENT	53	330
" + fuel oil	47	155
SEA MASTER, NS-555	5,000	100,000
" + fuel oil	288	58
SLIK-A-WAY	42	14.5
" + fuel oil	1,200	255
DISPERSANT 11	126	240
" + fuel oil	1,230	470
TOPS ALL #30	254	370
No. 2 fuel Oil	3,870	93
TOPS ALL #30 and No. 2 Fuel Oil	2,380	49
COREXIT 9550	1,740	23
No. 2 fuel oil	1,800	980
COREXIT + fuel oil	370	960
JANSOLV - 60^R Dispersant	35	25
No. 2 fuel oil	>10,000	933
JANSOLV + fuel oil	210	130
RUFFNEK	610	360
No. 2 fuel oil	>3,200	>3,200
RUFFNEK + fuel oil	1,300	958
NEOS AB 3000	10,800	0.3
No. 2 fuel oil	13,200	43
NEOS + fuel oil	5,600	1.8
CRUDEX	32	115
No. 2 fuel oil	>10,000	>3,200
CRUDEX + fuel oil	200	355

Table 4.1 (cont'd)

Dispersant, Collecting Agent and Miscellaneous Oil Control Agent Toxicities

SURFACE COLLECTING AGENTS

MATERIAL TESTED	LC50 (ppm) Fundulus (96 hr.)	LC50 (ppm) Artemia (48 hr.)
COREXIT OC-5	4,600	7.7
No. 2 fuel oil	4,280	44,000
COREXIT + fuel oil	4,440	630
OILCOMPRESS/OILBINDER	149	31
No. 2 fuel oil	67,668	116
OILCOMP/OILBIND + fuel oil	1,698	32.5
OIL HERDER	>1,000	2.5
" + fuel oil	>1,100	29
OIL SPILL REMOVER	700	780
" + fuel oil	6,930	6,400

MISC. OIL CONTROL AGENTS

MATERIAL TESTED	LC50 (ppm) Fundulus (96 hr.)	LC50 (ppm) Artemia (48 hr.)
SEE-JELL	3,800	>800
No. 2 fuel oil	3,900	600
SEE-JELL + fuel oil	3,100	430
OIL BOND-100	>10,000	30,000
No. 2 fuel oil	>10,000	600
OIL BOND + fuel oil	>10,000	1.9
LIQUID OIL BOND-200	7,000	13,000
No. 2 fuel oil	10,000	600
LIQUID OIL BOND + fuel oil	6,000	0.13
ELASTOL	>50,000	>100,000
No. 2 fuel oil	4,400	175
ELASTOL + fuel oil	3,900	340

Table 4.2

No. 2 Fuel Oil Toxicity

MANUFACTURER/PRODUCT	LC50 (ppm) Fundulus (96 hr.)	Artemia (48 hr.)
EXXON		
COREXIT		
7664	4,280	44,000
8667	4,280	44,000
9527	4,280	44,000
OC-5	4,280	44,000
9550	1,800	980
STUTTON NORTH CORP.		
TOPS ALL #30	3,870	93
PETROMEND, INC.		
PETRO-GREEN ADP-7	>1,000	>1,000
PETROMEND, MP-900-W	>1,000	>1,000
LISTEX CHEMICALS		
OILCOMPRESS/OILBINDER	67,667	116
SUNSHINE TECHNOLOGY CORP.		
JANSOLV - 60[R]	>10,000	933
MALTER INTERNATIONAL CORP.		
RUFFNEK	>3,200	>3,200
NEOS CO. LIMITED		
NEOS AB 3000	13,200	43
ENVIRONMENTAL SECURITY INC.		
CRUDEX	>10,000	>3,200
AJINOMOTO CO., INC.		
SEE JELL	3,900	600
C d F CHIMIE S.A.		
OIL BOND-100	>10,000	600
TOHO TITANIUM CO., LIMITED		
LIQUID OIL BOND-200	10,000	600
GTA ADDITIVES, INC.		
ELASTOL	4,400	175

Table 4.3

Dispersant Field Tests[1]

- AVERAGE EFFECTIVENESS = 24 - 30%
- MAJOR FACTORS
  - SEA STATE
  - DOSE RATE
  - DISPERSANT ACCESS TO OIL
  - LOW SEA STATE and LOW DOSE RATE → LOW EFFECTIVENESS
  - HIGH SEA STATE and HIGH DOSE RATE → AVERAGE OR ABOVE EFFECTIVENESS
- OTHER FACTORS
  - HERDING (SPREADING COEFFICIENT)
  - DISPERSANT DROPLET SIZE
  - OIL VISCOSITY
  - OIL COMPOSITION
  - SALINITY
  - DISPERSANT
  - DISPERSANT PARTITIONING

[1]M. Fingas (1983) The Effectiveness of Oil Spill Dispersants. Spill Technical Newsletter 10, 47-64.

REGIONAL STRATIGRAPHIC MAPPING PROGRAM

Session: REGIONAL STRATIGRAPHIC MAPPING PROGRAM

Co-Chairs: Dr. William E. Sweet
Ms. Gay H. Larre'

Date: November 5, 1986

Presentation Title	Speaker/Affiliation
Regional Stratigraphic Mapping Program Session Overview	Dr. William E. Sweet Minerals Management Service Gulf of Mexico OCS Region
Summary of Paleontological and Ecological Input to the Regional Stratigraphic Mapping Program	Ms. Gay H. Larre' Minerals Management Service Gulf of Mexico OCS Region
The Role of Seismic Data in the Regional Mapping Program	Mr. Alfred E. LaPointe Minerals Management Service Gulf of Mexico OCS Region
The Gulf of Mexico Exploration and Development Prospects for the Future: Relationship to the Regional Mapping Program	Dr. Pulak K. Ray Minerals Management Service Gulf of Mexico OCS Region

Regional Stratigraphic Mapping Program Session Overview

Dr. William E. Sweet
Minerals Management Service

The Minerals Management Service (MMS) Gulf of Mexico OCS Region's Office of Resource Evaluation (RE) has been conducting Regional Stratigraphic Studies in support of the areawide lease sales which began in 1981. The purpose of the studies is to establish a regional stratigraphic correlation grid using geology, geophysics, and paleontology. The stratigraphic grid includes all major productive intervals. The results of the work are used in the RE program and in postsale tract evaluation and bid adequacy determination.

Minerals Management Service has decided to publish this work to increase the geological knowledge of the Gulf of Mexico basin, to support continued economic development of the Outer Continental Shelf (OCS), and to provide a comprehensive database to promote future research and publications.

The reason for participating in the Information Transfer Meeting (ITM) was to explain what The Office of Resource Evaluation is doing with our studies program, to reach a wider audience and inform the scientific and academic communities of what we have accomplished and how we accomplished it, and to say which information will be available to the public. We hope that the work will serve as a basic framework and stimulate further study and research.

We take this opportunity to thank MMS planners for inviting us to participate in the ITM. It gave us the opportunity to show that MMS is engaged in lease-related studies which are not directly environmentally oriented. Our participation in the ITM also demonstrated that the process of lease sale activity is truly a complex multidisciplinary operation.

Dr. William E. Sweet received a BS in geology from Tufts University, and an MS in geology, and a Ph.D. in oceanography from Texas A&M University. He is presently staff geologist in the Office of Resource Evaluation.

Summary of Paleontological and Ecological Input to the Regional Stratigraphic Mapping Program

Ms. Gay H. Larre'
Minerals Management Service

Paleontology is a useful tool for determining specific ages of sediments and paleomarine environments in the Gulf of Mexico. The basic concept of paleontology used in the Gulf of Mexico Region to determine ages is extinction points of specific Foraminifera (one-cell animals) and their associated faunas in subsurface sediments. Paleontological examination of sediments of a borehole begins at the top of the well and ends at the total depth of the well. Therefore, the first time a specific Foraminifera and its associated fauna are observed is their extinction point. This extinction point in several wells forms a time-correlative surface which can be used by geologists and geophysicists.

Paleoecology or paleomarine environments can be determined by specific foraminiferal assemblages. This information is important because the major reservoirs of hydrocarbon accumulation are found in outer shelf (zone 3) and upper slope (zone 4) environments.

Because of the variance of opinion concerning the Plio-Pleistocene

Boundary and the fact that much of the section is missing in the Lower Pleistocene and Upper Pliocene, for practical purposes Lenticulina 1 and, when present, Valvulineria "H" are considered Lower Pleistocene: Buliminella 1 is considered the first major marine transgression within the Upper Pliocene.

Over 1,000 proprietary and nonproprietary paleontological reports were used for this study. Of these reports, 175 wells will be published with Part I of the study.

Ms. Gay H. Larre' is a Senior Paleontologist, Minerals Management Service. She received a BS (1966) in biology from Newcomb College of Tulane University, and pursued graduate studies in geology at Tulane University, University of Washington (Seattle, Washington), and University of New Orleans. She has been a Petroleum Micropaleontologist since 1966.

The Role of Seismic Data in the Regional Mapping Program

Mr. Alfred E. LaPointe
Minerals Management Service

It was demonstrated how seismic data were traced around a closed grid in order to verify the correlations made on well logs. Examples of dip and strike lines in the western part of the study area were shown.

Since the study is incomplete, no conclusions were drawn nor hypotheses made. However, it was pointed out that seismic corroboration of well log correlations increased the confidence placed in both. Future mapping and velocity studies will be tied to this work.

Mr. Alfred E. LaPointe is a Staff Geophysicist from Louisiana State University. He has been employed in various geophysical and supervisory positions in industry and government for the past 36 years.

The Gulf of Mexico Exploration and Development Prospects for the Future: Relationship to the Regional Mapping Program

Dr. Pulak K. Ray
Minerals Management Service

The Gulf of Mexico represents a matured hydrocarbon province with a long exploration and development history. The hydrocarbon occurrences in this province are delineated into several approximately shore-parallel trends of Miocene through Pleistocene age and a recently discovered northwest-southeast trending deep Jurassic Norphlet trend. In addition, an Oligocene trend of limited extent is present in the Western Gulf. Some of the current hottest plays of the Gulf of Mexico include Jurassic Norphlet trend, Middle Miocene Corsair trend, and Pliocene and Pleistocene Flexure trend.

The Cenozoic Sediments of the Gulf of Mexico, which are primarily regressive, were deposited in fluvial, deltaic, and interdeltaic barrier plain environments. As the sediment source moved from the Rio Grande Embayment to the Mississippi Embayment, during Cenozoic time, so did the depocenters. Salt/shale tectonics played a major role in forming hydrocarbon traps in this otherwise tectonically stable area. Most of the hydrocarbons are associated with the salt-shale domal structures and their associated fault systems, and with growth faults and their associated rollover structures.

Historical leasing activity on the continental margin of the Gulf of

Mexico indicates that the oil industry steadily moved their exploration and development activity into deeper waters and to deeper plays. The institution of areawide lease sales significantly accelerated the exploration and development activity of this area. Historically, the response of the activity in the Gulf of Mexico area to the fluctuation of oil and gas prices has been somewhat different from that of the other areas of the United States. The short term adverse impact of declining prices on the exploration and development in the Gulf of Mexico area, especially the deep water area, may be significant, but the long-term effect will be minimal.

Dr. Pulak K. Ray is presently Supervisory Geologist, Development Evaluation Unit, Resource Evaluation of Minerals Management Service, Gulf of Mexico OCS Region. He obtained his BS and MS in 1967 and 1969, and his Ph.D. from Louisiana State University in 1972. Prior to joining MMS he taught at the University of South Carolina and the State University of New York. He has conducted various research projects and was the director of Great Lakes Research Laboratory.

SEAGRASSES: ECOLOGY AND DISTRIBUTION

Session: SEAGRASSES: ECOLOGY AND DISTRIBUTION

Co-Chairs: Dr. Robert M. Rogers
Dr. Edward Pendleton

Date: November 5, 1986

Presentation Title	Speaker/Affiliation
Seagrasses: Ecology and Distribution Session Overview	Dr. Robert M. Rogers Minerals Management Service Gulf of Mexico OCS Region and Dr. Edward Pendleton U.S. Fish and Wildlife Service National Wetlands Research Center
Regional Variation in the Seagrass Ecosystem of Florida	Dr. Joseph C. Zieman University of Virginia Department of Environmental Sciences
Assessment of Hurricane Damage in the Florida Big Bend Seagrass Beds	Mr. John M. Thompson and Mr. Steve Dial Continental Shelf Associates, Inc.
Trends in Seagrass Distribution on the West Florida Shelf	Mr. Kenneth D. Haddad Florida Department of Natural Resources
Ecology and Distribution of Seagrasses Along the Lower Texas Coast	Dr. Warren M. Pulich, Jr. University of Texas Marine Science Institute

Seagrasses: Ecology and Distribution Session Overview

Dr. Robert M. Rogers
Minerals Management Service
and
Dr. Edward Pendleton
U.S. Fish and Wildlife Service

This session was organized in the interest of discussing the ecology and distribution of seagrass communities in the Gulf of Mexico. The Minerals Management Service (MMS) has long been aware of the potential sensitivity of this resource to petroleum exploration and production activities. As a result, a number of studies have been initiated to delineate and inventory seagrass beds, especially emphasizing distribution on the OCS.

Seagrasses generally are distributed in low-energy environments of high-light intensity. This implies shallow, protected waters. Often their distribution is limited to the protected waters of coastal estuaries and lagoons. The exception to this is the Big Bend of Florida where beds extend far out on the continental shelf. This shallow marine ecosystem is a critical habitat for numerous species of finfish, shellfish, and waterfowl.

In addition to potential impacts from OCS drilling activities on seagrasses, environmental concerns have been expressed about impacts from oil spills affecting offshore habitats and pathways of migratory organisms. In addition, during resource development, information on seagrass distribution is essential for transportation of products by pipeline.

The U.S. Fish and Wildlife Service (FWS) interest in seagrass revolves around two issues -- the ecologic functions and values seagrass communities perform and the decline of seagrasses due to human activities. Seagrass detritus forms the base of a food web that includes a number of important fishery and forage organisms. Seagrass beds further provide cover for the postlarval and juvenile stages of many species of fish and invertebrates and serve as nurseries for these young-of-the-year organisms. Important for FWS and other interests in the Gulf of Mexico, seagrasses and invertebrates that feed on them are consumed directly by many species of overwintering migratory waterfowl. As the values and functions of seagrasses become better known, however, it is also evident that this community is becoming increasingly vulnerable to the direct and indirect effects of dredging and filling, increased suspended sediment and contaminant loading of the water column, and other perturbations. Of high priority in the FWS is the preservation of these valuable coastal resources, the mitigation of unavoidable losses, and the restoration of areas where seagrass beds have deteriorated or declined.

Through the Gulf of Mexico OCS Regional Office and the National Wetlands Research Center (formerly the National Coastal Ecosystems Team), MMS and the FWS have mapped seagrass distributions in the Gulf of Mexico, analyzed changes in seagrass acreage over time, and synthesized scientific information in a community profile on the seagrasses of the Florida west coast (to be completed this fall). Thus, it is appropriate that the two agencies have collaborated in presenting this session to exchange information of the current status of seagrass ecology and distribution in the Gulf.

The first speaker for the session was Dr. Joseph C. Zieman of the University of Virginia. Dr. Zieman discussed regional variation in the seagrass ecosystems of coastal Florida. These ecosystems constitute a major ecologic and economic resource within the Gulf Coast Region, protection from sediment erosion, sheltering and feeding role in sediment accretion, high primary productivity, and vast quantities of commercially and tropically important consumers. Due to their specific requirements for light and substrate, they are restricted to a narrow band of shallow coastal waters where the often conflicting demands of man are the greatest.

Florida possesses one of the largest seagrass resources on earth. Surveys by Iverson and Bittaker (1986) found that the offshore bed in the Big Bend region encompassed approximately 3,000 km^2 while the southern bed, comprised of Florida Bay and the seagrasses behind the reef tract, are over 5,500 km^2. When the smaller, but still extensive estuarine seagrass beds throughout the State are included, the total is approximately 10,000 km^2. A detailed study of the Big Bend area has increased the seagrass coverage of this region to 2,329 km^2 of dense seagrass beds, 4,980 km^2 of sparse seagrasses and algal assemblages, and 2,797 km^2 of patchy seagrasses and live bottom (Continental Shelf Associates, 1986). While most of this resource is healthy and productive, there are large areas that are moderately to heavily impacted, and where complete destruction of the resource is probable if current environmental conditions are not improved. Destruction of 80% of the seagrasses of Tampa Bay and 50% of the seagrasses of the Indian River are indications of ecosystems that have been severely compromised and could face total destruction.

Throughout the entire coastal regions of Florida, the seagrass meadows visually appear to be the same whether they are from Apalachee Bay in the north or Florida Bay in the southernmost part of the state because the seagrasses are identical throughout the state. In addition, and of great importance, the processes within the beds--ecological -- chemical, and geological, are the same everywhere. However, several highly important, but often subtle changes occur along this gradient, particularly with changes in rates of processes, and the associated animal communities, which can change greatly over sometimes short distances.

Changes in the distribution and abundance of seagrasses throughout the west coast of Florida, or anywhere else, occur at several scales: local, 1 to 1,000 m; regional, 10 to 100 km; and latitudinal, 100 to 1,000 m. These variations exist in the few dynamic ecological parameters that have thus far been systematically studied. On a local basis, leaf to belowground biomass values change as a function of sediment grain size, and presumably, nutrient content. Regional scale studies in Florida Bay have found standing crop and productivity to vary systematically across the bay. On a latitudinal scale, turnover rate is found to increase monotonically from central Florida to the central Caribbean.

Mr. Steve Dial of Continental Associates, Inc. (CSA), discussed an assessment of hurricane damage on the Florida Big Bend seagrass beds. In 1984, MMS contracted with CSA to delineate the seagrass beds of Florida's Big Bend area. Delineated were 232,893 ha (575,479 acres) of dense seagrass beds (composed of <u>Thalassia testudinum</u>, <u>Syringodium filiforme</u>, and <u>Halodule wrightii</u>); 498,034 ha (1.2 million acres) of sparse seagrass beds (composed of <u>Halophila decipiens</u>, <u>Halophila engelmanni</u>, and algal-live bottom assemblages); and 279,722 ha (691,193 acres) of patchy seagrass beds where all five vascular plant species may overlap.

During the 1985 hurricane season, four major storms passed through the Gulf of Mexico. Reports from coastal observers suggested that these storms, particularly Hurricanes "Elena" and "Kate," severely affected seagrass beds in the Big Bend area.

Quantitative seagrass monitoring, conducted in Gainesville OCS Area Block 707 at the time by CSA showed an area of 116,554 ha (288,000 acres) completely denuded of the H. decipiens and H. engelmanni seagrass species found there.

The existence of an extensive database for the Florida Big Bend area provided an ideal opportunity to assess the impacts of hurricanes upon seagrasses over a large geographic area. Responding to this opportunity, MMS extended the Florida Big Bend Seagrass Habitat Study to include an assessment of the impacts of, and recovery from, these hurricanes in the Florida Big Bend area. The combined impact and recovery assessment survey took place in August 1986.

Qualitative observations showed no observable changes in either the dense inshore Thalassia-Syringodium-Halodule beds or the sparse offshore Halophila beds off Tarpon Springs between the October 1984 and August 1986 surveys. Interpretation of observations made off Cedar Key was more difficult. In known areas of seagrass destruction, recovery seemed to be taking place, but changes were noted in the physical characteristics of specific stations.

Comparison of percentages covered by various habitat types along towed diver and television transects showed no major changes between the 1984-1985 and 1986 surveys. Approximately the same percentages of seagrass-covered bottom, bare sand bottom, and live bottom were recorded, although the seagrass was not always present at the same locations where it was noted previously. Quantitative comparisons of leaf biomass of H. decipiens also indicated comparable values of before and after surveys.

Mr. Kenneth Haddad of the Florida Department of Natural Resources (DNR) discussed trends in seagrass distribution on the West Florida shelf. Seagrasses serve as nursery grounds, protective structure, and food sources for many marine organisms. Therefore, quantifying habitat distribution and alteration and documenting the dependency of fisheries on habitat may provide managers with a tool to predict future fishing stocks.

With support from the NOAA Office of Ocean and Coastal Resource Management through the Florida Department of Environmental Regulation, the Florida Department of Natural Resources' Bureau of Marine Research implemented a fisheries habitat assessment program. A Marine Resources Geographic Information System (MRGIS) was developed which houses a geographically referenced database of fisheries habitat information. The project also includes (1) a sampling program to quantify faunal abundance and diversity within habitats, (2) stable isotope analyses of associated plants and animals to establish habitat dependency, and (3) an assessment of growth and mortality of juvenile fish.

Initially, the project focused on developing techniques for habitat mapping and monitoring. The extent of Florida's coastal zone (2,172 km) precluded standard cartographic approaches. Digital LANDSAT Thematic Mapper (TM) data were selected as the optimal base for a statewide assessment effort. Analyses early in the program determined that TM data generally were not sufficient to consistently delineate seagrasses. Aerial photography are photointerpreted for seagrass and digitized into the TM database.

Mapping seagrasses of the west Florida coast is currently underway. Recent mapping efforts by various Federal agencies also will be incorporated into the MRGIS database.

Analyses comparing historical with recent data were conducted on selected areas along the west Florida coast to determine trends in seagrass distribution. Initial findings suggest that distribution has changed notably in many bay systems since the 1940's. Areas of decline included Charlotte Harbor (29%), Tampa Bay (44%), Bayport (13%), western Choctawatchee Bay (30%), and eastern Perdido Bay (45%). Only Big Lagoon (west of Pensacola) increased (55%).

Seagrass declines pose a significant management problem because the factors causing the declines, in many areas, are not known. Loss has generally occurred in deeper waters, suggesting that decreased water quality and light penetration may influence seagrass distribution. Nutrient enrichment, which promoted phytoplankton growth, and resuspended fine organics and clays may explain reduced water clarity, but effects on seagrass growth has not been documented.

Dr. Warren M. Pulich, Jr., of the University of Texas Marine Science Institute discussed the ecology and distribution of seagrasses along the lower Texas coast. Under the hypersaline hydrological regime existing in South Texas coastal estuarines, typical emergent salt marsh systems (e.g., Spartina) are noticeably limited, and submergent seagrass meadows become the dominant marine vascular plant communities. This situation presents a dramatic contrast with coastal areas to the north along the Upper Texas coast, where emergent salt marshes are dominant; the situation also has significant implications for fish and wildlife populations dependent on seagrass beds.

A relatively high diversity of seagrasses -- five species -- exists. Three pioneer or colonizing species occur widely over the entire region: Halodule wrightii (shoalgrass), Ruppia maritima (widgeongrass), and Halophila engelmanni. The climax community species, Thalassia testudinum (turtlegrass) and Syringodium filiforme (manateegrass), are locally abundant, but absent over most of the region. Peak summertime biomass values range from over 1000 g/m^2 for Thalassia and Syringodium to 500 g/m^2 for Halodule, 250 g/m^2 for Ruppia, and 100 g/m^2 for Halophila. All five species can be found as monospecific beds, and certain parts of bays and lagoons are well-known for specific communities. In general, however, Syringodium occurs mixed with Thalassia, and Halophila is mixed with Halodule. Pioneer species only rarely occur mixed with climax species.

Species distribution in south Texas is function of several key environmental factors: temperature, salinity, and tidal regimes. Temperature regimes account for latitudinal distribution patterns. The farther north one goes along the coast, the less Thalassia and Syringodium and the more Ruppia and Halodule are encountered. While all four other seagrasses have warm temperature optima (i.e., above 25°C), Ruppia is adapted to cooler temperatures. Temperature limits then explain the frequent dominance of Ruppia during winter and spring in both low and high salinity environments (e.g., Redfish Bay or Laguna Madre, respectively).

Salinity regimes control distribution according to the salinity tolerance limits of the species. In general, the distribution of Thalassia and Syringodium can be predicted from salinity and temperature regimes, while Halodule and Ruppia are readily adaptable to fluctuations in these parameters (e.g., Upper Laguna Madre and Baffin Bay).

Where salinity regimes are favorable (i.e., annual average between 20 to 36 $^{o}/oo$), tidal regimes control the distribution of south Texas seagrasses. Yearly, astronomical tidal cycles in the Texas Coastal Bend are characterized by spring/fall high periods and low periods. Very low winter tides expose shallow flats to ruin and often kill seagrass leaves by desiccation or cold shock. Consequently, only the fast-growing species can become established in these shallow flats.

A typical distribution profile of species with depth shows that Halodule occupies shallow and deep zones, while Thalassia is dominant in mid-depth zones (approximately -1.5 to -3 ft means sea level). The Laguna Madre is interesting since it provides evidence that Halodule grows well at deep depths (-4 ft MSL). Thalassia and Syringodium both exhibit maximum photosynthetic rates of 30% of those measured for Halodule, Ruppia, or Halophila. Based on these photosynthetic rates, then, Thalassia and Syringodium are slower-growers than the others, and they will be out-competed by the faster-growing species in shallow areas subject to long periods of tidal exposure.

The effects of tidal and salinity factors on seagrass distribution are evident from the historical changes in wetland communities of the South Texas barrier island lagoons and tidal delta systems. A relative rise in sea level has probably produced increased seagrass distribution wind tidal flats and shallow subaqueous mud flats in certain areas.

In the Texas Laguna Madre, major shifts in seagrass species abundance and community structure have occurred in less than 20 years. Numerous changes in seagrass populations noted between the mid-60's and 1974 have been attributed to alteration in the salinity regimes and possibly water column light conditions. The construction of the Gulf Intracoastal Waterway (GIWW) and Mansfield Pass has stabilized salinities in the Lower Laguna. Some evidence exists for increased overall turbidity in the Lower Laguna from The Arroyo Colorado runoff and boat/barge traffic.

In the Upper Laguna, salinities regularly are in the range of 40-50 $^{o}/oo$ (average 40 $^{o}/oo$), which precludes Thalassia and Syringodium from establishing. Halodule and Halophila are favored by the very clear, hypersaline waters and warm temperatures.

Research projects underway at the University of Texas Marine Science Institute have focused on the production ecology of Halodule and Ruppia, the most abundant seagrasses in South Texas estuaries, in relation to local habitat conditions. Studies of growth dynamics will reflect the integrated short-term responses of the plants to habitat parameters besides light (e.g., nutrients, substratum, or epiphyte loads). Such short-term production data can indicate incipient changes in environmental processes critical to seagrass ecosystems well before such changes become irreversible.

Interactions between light regimes and other growth parameters are detectable by monitoring seagrass production at different water depths. While plant production is expected to be proportional to light levels at the various depths, quantitative relationships will vary with particular locations and the season. One project has examined the growth dynamics of Halodule at five sites in the Corpus Christi area. The growth dynamics represent different environmental gradients of light, salinity, and nutrient loading. In another project, the influence of adaphic (sediment-related) factors was examined at old dredge spoil deposit sites. This work has shown that significant changes in sediment redox properties occur during colonization of bare sediments by Halodule.

RECOMMENDATIONS

Speakers agreed that the intimate relation between fisheries and seagrasses has not adequately been studied. Seagrass beds are a dominant habitat on the west Florida shelf and certainly contribute to the success of the fisheries. Funding for research to develop the information required for adequate management has not been commensurate with the economic and environmental value of the resource. Federal and state resource managers should address this issue. Research is necessary 1) to determine if changes in water quality and light penetration affect seagrass distribution and 2) to identify other possible causative factors. Although these should be research priorities, all facets of seagrass research remain inadequately funded.

In south Texas coastal estuaries, research on growth dynamics should provide information in situations where impacts on coastal seagrass ecosystems are expected: (1) when freshwater inflow regimes are altered in an estuary; (2) when pollutant discharges or wastewater effluents enter an estuary; (3) when a natural climatic catastrophe has occurred, e.g., hurricane or severe freeze; or (4) when channel dredging or other development projects are proposed in coastal wetlands. In these cases, results from short-term process measurements can be used to predict effects on species production and plant community structure. However, synergistic relationships between estuarine processes and seagrass production are still inadequately defined. Maintenance of quality seagrass habitats for the future requires research to refine the criteria used for monitoring seagrass production and/or physiological status.

Dr. Robert M. Rogers is an oceanographer on the Environmental Studies Staff of the MMS Gulf of Mexico OCS Region. He has served as Contracting Officer's Technical Representative (COTR) on numerous marine ecosystems studies. Recently, this has included a study of seagrass distributions off the Florida Big Bend and an ecological study of the Mississippi/Alabama OCS. Dr. Rogers received his BS and MS degree in zoology from Louisiana State University and a PhD in marine biology from Texas A&M University.

Dr. Edward Pendleton is chief of the Community Ecology Branch of The U.S. Fish and Wildlife Services's National Wetlands Research Center, where he is in charge of the FWS Community and Estuarine Profile publication series and community simulation modeling activities. He received his Ph.D. from North Carolina State University in estuarine ecology. Before joining FWS in 1981, he was a research associate at the University of Maryland's Horn Point Environmental Laboratories, where he worked on marsh loss problems on Maryland's Eastern Shore.

Regional Variation in the Seagrass Ecosystem of Florida

Dr. Joseph C. Zieman
University of Virginia

INTRODUCTION

The seagrass ecosystems of coastal Florida constitute a major ecologic and economic resource within the Gulf coast region. Because of the protection they provide from erosion, their role in sediment accretion, their high primary productivity, and the vast quantities of commercially and tropically important consumers that they shelter and feed, seagrasses are extremely important to both the ecology and the economy of the region. As photosynthetic organisms they require light; in fact, high light levels are needed to sustain their high rate of productivity. However, as rooted plants, they require sediments for both attachment and nutrition. Thus, they are restricted to a narrow band of shallow coastal waters where the often conflicting demands of man are the greatest.

Studies of seagrasses have lagged behind studies of other coastal ecosystems such as salt marshes, mangroves, and coral reefs until comparatively recently. In large part this is because they are submerged and, therefore, less visible than the emergent marshes and mangroves.

Commercial and sports fisheries are extremely important to the economy of Florida, and numerous studies have linked the complex coastal estuaries and seagrass meadows to the productivity of the abundant fisheries of the region. In the U.S. portion of the Gulf of Mexico, about 70% of the recreational fisheries and 90% of the commercial fisheries are estuarine dependent at some stage in their lives. Other studies have linked consumer abundance directly to seagrasses. In Rookery Bay, a mangrove lined estuary, although seagrasses covered substantially less then 20% of the estuary bottom, the seagrass habitat accounted for 77% of the total catch of fish, crustacea, and mollusks, and over 82% of the commercial shrimp catch. This pattern of high abundance of organisms in the seagrass meadows of Florida has been found repeatedly.

FLORIDA SEAGRASS RESOURCES

Florida possesses one of the largest seagrass resources on earth. Surveys by Iverson and Bittacker (1986) found that the offshore bed in the Big Bend region encompassed approximately 3,000 Km^2 while the southern bed, comprised of Florida Bay and the seagrasses behind the reef tract are over 5,500 Km^2. When the smaller, but still extensive estuarine seagrass beds throughout the state are included, the total is approximately 10,000 Km^2. A detailed study of the Big Bend area has increased the seagrass coverage of this region to 2,329 Km^2 of dense seagrass beds, 4,980 Km^2 of sparse seagrasses and algal assemblages, and 2,797 Km^2 of patchy seagrasses and live bottom (Continental Shelf Associates, 1986). While most of this resource is healthy and productive, there are large areas that are moderately to heavily impacted, and areas where complete destruction of the resource is probable if current environmental conditions are not improved. Destruction of 80% of the seagrasses of Tampa Bay and 50% of the seagrasses of the Indian River are indications of ecosystems that have been severely compromised and could face total destruction.

FLORIDA GRADIENT

Throughout the entire coastal regions of Florida, the seagrass meadows visually appear to be the same whether they are from Appalachee Bay in the north or Florida Bay in the southernmost part of the state. This similarity is because the defining species of the community, the seagrasses, are identical throughout the region; in particular, the 3 dominant species do not change throughout the state. In addition, and of great importance, the processes within the beds; ecological, chemical, and geological, are the same everywhere. However, several highly important, but often subtle changes occur along this gradient, particularly with changes in rates of processes, and in the associated animal communities, which can change greatly over sometimes short distances.

Changes in the distribution and abundance of seagrasses throughout the west coast of Florida, or anywhere else, occur at several scales: local, 1 to 1000 m; regional, 10 to 100 km; and latitudinal, 100 to 1000 km. These variations exist in the few dynamic ecological parameters that have thus far been systematically studied. On a local basis, leaf to belowground biomass values change as a function of sediment grain size, and presumably, nutrient content. Regional scale studies in Florida Bay have found standing crop and productivity to vary systematically across the bay. On a latitudinal scale, turnover rate is found to increase monotonically from central Florida to the central Caribbean.

Dr. Joseph C. Zieman is an associate professor in the Department of Environmental Sciences at the University of Virginia. He received his M.S. and Ph.D. from the Institute of Marine Sciences of the University of Miami. He has studied seagrasses throughout the world, from Alaska to Australia, since 1965, but with special emphasis on Florida and Caribbean seagrass ecosystems.

Assessment of Hurricane Damage in the Florida Big Bend Seagrass Beds

Mr. John M. Thompson
and
Mr. Steve Dial
Continental Shelf Associates, Inc.

In 1984-1985 the Minerals Management Service (MMS) contracted Continental Shelf Associates, Inc. (CSA) to map and investigate the seagrass beds of Florida's Big Bend area. This study produced maps, a photographic atlas, and a technical report dealing with the species composition and distribution of seagrass within the Big Bend area. Delineated were 232,893 ha (575,479 acres) of dense seagrass beds (composed of _Thalassia testudinum_, _Syringodium filiforme_, and _Halodule wrightii_), 498,034 ha (1.2 million acres) of sparse seagrass beds (composed of _Halophila engelmanni_, and algal-live bottom assemblages), and 279,722 ha (691,193 acres) of patchy seagrass beds where all five vascular plant species may overlap.

During the 1985 hurricane season, four major storms passed through the Gulf of Mexico (Figure 6.1). Reports from coastal observers suggested that these storms, particularly Hurricanes "Elena" and "Kate,"severely affected seagrass beds in the Big Bend area. Quantitative seagrass monitoring being conducted in Gainesville OCS area Block 707 by CSA at that time showed an area of 116,554 ha (288,000 acres) to be completely denuded of the _H. decipiens_ and _H. engelmanni_ seagrass species found there.

The existence of an extensive database for the Florida Big Bend area provided an ideal opportunity to assess the impacts of hurricanes upon seagrasses over a large geographic area. Responding to this opportunity, the MMS extended the Florida Big Bend Seagrass Habitat Study to include an assessment of the impacts of, and recovery from, these hurricanes in the Florida Big Bend area.

The combined impact and recovery assessment survey took place in August 1986. Twenty of the 50 seagrass stations established in October 1984 were resampled (Figure 6.2). The stations included 11 offshore of Tarpon Springs, Florida--approximately 97 to 129 km (60 to 80 mi) from the area where Hurricane "Elena" stalled for 48 hrs--and nine stations offshore of Cedar Key, Florida, ranging from 0 to 39 km (0 to 24 mi) from this same area. Portions of three of the nine transects surveyed by divers and underwater television during October 1984 and February 1985 were also resampled (Figure 6.3). In addition, three of the monitoring stations occupied during the June through October 1985 CSA monitoring study of Gainesville area Block 707 were resampled.

Quantitative observations showed no observable changes in either the dense inshore Thalassia-Syringodium-Halodule beds off Tarpon Springs between the October 1984 and August 1986 surveys. Interpretation of observations made off Cedar Key was more difficult. In known areas of seagrass destruction, recovery seemed to be taking place, but changes were noted in the physical characteristics of specific stations.

Comparison of the percentages covered by various habitat types along towed diver and television transects showed no major changes between the 1984-85 and 1986 surveys. Approximately the same percentages of seagrass-covered bottom, bare sand bottom, and live bottom were recorded, although the seagrass was not always present at the same locations where it was noted previously.

The 1985 seagrass monitoring program conducted by CSA in the Gainesville OCS Area Block 707 area provided a database from which leaf biomass (grams dry weight) for the species H. decipiens may be calculated based on quantitative photographic data. A relationship between leaf length and leaf biomass was established by measuring, drying, and weighing harvested leaves. Leaf counts and leaf length measurements in photographed quadrants were converted to biomass by using this relationship.

Six of the 11 quantitative signature control stations, sampled both in October 1984 and August 1986 proved amenable to this type of analysis. Within the analyzed data set, Stations 5, 6 and 7 are from the area offshore of Tarpon Springs, and Stations 37, 38, and 40 are from the area off Cedar key. In the latter set, Stations 38 and 40 are within the area surveyed by CSA in October 1985 and found to be completely denuded of seagrass. Biomass data (mg dry wt/m^2) for H. decipiens at the stations offshore Tarpon Springs are as follows:

Station	10/84 Biomass	8/86 Biomass
5	50	272
6	299	29
7	224	529
Mean	191	277

The data for stations off Cedar key are as follows:

Station	10/84 Biomass	8/86 Biomass
37	115	123
38	318	409
40	7	211
Mean	147	248

The data show considerable variability in H. decipiens biomass among stations and between surveys. However, the average values for the two surveys are comparable. Higher average values for the 1986 survey may be due to the different timing of the surveys in relation to the seasonal growth pattern of the seagrass.

Mr. John Thompson received his Master Science degree in marine biology from Florida Atlantic University in 1974 and his presently a senior staff scientist with Continental Shelf Associates, Inc., (CSA) in Jupiter, Florida. Prior to joining CSA in 1980, he was with the Harbor Branch Foundation where he headed their Remote Sensing Services Department. He has been involved in remote sensing and seagrass bed mapping since 1977 and has mapped seagrass distribution along both the east and west Florida coasts.

Mr. Steve Dial is presently employed as an environmental specialist for Continental Shelf Associates, Inc. He received his BS degree in biology from Kent State University in 1977 and MS degree in marine ecology from Florida Atlantic University in 1984.

Trends in Seagrass Distribution on the West Florida Shelf

Mr. Kenneth D. Haddad
Florida Department of Natural Resources

Marshes, mangroves, and seagrasses are crucial components of fisheries habitat along the Florida west coast. These habitats may serve as nursery grounds, protective structure, and food sources for many marine organisms. Therefore, quantifying habitat distribution and alteration and documenting the dependency of fisheries on habitat may provide managers with a tool to predict future fishing stocks.

With support from the NOAA Office of Ocean and Coastal Resource Management through the Florida Department of Environmental Regulation, the Florida Department of Natural Resources Bureau of Marine Research implemented a fisheries habitat assessment program. A Marine Resources Geographic Information System (MRGIS) was developed which houses a geographically referenced database of fisheries habitat information. The project also includes 1) a sampling program to quantify faunal abundance and diversity within habitats, 2) stable isotope and analyses of associated plants and animals to establish habitat dependency, and 3) an assessment of growth and mortality of juvenile fish.

Initially, the project focused on developing techniques for habitat mapping and monitoring. The extent of Florida's coastal zone (2172 km) precluded standard cartographic approaches. Digital LANDSAT Thematic Mapper (TM) data were selected as the optimal base for statewide assessment effort. Analyses early in the program determined that TM data generally were not sufficient to consistently delineate seagrasses. Aerial photography is photo interpreted for seagrass and digitized into the TM database. Mapping seagrasses of the west Florida Coast is currently underway. Recent mapping efforts by various Federal agencies also will be incorporated into the MRGIS database.

Analyses comparing historical with recent data were conducted on selected areas along the west Florida coast to determine trends in seagrass distribution. Initial findings suggest that distribution has changed notably in many bay systems since the 1940's. Areas of decline included Charlotte Harbor (29%), Tampa Bay (44%), Bayport (13%), Western Choctawhatchee Bay (30%), and eastern Perdido Bay (45%). Only Big Lagoon (west of Pensacola) increased (55%).

Seagrass declines pose a significant management problem because the factors causing the declines, in many areas, are not known, Loss has generally occurred in deeper waters suggesting the decreased water quality and light penetration may influence seagrass distribution.

Nutrient enrichment, which promotes phytoplankton growth, and resuspended fine organics and clays may explain reduced water clarity, but its effect on seagrass growth have not been documented. Research is necessary to determine if changes in water quality and light penetration affect seagrass distribution and to identify other possible causative factors. Although this should be a research priority, all facets of seagrass research remain inadequately funded.

Seagrass beds are a dominant habitat on the west Florida shelf and certainly contribute to the success of the fisheries. Funding for research to develop the information required for adequate management has not been commensurate with the economic and environmental value of the resource. Federal and State resource managers should address this issue.

Kenneth Haddad is a biological scientist with the Florida Department of Natural Resources, Bureau of Marine Research. His research has involved the development of applications in remote sensing, to coastal and ocean resource assessment. This has included the development of a remote sensing facility at the Bureau of Marine Research. He received a B.S. in biology from Presbyterian College and M.S. in marine science from the University of South Florida.

Ecology and Distribution of Seagrasses Along the Lower Texas Coast

Dr. Warren M. Pulich, Jr.
University of Texas Marine Science Institute

PROJECT HISTORY

The south Texas coast from Aransas and Copano Bays southward to the Mexican border is a subtropical area, lying at the northern edge of the Tamaulipan Biotic Province. The climate is dry subhumid, with an average rainfall of 25-30 inches, and evapotranspiration normally exceeds precipitation. The low volume of consistent riverine inflows and uniformly small, astronomical tidal amplitudes lead to development of lagoonal estuaries, often with hypersaline conditions. Under this hydrological regime, typical emergent salt marsh systems (e.g. Spartina) are noticeably limited, and submergent seagrass meadows ("beds") become the dominant marine vascular plant communities. This situation presents a dramatic contrast with coastal areas to the north along the upper Texas coast, where emergent salt marshes are dominant, and obviously has significant implications for fish and wildlife populations dependent on seagrass beds.

A relatively high diversity of seagrasses, five species, exists (approx. 1/10th of the total species worldwide). Three pioneer or colonizing species occur widely over the entire region: Halodule wrightii (shoalgrass), Ruppia maritima (widgeongrass), and Halophila engelmanni. The climax community species, Thalassia testudinum testudinum (turtlegrass) and Syringodium filiforme (manateegrass), are locally abundant, but absent over most of the region. Peak summertime biomass values range from 1000 g/m2 for Thalassia and Syringodium, to 500 g/m^2 for Halodule, 250 g/m^2 for Ruppia, and 100 g/m^2 for Halophila. All five species can be found as monospecific beds, and certain parts of bays and lagoons are well-known for specific communities. In general, however, Syringodium occurs mixed with Thalassia, and Halophila is mixed with Halodule. Pioneer species only rarely occur mixed with climax species.

SIGNIFICANT FINDINGS

Species distribution in south Texas is a function of several key environmental factors: temperature, salinity, and tidal regimes. Temperature regimes account for latitudinal distribution patterns. The further north one goes along the coast, the less Thalassia and Syringodium, and the more Ruppia and Halodule, are encountered. While all four other seagrasses have warm temperature optima (i.e. above 25oC), Ruppia is adapted to cooler temperatures. Temperature limits then explain the frequent dominance of Ruppia during winter and spring, in both low and high salinity environments (e.g. Redfish Bay or Laguna Madre, respectively).

Salinity regimes control distribution according to the salinity tolerance limits of the species. McMillan has determined that the order of salinity tolerance is greater than 60 o/oo for Halodule and Ruppia, ca 45 o/oo for Halophila, and less than 40 o/oo for Thalassia and Syringodium. In general, the distribution of Thalassia and Syringodium can be predicted from salinity and temperature regimes, while Halodule and Ruppia are readily adaptable to fluctuations in these parameters (e.g. Upper Laguna Madre and Baffin Bay).

Where salinity regimes are favorable (i.e. annual average between 20 to 36 o/oo), tidal regimes control the distribution of south Texas seagrasses. Yearly, astronomical tidal cycles in the Texas Coastal Bend are characterized by spring and fall high periods, with very low periods during the winter. This situation produces long periods of exposure to air during the coldest months of the year, and still longer periods of inundation by bay water of low light transmittance at other times. During exposure of shallow flats to air, the seagrass leaves are often killed by desiccation or cold shock. Consequently, only the fast-growing species can become established in these shallow flats. This makes productivity rates critical to the outcome of interspecific competition between South Texas seagrasses.

A typical distribution profile of species with depth, shows that Halodule occupies shallow and deep zones, while Thalassia is dominant in mid-depth zones (ca -1.5 to -3 ft MSL). The Laguna Madre is interesting since it provides evidence that Halodule grows well at deep depths (--4 ft MSL). When the productivity rates of the five species are compared, the influence of light levels on species colonization rates can be assessed. Williams measured the photosynthetic rates (carbon fixation) under various light levels. Her data showed that all five species saturated at approximately the same irradiance level (60-70% full summertime sunlight), but the maximum photosynthetic rates achieved varied between species. Thalassia and Syringodium both exhibited maximum rates of 30% of those measured for Halodule, Ruppia or Halophila. Based on these photosynthetic rates, then Thalassia and Syringodium are slower-growing than the others, and they will be out-competed by the fast-growing species in shallow areas subject to long periods of tidal exposure.

The effects of tidal and salinity factors on seagrass distribution are evident from the historical changes in wetland communities of the south Texas barrier island lagoons and tidal delta systems. In 1958, Brown and others with the U.T. Bureau of Economic Geology documented extensive areas of wind-tidal flats and shallow, subaqueous mud-flats in the harbor island tidal delta complex at the confluence of Corpus Christi-Redfish-Aransas Bays. In 1979, White and coworkers updated the wetland maps for this area; they noted that seagrasses had spread into these previously unvegetated flats. These workers postulate a relative rise in sea level over this time, probably from compactional subsidence, complemented by eustatic rise in sea level. Some erosion of subaqueous dredge spoil deposits has also occurred such that seagrasses remain adequately submerged in these areas over most of the year. It is estimated that grassflats have increased approximately 150% in area in the Corpus Christi Bay region (from 4 to 10 sq. miles).

In the Texas Laguna Madre, major shifts in seagrass species abundance and community structure have occurred in less than 20 years. In the mid-60's, McMahan surveyed seagrasses of both the Upper and Lower Laguna Madre as part of resource inventory for the Texas Fish and Wildlife Commission. Thalassia and Syringodium were found only in the extreme southern part of the Lower Laguna, while Halodule was the dominant species, extending up to the Land Cut. In the Upper Laguna, Ruppia was generally the most abundant species, but often mixed with Halodule. Very little Halophila was present. By 1974, significant changes were found when Merkord re-mapped the Laguna vegetation. He reported that Syringodium had spread in great abundance ca. 25 miles northward in the Lower Laguna, well past Port Mansfield. Halodule biomass had decreased greatly, particularly south of the Arroyo Colorado, apparently displaced by Syringodium. In the Upper Laguna, Halophila had become quite common, while Ruppia biomass had declined. Halodule was increased in density here and had also expanded its range southward past Baffin Bay. In recent years, (late 70's), large increases have been noted for Halodule and Halophila in Baffin Bay proper.

These changes in Laguna Madre seagrass populations have been attributed to changes in the salinity regimes and possibly water column light conditions. The construction of the GIWW and Mansfield Pass (latter in 1948) have changed the Lower Laguna from a hypersaline environment, characterized by extremes of high and occasionally low salinities, to a less saline, more stable environment. Salinities there now rarely reach 40 °/oo. Some evidence exists for increased overall turbidity in the Lower Laguna from Arroyo Colorado runoff and boat/barge traffic. In the Upper Laguna, salinities regularly are in the range of 40-50 °/oo), which precludes Thalassia and Syringodium from establishing. Halodule and Halophila are favored by the very clear, hypersaline waters and warm temperatures.

RECENT ACCOMPLISHMENT

Recent projects underway at the University of Texas Marine Science Institute have focused on the production ecology of Halodule and Ruppia, the most abundant seagrasses in the south Texas estuaries, in relation to local habitat conditions. Studies of growth dynamics will reflect the integrated short-term responses of the plants to habitat parameters besides light (e.g. nutrients, substratum, or epiphyte loads). Such short-term production data can indicate incipient changes in environmental processes critical to seagrass ecosystems well before such changes become irreversible.

Interactions between light regimes and other growth parameters are detectable by monitoring seagrass production at different water depths. While plant production is expected to be proportional to light levels at the various depths, quantitative relationships will vary with particular locations and the season. One project has examined the growth dynamics of Halodule at five sites in the Corpus Christi area which represent different environmental gradients of light, salinity, and nutrient loading. Biomass and shoot production, plus environmental quality data, were followed for the four peak months during the growing season (June - Sept.). Shoot numbers were directly correlated for most months with bottom light levels (as % of surface irradiance) below the half-saturation light level of photosynthesis (ca. 50%). Above this light level, shoot production appears controlled by other factors. When biomass data are considered, the same pattern is discernible for below-ground (i.e. root) production. For above-ground biomass (i.e. standing crop), the relationship is less clear. Other factors, besides light levels (probably grazing or epiphyte loads), play an important role in maintaining the above-ground biomass levels.

In another project, the influence of edaphic (sediment-related) factors was examined at old dredge spoil deposit sites. This work has shown that significant changes in sediment redox properties occur during colonization of bare sediments by Halodule. The rate of spreading by Halodule into such areas appears dependent on proper conditioning of sediment by microbial processes such as sulfate reduction, organic nitrogen enrichment, and trace metals chelation. Nitrogen nutrition of Halodule, in particular, appears coupled to the presence of specific microbial populations in the rhizosphere. These observations establish a critical role for nitrogen cycling in the sediments to Halodule production (and possibly other species). They may also provide the basis for competitive interactions between some seagrass species (e.g. Halodule and Ruppia).

RECOMMENDATIONS FOR FUTURE RESEARCH

Information on growth dynamics is applicable to situations where impacts on coastal seagrass ecosystems are expected: (1) when freshwater inflow regimes are altered in an estuary; (2) when pollutant discharges or wastewater effluents enter an estuary; (3) when a natural climatic catastrophe has occurred, e.g., hurricane or severe freeze; or (4) when channel dredging or other development projects are proposed in coastal wetlands. In these cases, results from short-term process measurements can be used to predict effects on specie production and plant community structure. However, synergistic relationships between estuarine processes and seagrass production are still inadequately defined. Maintenance of quality seagrass habitats for the future requires research to redefine the criteria used for monitoring seagrass production and/or physiological status.

Dr. Warren M. Pulich, Jr., is a Senior Research Biologist at the University of Texas at Austin, Marine Science Institute, where he is a specialist in aquatic botany and coastal wetlands ecology. His research work has concentrated on the physiological ecology of Texas marine vascular plant ecosystems, viz., seagrass beds and salt marsh communities. Studies of effects of environmental factors on the production ecology of these plants are directed toward fish and wildlife habitat management and coastal resource protection programs.

Dr. Pulich received his B.S. in biological sciences from Loyola University, New Orleans, and his Ph.D. in biology (with emphasis on environmental studies) from Rice University.

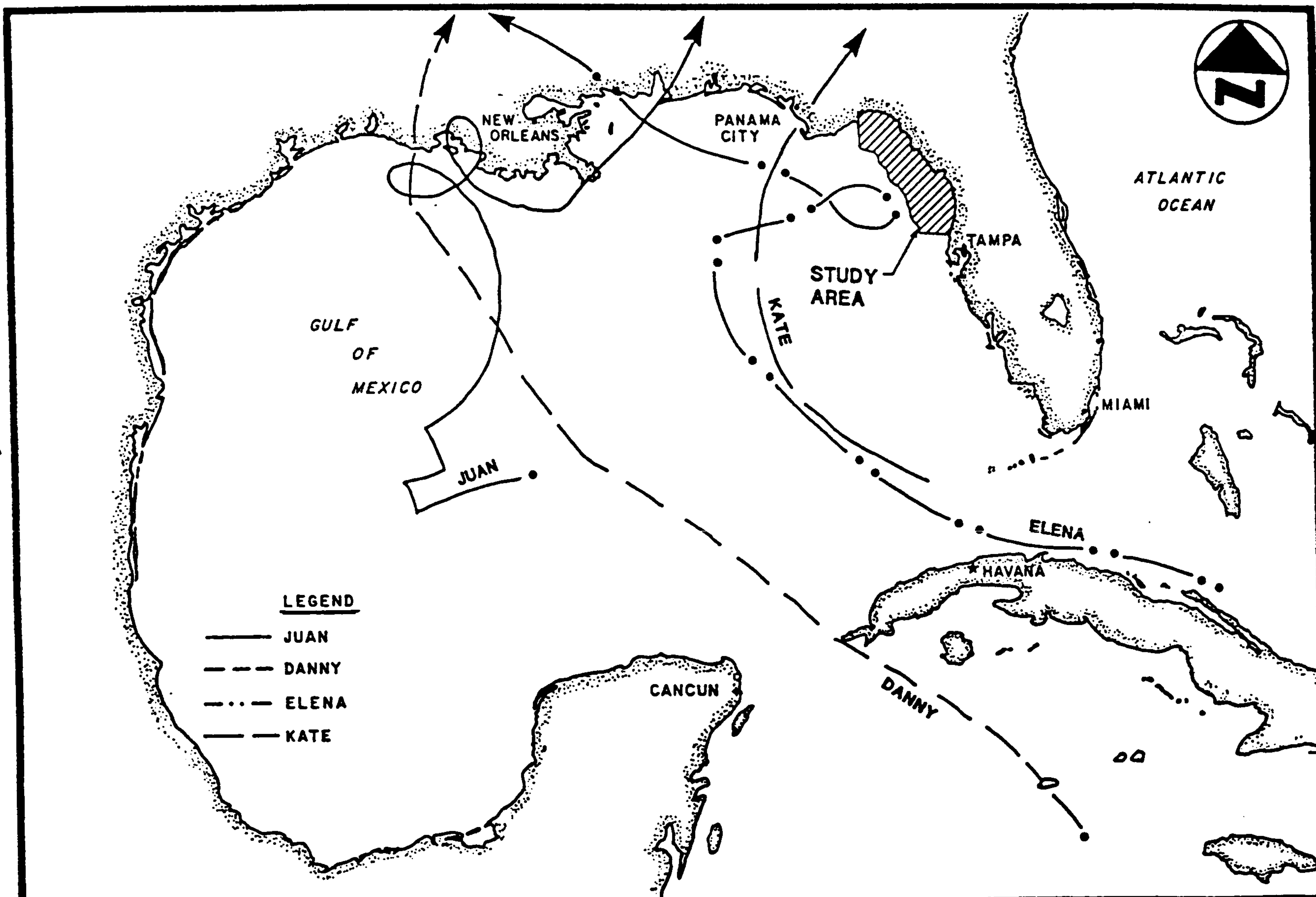

Figure 6.1.--Major hurricanes of the 1985 season.

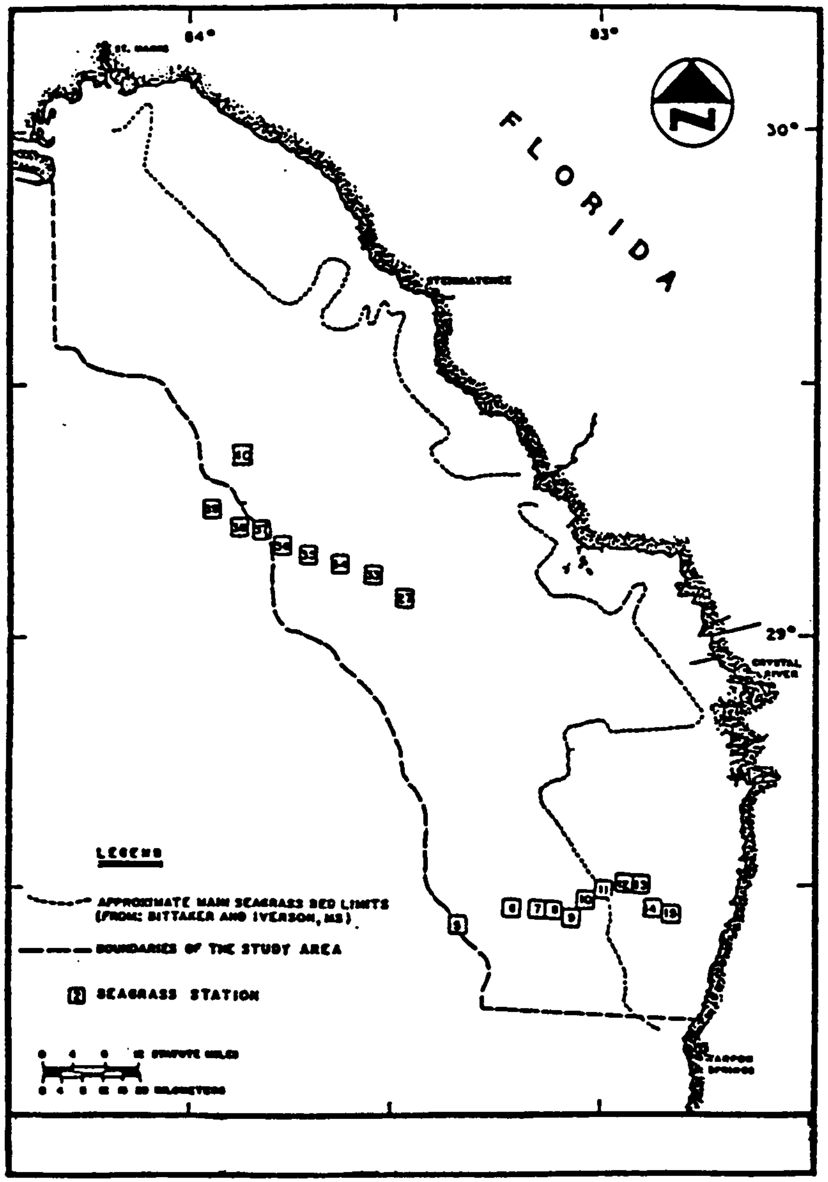

Figure 6.2.--Quantitative seagrass stations sampled during 1986.

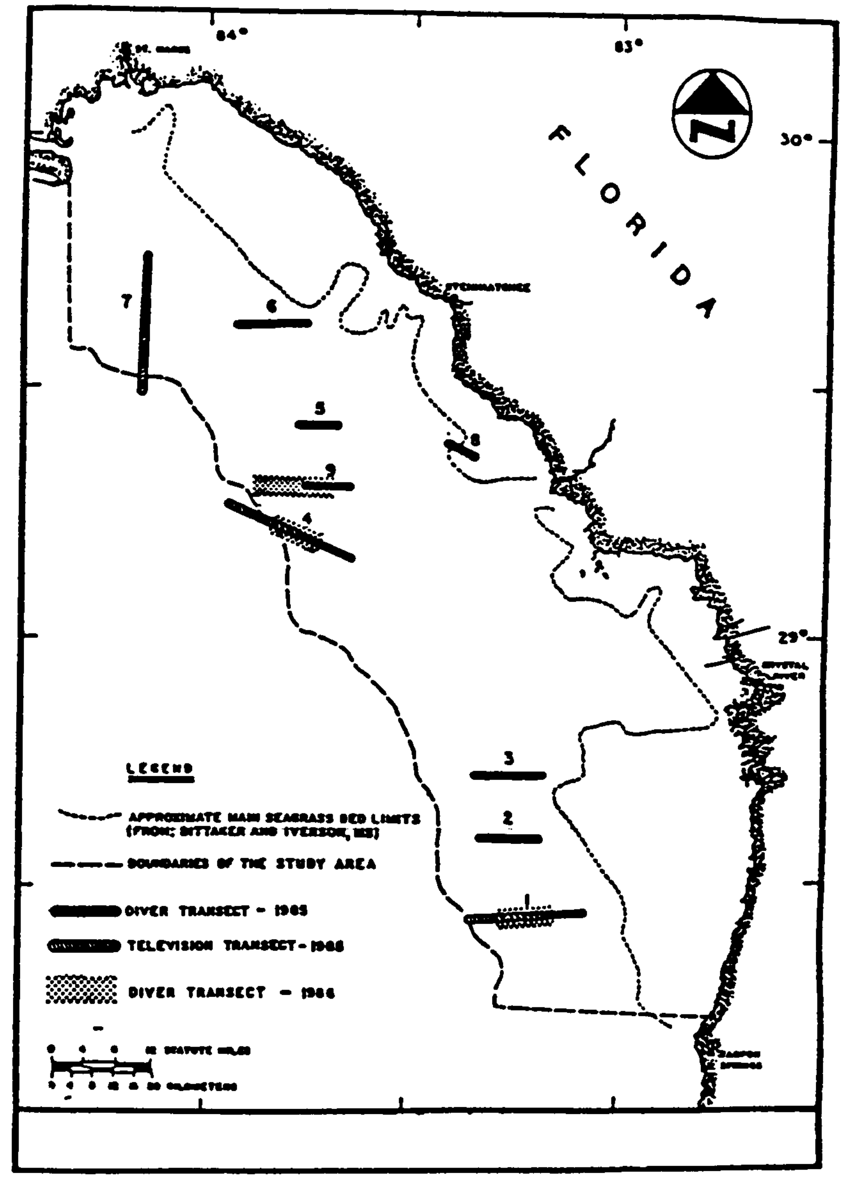

Figure 6.3.--Diver and television transects surveyed.

SEA TURTLE PROBLEMS IN THE GULF OF MEXICO

Session:	SEA TURTLE PROBLEMS IN THE GULF OF MEXICO
Co-Chairs:	Mr. Kenneth Graham Mr. Jacob Lehman Mr. Lars Herbst
Date:	November 5, 1986

Presentation	Author/Affiliation
Sea Turtle Problems in the Gulf of Mexico: Session Overview	Mr. Kenneth Graham Mr. Jacob W. Lehman and Mr. Lars Herbst Minerals Management Service Gulf of Mexico OCS Region
An Overview of Marine Turtles in the Gulf of Mexico	Mr. Paul Raymond National Marine Fisheries Service
The Occurrence of Sea Turtles in Coastal Louisiana Waters	Ms. Deborah A. Fuller, and Ms. Anne M. Tappan Coastal Fisheries Institute Louisiana State University
Effects of Oil on the Physiology of Marine Turtles	Dr. Peter L. Lutz Dr. Molly Lutcavage Rosentiel School of Marine and Atmospheric Science, University of Miami and Dr. Gregory D. Bossart, Wildlife Veterinary Center
Effects of Underwater Explosions on Fish and Marine Mammals	Mr. George A. Young Naval Surface Weapons Center
Kemp's Ridley Sea Turtle Research	Dr. Edward Klima National Marine Fisheries Service
Stranding and Natural History of Sea Turtles Along the Northern Gulf	Dr. Andre Landry, Jr. Texas A & M University of Galveston Department of Marine Biology
General Theory for the Cutting of Conductors and Platform Legs With Bulk and Shaped Charges	Mr. Peter DeMarsh Demex International
Alternatives to Explosives in Platform Removal	Mr. W. J. Ruez Offshore Operators Committee

Session: SEA TURTLE PROBLEMS IN THE GULF OF MEXICO (Cont'd)

Studies, Objectives, and Methodologies to Determine the Impact of Platform Removal on Sea Turtles and Alternative Removal Methods to Reduce These Impacts	Open Discussion

Sea Turtle Problems in the Gulf of Mexico: Session Overview

Mr. Ken Graham, Mr. Jacob W. Lehman,
and
Mr. Lars Herbst
Minerals Management Service

Both the morning and the afternoon sessions consisted of four topics each. The major concerns for discussion were 1) oil spills and 2) the use of explosive charges to remove offshore platform legs, piling, and conductors, and their potential effects on endangered sea turtles.

The first speaker was Mr. Paul Raymond from the Protected Species Management Branch of the National Marine Fisheries Service (NMFS) in St. Petersburg, Florida. Mr. Raymond discussed the five species of sea turtles which occur in the northern Gulf of Mexico, their endangered species status, ecology, general distribution, and abundance. Much emphasis in his discussion was placed on the severely depleted Kemp's ridley turtle and the major causes of its reduced population. The current estimate of about 500 nesting females is indicative of the Kemp's problem.

The second speaker was Ms. Deborah Fuller, a research associate at the Center for Wetland Resources at Louisiana State University. Ms. Fuller discussed her research to add to the existing database by obtaining detailed information on turtle sightings in Louisiana through informal interviews of commercial fishermen and other marine-oriented individuals along the coast. In addition to collecting data, she sought to increase fishermen's awareness of sea turtles and establish a long-term network for reporting sea turtle sightings.

Data on 141 sightings and strandings from 1982 to the present were collected during this study. The species could not be identified in one-third of these sightings. Of the species identified by respondents, 67% were Kemp's ridleys, 17% loggerheads, 10% green turtles, 4% leather-backs, and 1% hawksbills.

The third speaker was Dr. Peter Lutz, of the University of Miami, Rosenstiel School of Marine and Atmospheric Science. Dr. Lutz discussed the results of the recent MMS funded study, "The Effects of Oil on the Physiology of Marine Turtles." The experimental and field results indicate that marine turtles would be at risk if they encountered an oil spill or large amounts of tar in the environment. Despite the high tolerance of marine turtles to severe physical damage, they have proved surprisingly sensitive to oil. Their limited ability to avoid oil slicks, and numerous adverse physiological and clinicopathological effects from exposure to oil, means that the marine turtles could be heavily impacted. This impact would be particularly critical if it occurred during the nesting season when turtles aggregate on nesting beaches to lay their eggs, or when the hatchlings return to the sea in large numbers.

Dr. George A. Young of the Naval Surface Weapons Center discussed the effects of underwater explosions on fish and marine mammals. The U.S. Navy has been conducting research on the environmental effects of underwater explosions since 1970. The objectives are to develop prediction models for the important effects, to develop guidelines for avoiding or minimizing adverse impacts, and to investigate possible techniques to influence fish and marine mammals to temporarily leave a test site.

Mathematical models have been developed for the dispersion of explosion products, for injury to fish with and without swimbladders, and for safe ranges for sea mammals. Rough estimates of noise can be made, although noise is usually not a problem.

In early investigations, it was often assumed that injury to marine life could be related to the peak pressure in the underwater shock wave. However, it was learned that effects on fish with swimbladders were more complex and depended on the direct shock wave, the negative wave that reflected from the sea surface, and the size and depth of the fish. In the case of sea mammals, a model based on the oscillation response of the lung cavity and of small bubbles of intestinal gas was developed.

A limited amount of data was acquired on sea turtles as a result of the accidental exposure of three turtles to a test in the Gulf of Mexico. Sea turtles are thought to be vulnerable to explosion shock-wave injury because they too have lungs and sometimes bubbles of intestinal gas.

Dr. Edward F. Klima of the National Marine Fisheries Service in Galveston, Texas, discussed research on Kemp's Ridley sea turtles. The NMFS Southeast Fisheries Center has been involved in an international program to restore and preserve the Kemp's ridley turtle since 1978. The program is divided into three main parts: 1) the enhancement of nesting success and survival at Rancho Nuevo, Tamaulipas, Mexico; 2) the establishment of a second breeding population at Padre Island National Seashore in Texas; and 3) the study and evaluation of the headstarting concept.

The Galveston Laboratory of the Southeast Fisheries Center has, since 1978, released 10,792 headstarted turtles. The released yearlings survive in the wild, grow normally, and are recaptured in locations where wild turtles have been recorded. Although this program has been in effect for almost nine years, the number of nesters has not increased at Rancho Nuevo, nor have any headstarted turtles been observed nesting on any beach.

The NMFS program on sea turtles also includes the development of the Turtle Excluder Device for shrimp trawlers and the collection of biological information on the life history, distribution, and dynamics of the Kemp's ridley stock.

Recent strandings of turtles and porpoises along the Texas coast may have been associated with the removal of oil and gas platforms using explosives in the northern Gulf of Mexico. While the occurrence of turtles and marine mammals around platforms is not well documented, it has been demonstrated that sea turtles in the vicinity of explosive detonations during platform removals can be injured or killed.

Dr. Andre M. Landry, Jr., of Texas A&M University at Galveston, Texas, discussed the stranding and natural history of sea turtles along the northern Gulf of Mexico. The NMFS and Sea Turtle Standing and Salvage Network (STSSN) have documented turtle strandings along the Texas Coast since 1979. Texas ranks first in annual number of strandings along the Gulf coast. Texas A&M University, with the aid of NMFS, The U.S. Fish and Wildlife Service, and The Texas Parks and Wildlife Department (TPWD), recovered many stranded carcasses and conducted necropsies in an attempt to determine the causes of death. Food habit analyses were performed on some of these animals.

Systematic beach surveys and responses to stranding reports from the public, recovered 251 sea turtles along the upper Texas and southwestern Louisiana coast (176 km-110 miles) from 7 March through 29 October 1986. Kemp's ridley (Lepidochelys kempi) and loggerhead sea turtles (Caretta caretta) comprised over 86% of these strandings. Peak ridley strandings in Texas and Louisiana occurred during March through May and June and August, respectively. April Kemp's ridley strandings exceeded the total number of non-headstarted ridleys stranded along the entire Texas coast in 1985. Loggerheads exhibited the highest stranding frequency during April (Texas) and June (Louisiana). Preliminary findings indicate that the sea turtle stranding rate (number of strandings/mile of coastline) increases gradually from the western limit of the Texas survey boundary (0.04/mile) through the Louisiana survey area (0.62/mile).

Necropsy analyses indicated that over 21% of all stranded turtles exhibited man-related mutilation. Anomalies of the lung (deflated/presence of fluid), heart (rupture/lesion), pericardial sac (rupture/presence of fluid), trachea (presence of fluid), and skeletal muscle (hemorrhaging) were detected in Kemp's ridleys and loggerheads at varying frequencies of occurrence.

Mr. Peter DeMarsh of Demex International discussed the various explosives used in the oil field, their characteristics, and how explosives work. In the past, explosives contractors have had few guidelines in removing offshore platforms and other structures with explosives. Consequently, economics, instead of environmental concerns or best engineering/demolition practices, have dictated explosives practices. The common practice for severing structures has been to obtain large quantities of low-cost explosive and place it down in the hole. Overcharging has been common because failure to cut a piling or caisson on the first shot would be costly to the salvage company. Two methods were suggested for reducing the amount of energy explosives released into the water column; the use of shaped charges, and the severing of structures deeper below the mudline. Mr. DeMarsh indicated that if guidelines could be developed which specified a safe energy level that could be received by sea turtles, the explosives industry could tailor their charges to meet that criterion.

The last paper of the session was given by Mr. Win Thornton on behalf of Mr. W. J. Ruez representing the Offshore Operators Committee (OOC). He discussed non-explosives alternatives for platform removal. Mr. Thornton stated that of the current alternatives to explosives (including torch cutting and abrasive cutter), mechanical cutting is the most favorable technique. Future alternatives might include plasma arc cutting, mechanical or torch cutting with downhole rotation, thermal cutting, chemical cutting, and laser cutting.

Job-specific influences on the application of a removal technique was reviewed. These include varying structural configurations, site conditions, and platform conditions. Structural geometry, complexity, and size can all vary widely from the early generation platforms to the modern conventional platforms. Site conditions such as water depth, soil properties, prevailing currents, and visibility all effect platform removal. The platform's physical condition, its stability upon removal, and the existence of potential obstruction must be considered when selecting the removal technique.

Mr. Ken Graham is currently employed as an environmental protection specialist by the Minerals Management

Service, Gulf of Mexico OCS Region in New Orleans, Louisiana. Prior to that time he worked as a biologist for the Jacksonville District, U.S. Army Corps of Engineers. He received a BA degree in biology from Luther College and a MS degree in botany from North Dakota State University.

Mr. Jacob W. Lehman is employed by the Minerals Management Service, Gulf of Mexico OCS Region in New Orleans, Louisiana, as a fish and wildlife biologist. He was previously employed as a fishery biologist with the Environmental Protection Agency in Washington, D.C. He received his BS in natural resources and MS in zoology from Ohio State University. He has been involved with the Bureau of Land Management and Minerals Management Service's Environmental Assessment Program since 1974.

Mr. Lars Herbst is employed as a petroleum engineer in the Technical Assessment and Operations Support Section of the Minerals Management Service. He was previously employed by Flopetrol-Johnston Schlumberger as a field engineer in production testing. He received his BS in petroleum engineering from Louisiana State University. He is currently investigating alternative techniques for platform removal and is developing monitoring programs for platform removal using explosives.

An Overview of Marine Turtles in the Gulf of Mexico

Mr. Paul W. Raymond
National Marine Fisheries Service

Five species of sea turtle are discussed that occur in the U.S. Gulf of Mexico (GOM): the Kemp's ridley, the loggerhead, the green, the hawksbill, and the leatherback. Although nesting population estimates are available for U.S. beaches, estimates are lacking for all species when considering juveniles, subadults, and males in the GOM. The literature on the abundance, distribution, and foraging habits of the five species in reviewed and discussed. The Kemp's ridley nesting population at Ranch Nuevo, Mexico, has continued to decline (average annual decline of 3%). A large portion of this loss is attributed to the incidental take of adult and subadult ridleys by shrimp trawlers working in the U.S. and Mexican waters. It is estimated that 3,129 loggerheads, 501 Kemp's ridleys, and 125 green turtles drown in shrimp trawlers annually in the U.S. GOM. Sea turtles are also faced with a variety of other man-related problems, many of which have only recently been revealed. These include the following: entanglement and ingestion of synthetic discards, collisions with vessels/propellers, injury and/or mortality associated with oil platform removals using explosives, occurrence of tumorous growths (fibropapillomas) on subadult greens, oil impacts, direct and indirect effects of dredge and fill projects, and the loss of nesting habitat due to coastal development. Data from the sea turtle stranding and salvage network indicates an increase in the number of carcasses reported in the U.S. GOM (1,672 strandings from January 1980-October 1986). This may be a reflection of an increase in beach observer effort and/or an increase in actual mortality.

Mr. Paul Raymond is a biologist with the Protected Species Management Branch, National Marine Fisheries Service at the Southeast Regional Office in St. Petersburg, Florida. He conducts many interagency consultations under the Endangered Species Act (ESA) and monitors federal compliance with the Section 7 requirements of the ESA. He has been involved with sea turtle research and management for nine years and has had a special interest in the effects of coastal development on sea turtles and their nesting beaches. He received his B.S. and M.S. in zoology from the University of Central Florida.

The Occurrence of Sea Turtles in Coastal Louisiana Waters

Ms. Deborah A. Fuller
and
Ms. Anne M. Tappan
Coastal Fisheries Institute

INTRODUCTION

Five species of sea turtles inhabit Louisiana waters. Three species, Kemp's ridley (Lepidochelys kempi), hawksbill (Eretmochelys imbricata) and leatherback (Dermochelys coriacea) are listed as endangered by the U.S. Fish and Wildlife Service (USFWS). The loggerhead (Caretta caretta) is threatened throughout all of its range. The green turtle (Chelonia mydas), has a threatened status in the Gulf of Mexico and is considered endangered in some regions it inhabits. Because of their threatened/endangered population status, sea turtles are sensitive to potential impacts from a variety of activities in the Gulf, including commercial fishing, oil exploration and recovery, and pollution. Detailed information on the occurrence of sea turtles in Louisiana waters is needed to evaluate possible impacts. The existing database on sea turtles in Louisiana includes information from stranding reports, observations, and aerial surveys. There are many gaps in this database with respect to species, size class, seasonal, geographic, and specific habitat distributions. Preliminary studies conducted in 1984 showed that useful data on the occurrence of sea turtles could be obtained from interviews of coastal fishermen. The purpose of this study was to add to the existing data base by obtaining detailed information on turtle sightings in Louisiana through informal interviews of commercial fishermen and other marine-oriented individuals along the coast. In addition to collecting data, we sought to increase fishermen's awareness of sea turtles and establish a long-term network for reporting sea turtle sightings.

METHODS

Data were collected from a number of different sources throughout coastal Louisiana: informal interviews of fishermen and divers, stranding reports, reports of sightings from helicopter pilots, and reports from state and university biologists. Turtle sightings were tabulated according to National Marine Fisheries Service statistical zones. The sightings were then grouped into two categories: (1) recent, covering 1982 to the present, and (2) historical, covering sightings before 1982 and those sightings with no information on date of occurrence. The inability to accurately quantify shrimping effort in relation to our interview effort limits interpretations of seasonal and geographic trends.

RESULTS

We interviewed 131 persons during 1985-86. Commercial shrimpers, divers, recreational shrimpers, fishermen, offshore workers, and pilots accounted for 79%, 10%, 6%, 3%, and 2% of those interviewed, respectively. Twenty-eight percent of those interviewed had never seen a sea turtle.

Species could not be identified in nearly one-half of all historical sightings. When respondents could identify a species it was most often Kemp's ridley. Most of these sightings occurred along the coast from Terrebonne Bay east to the Lake

Borgne area. All historical records with known dates, reported sightings that occurred throughout the year.

Data on 141 sightings and strandings from 1982 to the present were collected during this study. The species could not be identified in one-third of these sightings. Of the species identified by respondents, 67% were Kemp's ridleys, 17% loggerheads, 10% green turtles, 4% leatherbacks and 1% hawksbills.

The mean reported carapace length for Kemp's ridleys was 1.4 ft with a range from .5 ft to 2.0 ft. No seasonal or geographic trend in carapace length was apparent for this species. Kemp's ridleys were observed in waters having an average depth of 26.3 ft (range: 7.5 ft to 72 ft).

Sixty-eight percent of the sightings were made during April through August, another 20% in October, and 3% in January. Over one-third of the ridley sightings occurred at the mouths of Barataria Bay and the Mississippi River. Another 20% were observed off the coast of Cameron. Several of these occurrences were reported in Calcasieu Pass and one in Calcasieu Lake. Reports of ridleys inside Barataria Bay along with the Calcasieu area reports support the general belief that ridleys prefer the nearshore and inshore waters. All of the loggerhead sightings occurred from Vermilion Bay eastward with over 50% occurring from Vermilion to Timbalier Bay.

The mean reported carapace length for loggerhead sea turtles was 2.6 ft (range: 1.0 ft to 4.0 ft) with no apparent geographic or seasonal trend. The mean water depth where loggerheads were observed was 33 ft (range: 5 ft to 140 ft). Sixty percent of the observations occurred from may through July.

Ninety percent of the green turtle sightings occurred in coastal waters at Terrebonne Bay and eastward. nearly 80% of these sightings were reported from April to July, but it should be noted that most of the fishermen who reported green turtles did not shrimp during the winter. The mean carapace length was 2 ft ranging from 1.5 ft to 3.0 ft. The mean depth of waters where green turtles were reported was 238 ft.

Only three leatherback sightings were reported and all these by pilots. The low number of sightings of this species may be the result of the lack of fishing effort in the areas where this turtle frequents.

One hawksbill turtle was reported, it being caught in a gill net in Cameron Parish.

Fifteen SCUBA divers were interviewed. Collectively they had been diving an average of 16 years in the Gulf. Only two of the 19 turtles reported by divers were seen at a rig structure. One of these sightings was a dead leatherback that had apparently become entangled in a cable beneath the rig. Most divers said they rarely saw sea turtles in Louisiana waters although they did see them in Florida waters.

Sea turtles were reported along the entire Louisiana coast. Juvenile Kemp's ridleys were the most frequently observed species particularly along the Cameron, Barataria Bay, and the mouth of the Mississippi River. Loggerheads were the next most frequently reported species. Leatherbacks, green turtles and hawksbill were not frequently observed. Data collected from divers is inconclusive concerning the occurrence of turtles at oil rigs and needs to be studied further. When fisheries dependent data such as this are obtained, effort needs to be quantified for better interpretation.

This could be accomplished through log-keeping by fisherman. Future surveys will be directed more at non-fisheries occupations such as divers and pilots.

Ms. Deborah Fuller received an M.S. in wildlife ecology and a M. Ap. Stat. in experimental statistics from Louisiana State University. Her Research Interests include:

- incidental capture of sea turtles
- succession and wildlife values of newly emerging river delta habitat
- historic trends in saltwater intrusion
- yield per recruit analyses of white shrimp

Effects of Oil on the Physiology of Marine Turtles

Dr. Peter Lutz, and Dr. Molly Lutcavage
Rosenstiel School of Marine and Atmospheric Science
and
Dr. Gregory D. Bossart
Wildlife Veterinary Center

All marine turtle species are thought to be at risk, being classified as either threatened or endangered.

It is of particular concern, therefore, that they may be vulnerable to oil spills or pelagic tar because they must surface to breathe, increasing the possibility of repeated contact with the oil or tar which floats at the surface.

The objective of this study was to determine the effects of petroleum on marine turtles. An experimental program was carried out on 12-15 month old loggerhead and green turtles to determine physiological effects of oil using South Louisiana Crude Oil (SLCO) preweathered for 48 hours. The physiological experiments showed that some aspects of respiration, blood chemistry and salt gland function of loggerhead sea turtles were significantly effected. Oil was observed clinging to the nares and eyes and in the upper portion of the esophagus and was found in the faces of all turtles in the physiological experiments. Deterioration was seen in the epidermis and dermis of some skin areas. All turtles fully recovered after removal of oil. Similar effects were found in stranded oil, fouled turtles.

Experimental and field results indicate that marine turtles would be at risk if they encountered an oil spill or large amounts of tar in the environment. Despite the high tolerance of marine turtles to severe physical damage, they have proved surprisingly sensitive to oil. The limited ability to avoid oil slicks and numerous adverse physiological and clinicopathological effects from exposure to oil mean that the marine turtles could be heavily impacted. This impact would be particularly critical if it occurred during the nesting season when turtles aggregate and lay their eggs, and the hatchlings return to the sea in large numbers from relatively restricted geographical areas.

Formulation of an emergency strategy for dealing with oil spills in areas with marine turtles is recommended. Key areas such as heavily utilized nesting beaches should receive special attention. The first option is to consider ways of stopping the oil from getting to the turtle. Any plans have to consider the threat to adults, hatchlings, and eggs. In certain circumstances it might be possible to physically restrict a spill; for example, a limited access beach might be protected by the use of booms. Use of dispersants is another means to consider to prevent the oil from reaching the turtles.

Dispersants with microbial nutrients are of particular interest, but they should only be used if they are found comparatively harmless to sea turtles.

Dr. Peter Lutz received his B.S. and Ph.D. degrees from Glasglow University in zoology and animal physiology. He is currently the Chairman of the Department of Marine Biology at the Rosentiel School of Marine and Atmospheric Science, University of Miami.

Dr. Molly Lutcavage received her Ph.D. in biological oceanography from the University of Miami in 1987. She has worked with seaturtles for the past 9 years. She recently accepted the position of Research Coordinator at the Portuguero Turtle Station in Costa Rica.

Dr. G. Bossart received his VMD from the University of Pennsylvania in 1978. He was a NIH Fellow in Pathology at the University of Miami School in Medicine from 1981-1985. He is currently pathologist at the Veterinary Reference Laboratory in Fort Lauderdale; veterinarian/curator at the Miami Seaquarium; adjunct associate professor at the University of Miami Rosentiel School of Marine and Atmospheric Science. For the past 7 years he has been involved in the disease pathology of seaturtles.

Effects of Underwater Explosions on Fish and Marine Mammals

Dr. George A. Young
Naval Surface Weapons Center

The U.S. Navy has been conducting research on the environmental effects of underwater explosions since 1970. The objectives are to develop prediction models for the important effects, to develop guidelines for avoiding or minimizing adverse impact, and to investigate possible techniques to influence fish and marine mammals to temporarily leave a test site.

Mathematical models have been developed for the dispersion of explosion products, for injury to fish with and without swimbladders, and for safe ranges for sea mammals. Empirical data have been acquired for crabs and oysters. In addition, cratering can be predicted for bottom and near- bottom explosions, and rough estimates of noise can be made, although noise is usually not a problem.

In early investigations, it was often assumed that injury to marine life could be related to the peak pressure in the underwater shock wave. However, it was learned that effects on fish with swimbladders were more complex and depended on the direct shock wave, the negative wave that reflected from the sea surface, and the size and depth of the fish. Fish without swimbladders are highly resistant to explosions, and the physiological effects are not well understood, though gill damage is a major factor. In the case of sea mammals, a model based on the oscillation response of the lung cavity and of small bubbles of intestinal gas was developed.

A limited amount of data was acquired on sea turtles as a result of the accidental exposure of three turtles to a test in the Gulf of Mexico. The general rule that structures containing air are the most vulnerable to explosion shock wave injury would probably apply to turtles as well as to other forms of marine life.

Investigations of methods to control the movement of fish have had little success. The use of feeding stations is helpful with some species. Scaring fish with small charges is probably not effective. Research has just started on methods to cause sea mammals to leave a test site.

To avoid or minimize adverse effects on marine life, the following guidelines are used: avoid testing during fish migration and spawning; avoid known fishing spots and oyster beds; use fish finders, patrol boats and spotter aircraft. If a school of fish, or any sea mammals or turtles are observed, testing is delayed. Controls of this nature can reduce injuries by a factor of ten.

Dr. George A. Young has been investigating the effects of underwater explosions, both conventional and nuclear, since 1950. In recent years, he directed research on the environmental impact of Navy explosive testing and developed guidelines to minimize possibly adverse effects.

Dr. Young received his B.S. and Ph.D. in meteorology from New York University.

Kemp's Ridley Sea Turtle Research

Dr. Edward F. Klima
National Marine Fisheries Service

The National Marine Fisheries Service, Southeast Fisheries Center has been involved in an international program to restore and preserve the Kemp's ridley turtle since 1978. The program is divided into three main parts:

1. Enhancement of nesting success and survival at Rancho Nuevo, Tamaulipas, Mexico.
2. Establishing a second breeding population at Padre Island National Seashore in Texas
3. An experimental study to evaluate the concept of headstarting.

The Galveston Laboratory of the Southeast Fisheries Center has, since 1978, released 10,792 headstarted turtles. Each year, up to 1700 hatchlings are received and reared for up to one year and then released within the Gulf of Mexico. To date, the program appears extremely successful in that: hatchlings can be reared in captivity successfully; the yearlings released survive in the wild, grow normally, and are recaptured in locations where normal wild turtles have been recorded. Although this overall program has been in effect for almost 9 years, the number of nesters has not increased at Rancho Nuevo, nor have any headstarted turtles been observed to return to any beach to nest.

Other parts of the National Marine Fisheries sea turtle program are development of the Turtle Excluder Device and collection of biological information on life history, distribution, and dynamics of the Kemp's ridley stock.

Recently, strandings of turtles have been associated with the removal of oil platforms using explosives in the northern Gulf of Mexico. The occurrence of turtles around platforms, as well as marine mammals, is not well documented. However, direct observations have shown that porpoises and sea turtles have been either harassed, injured or killed when oil platforms are removed using explosives. Further, an assortment of commercial and recreational fishes are killed with the use of explosives in the removal of platforms. This report documents some of these findings.

Dr. Ed Klima received his Ph.D. in fisheries at the University of Utah. He has 25 years of experience in fisheries in the Gulf of Mexico and over 50 publications on fisheries. For the past 9 years, he has been the Director of the Galveston Laboratory of the National Marine Fisheries

Service.

Stranding and Natural History of Sea Turtles Along the Northern Gulf

Dr. Andre M. Landry, Jr.
Texas A&M University

The National Marine Fisheries Service (NMFS) and Sea Turtle Stranding and Salvage Network (STSSN) have documented turtle strandings along the Texas coast since 1979. Texas ranks first in annual number of strandings along the Gulf coast. A major stranding event which began along the upper Texas coast in March 1986 aroused the concern of biologists with NMFS, STSSN, Texas A&M University (TAMU), Texas Parks and Wildlife Department (TPWD) and U.S. Fish and Wildlife Service (USFWS). This event, together with a need to document sea turtle strandings and gather natural history data on these endangered animals, precipitated NMFS' initiation of beach surveys along the upper Texas and southwestern Louisiana coasts. TAMU and McNeese State University assisted NMFS in the design and conduct of systematic surveys to document strandings from Cameron, Louisiana to Freeport, Texas. University personnel also responded to stranding reports from the public. TAMU, with the aid of NMFS, USFWS, and TPWD, recovered many stranded carcasses and conducted necropsies in an attempt to determine cause of death. Food habit analyses were performed on a portion of these animals.

Systematic beach surveys and responses to stranding reports from the public recovered 251 sea turtles along the upper Texas and southwestern Louisiana coasts (176 km - 110 miles) from 7 March through 29 October 1986. Kemp's ridley (Lepidochelys kempi -153 specimens) and loggerhead sea turtles (Caretta caretta - 63 specimens) comprised over 86% of these strandings. Peak ridley strandings in Texas (75.7%) and Louisiana (63.8%) occurred during March through May, and June and August, respectively. April Kemp's ridley strandings exceeded the total number of non-headstarted ridleys stranded along the entire Texas coast in 1985. Loggerheads exhibited highest stranding frequency during April (26.8% -Texas) and June (50%-Louisiana). Preliminary findings indicate that sea turtle stranding rate (number of strandings/mile of coastline) increases gradually from the western limit of the Texas survey boundary (0.04/mile) through the Louisiana survey area (0.62/mile).

Stranded Kemp's ridleys ranged in size from 13 to 67 cm carapace length (CL), with over 86% considered subadults (less than 50 cm CL). Approximately 60% of all stranded loggerheads, ranging from 23 to 95 cm CL, were subadults (less than 60 cm CL).

Necropsy analyses indicated that over 21% of all stranded turtles exhibited man-related mutilation. Anomalies of the lung (deflated/presence of fluid), heart (rupture/lesion), pericardial sac (rupture/presence of fluid), trachea (presence of fluid) and skeletal muscle (hemorrhaging) were detected in Kemp's ridleys and loggerheads at varying frequencies of occurrence. One 64-cm ridley contained well developed eggs. Histological examination of gonads from a small number of turtles indicated that females comprised 60 and 100%, respectively, of the ridleys (n=15) and loggerheads (n=6) necropsied.

The blue crab (Callinectes sapidus) was the food item most frequently found in stranded turtles. Other items commonly observed from ridley and loggerhead stomachs included fish, Nassarius gastropods, purse and calico crab, and tube worms.

Presence of relatively large, demersal fish and the scavaging gastropod Nassarius in stranded carcasses may indicate that turtles forage on bycatch discarded from shrimp trawls.

The following recommendations were developed as a result of preliminary study findings.

1). All dead, stranded turtles should be collected (where possible) and necropsied. Preliminary study results indicate that stomach, intestine, and gonad samples can be collected from stranded specimens at several stages of decomposition. These necropsy-generated data can be used to supplement traditional information in understanding biology and ecology of turtles along the Gulf coast.

2). Research must document frequency and possible cause(s) of death among turtles entrained in shrimp trawls. Field and laboratory experiments must establish the possible relationship between trawl-induced entrainment and organ compression in sea turtles. Diagnostic indicators of trawl-and/or demolition-related trauma such as ruptured hearts and deflated lungs must be developed as criteria distinguishing natural and man-induced mortality.

3). Subadult turtles (especially Kemp's ridleys) should not be sexed by secondary sex characteristics such as tail length. Tail measurements should be taken on all externally sexed specimens. Gonads should be analyzed from dead stranded specimens to verify sex determination.

4). Stranded turtle carcasses should be fully utilized for research purposes. Bones should be collected for age determination and attempts made to curate body parts for museums and universities.

Dr. Andy Landry received his Ph.D. in wildlife and fisheries science from Texas A & M University. He has worked on the headstart program for Kemps' ridley turtles for the past two years and for the past 11 months he has been studying turtle strandings. He is an associate professor of marine biology and wildlife and fisheries science at Texas A & M University at Galveston, Texas.

General Theory for the Cutting of Conductors and Platform Legs With Bulk and Shaped Charges

Mr. Peter L. DeMarsh
Demex International

The four most commonly used explosives in the oil field are nitromethane, Composition B, Composition C, and RDX. Each explosive has its own set of characteristics, but the most important traits are density and velocity, because they determine the amount of work an explosive can do. Upon detonation, 40% of the explosive energy is channeled into the formation of a gas bubble. The remaining 60% goes into the formation of a shock wave (the real mechanism for performing work). Two important characteristics of the shock wave are peak pressure and impulse (the pressure time).

In the past, explosives contractors have had few requirements during platform removals: sever the structures 5 m. (16 feet) below the mudline; and, on occasion, avoid harming the jacket because it is needed for reuse. As a result, commercial considerations (cost) have been more important in determining the explosive methodologies used. Not much consideration was given to environmental effects or good engineering/demolition practices. The most common practice has been to buy a quantity of the cheapest explosive available and place it down the platform piling or conductor. Since delays are costly in salvage operations, overcharging was the common practice to ensure successful severing of the structure. Bulk charges are often ring-shaped to minimize the charge volume and to keep the explosive on the same cutting plane as much as possible.

In contrast to bulk charges, the alternative of shaped charges was discussed. Shaped charges utilize a much smaller amount of high velocity explosive placed over a conical liner of copper or steel. Shaped charges form a high density jet as the explosive collapses the metal liner. This jet is the mechanism for cutting the structure (instead of the shock wave utilized by bulk explosives). Shaped charges can do many of the same jobs as bulk explosives with much lower peak pressure and impulse, but they are more costly to deploy. To be effective, shaped charges must be carefully placed with the correct standoff inside the piling/structure. Shaped charges would not be effective for severing multi-string grouted conductors.

A need was identified for information which would indicate how much peak pressure and impulse a sea turtle could safely take. Tests done by the navy indicate that humans can safely sustain a peak pressure of 125 pounds per square inch (psi) and an impulse of 5.5 psi x msec. If similar guidelines could be established for sea turtles, the explosives industry could do much to stay within those limits. Two mechanisms to achieve this would be the use of shaped charges and severing the structures deeper, below the mudline. it was calculated that a three-pound shaped charge could cut as much steel as a 50 pound bulk charge. A three-pound bulk charge buried fifteen feet below the mudline would produce a peak pressure of 40 psi at the mudline. The same charge buried thirty feet below the mudline would produce a peak pressure of .290 psi at the mudline. With proper guidelines, the explosives industry could calibrate their charges to a given amount of energy given off into the water column.

Mr. DeMarsh received a B.S. in physics from St. Lawrence University and a B.S. in civil engineering from Rice University. He has been involved in oil field operations since 1950. Fifteen years ago he founded Demex International, a corporation that deals exclusively in explosives.

Alternatives to Explosives in Platform Removal

Mr. W. J. Ruez
Offshore Cperators Committee

State and federal governments have established legal requirements for offshore platform removal. Aside from legal requirements, however, operators remove platforms for other reasons such as relocation to another site, obsolescence, or safety considerations. This presentation opened with a discussion of some reasons for platform removal and the legal definition of platform removal. Comments concerning the existing practice of using explosives in platform removal follows with a review of the characteristics of good removal technique. Desirable features include safety, reliability, adaptability, flexibility, cost effectiveness, and sensitivity to the environment.

Job-specific influences on the application of a removal technique were reviewed. These include varying structural configurations, site conditions, and platform conditions. The presentation reviewed structural geometry, complexity, and size which can vary widely from the early generation platforms to the modern conventional platforms, to deepwater structures, and to miscellaneous special application structures. Site conditions such as water depth, soil properties, prevailing currents, and visibility were also discussed, as well as consideration of the platform's physical condition, its stability upon removal, and the existence of potential obstructions to the removal technique.

The presentation concluded with a discussion of several alternative methods for platform removal. These alternatives include techniques that have received limited application thus far, such as using divers for cutting or employing downhole cutting tools developed by the drilling industry. Several techniques that could prove workable or adaptable through more research and testing were also discussed. Finally, methods were reviewed that might be adapted from and might employ the principles of existing technology used in other industries.

Although explosives have been shown to be safe, reliable, and cost effective in platform removal, much work is underway to develop alternative removal techniques. This presentation identified those alternatives that are most likely to be used or successfully developed in the near future. However, it is not the intent of the Offshore Operators Committee to suggest that these are the only alternatives that should be considered. Platform removal will always remain a vital concern for offshore operators, and the industry will continue to seek out and test alternatives to find better procedures.

Mr. Bill Ruez is a graduate of Texas A&M University. He is a platform design engineer and has worked for 23 of his 30 years for Exxon in platform design. He is currently the Head of the Platform Design Group for Exxon Production Research Company.

EFFECTS OF OIL AND GAS PRICES ON EMPLOYMENT IN THE GULF OF MEXICO REGION

Session:	EFFECTS OF OIL AND GAS PRICES ON EMPLOYMENT IN THE GULF OF MEXICO REGION
Co-Chairs:	Ms. Vicki Zatarain Ms. Janet Reinhardt
Date:	November 5, 1986

Presentation	Speaker/Affiliation
Effects of Oil and Gas Prices on Employment in the Gulf of Mexico Region: Session Overview	Ms. Vicki Zatarain Minerals Management Service Gulf of Mexico OCS Region and Ms. Janet Reinhardt Minerals Management Service Gulf of Mexico OCS Region
Oil and Gas Price Forecast	Dr. Karen M. Blanford Data Resources Inc.
Sensitivity of Leasable Resources in the Gulf of Mexico to Changing Prices	Mr. Lawrence J. Slaski Minerals Management Service Headquarters Office
Direct Oil and Gas Related Employment	Mr. G. Allen Brooks Offshore Data Services, Inc.
Socioeconomic Impact of OCS Oil and Gas Development in the Gulf of Mexico, Year II Study	Dr. F. Charles Lamphear and Dr. James R. Schmidt University of Nebraska-Lincoln Resource Economics and Management Analysis
The Impact of the Oil and Gas Industry on the Louisiana Economy	Dr. Timothy Ryan University of New Orleans Division of Business and Economic Research
Falling Oil Prices and Their Impact on the Texas Economy	Dr. Harold T. Gross and Dr. Bernard L. Weinstein Southern Methodist University

Effects of Oil and Gas Prices on Employment in the Gulf of Mexico Region: Session Overview

Ms. Vicki Zatarain
and
Ms. Janet Reinhardt
Minerals Management Service

The purpose of this session was to discuss the effects that the recent declining oil and gas prices have had and could continue to have on the economy in the Gulf Region. The session was designed to discuss a price forecast, the affects of the actual and projected prices on future leasable resources, and the affects that these would have on primary, secondary, and tertiary employment, specifically in Texas and Louisiana coastal counties/parishes.

The first speaker, Dr. Karen Blanford of Data Resources, discussed the forecast for oil and gas prices through the end of the twentieth century. Various factors involved in forecasting for both oil and gas were also discussed.

Oil prices are expected to remain below $20 per barrel until 1990. It is not expected that OPEC will be strong enough to cause drastic price increases, or for the 1981 price peak to reappear until the mid 1990's. In the long term (after the 1990's), there will be rapid price increases after a production cutback in the United States causes dependence on imports.

It is expected there will be a further decline in natural gas prices, but they will increase by the 1990's. The oversupply of gas, "gas bubble," is currently keeping prices down for natural gas. Once the oversupply of gas has been utilized, prices are expected to increase.

In addition, total energy demand in the United States declined in the early 1980's. It should, however, increase at a steady rate for nuclear, natural gas, petroleum, coal, and other energy sources.

The second speaker was Mr. Larry Slaski from MMS headquarters. His discussion focused on MMS's price sensitivity analysis for economically recoverable resources. The model used (TSL80) compared monetary percentages of resources which could be recovered in the three OCS regions. Similar work by MMS on a sale-by-sale basis gives some indication as to the desirability of unleased tracks and industry's probable interest. At the present time, there is little interest in leasing due to three factors. First, low oil prices are expected to remain that way in the near future. Second, a belief exists that the highest yielding tracts have already been leased. Finally, a huge inventory of tracts from previous sales need to be explored and produced. Therefore, the monies spent bidding on tracts would be diverted from developing tracts already leased. In conclusion, it is expected the decline in oil prices will lead to a decline in leasing. For example, the amount of leasable resources in the Gulf of Mexico, expected at $29, $24, $19, and $14 per barrel ,are estimated at 9.2, 9.1, 8.9 and 7.9 billion barrels of oil equivalent, respectively. These figures are for comparative purposes only and reflect the assumption of gas, priced equivalently with oil. This decline leads to the topic of the next discussions, i.e., decreases in direct and indirect employment associated with the oil and gas industry in Louisiana and Texas.

The third speaker was Mr. G. Allen Brooks, from Offshore Data Services. He discussed the differing numbers of personnel employed in the various phases of developing an oil field.

The three phases are exploration, development, and production. Of these, production has the smallest impact on employment. Mr. Brooks also outlined recent studies which have been done on the decline in oil- and gas-related employment.

It is expected there will be a further decrease in the number of mobile rigs estimated for installation next year (22). If oil prices remain stable, even though they are much lower than industry would deem desirable, a slight positive impact on mobile rig use could result since industry is more likely to invest when prices are stable.

With lower prices, however, there is incentive for oil companies to explore cost-effective ways of getting a job done; i.e., developing new techniques for installing platforms. This could also result in a decrease of oil- and gas-related employment. Therefore, even if prices were to rebound, direct oil and gas related employment would not increase to the previous highs of recent years.

The fourth speaker was Dr. F. Charles Lamphear from Resource Economics and Management Analysis. Dr. Lamphear and Mr. James R. Schmidt are currently working on a study for MMS entitled "Indicators of the Indirect Economic Impacts Due to Oil and Gas Development in the Gulf of Mexico." The results of the Year One study have recently been published, and Dr. Lamphear and Mr. Schmidt are currently working on an input/output model to be used in-house by MMS to analyze indirect employment effects. The status of that study comprised the discussion from Dr. Lamphear.

The fifth speaker was Dr. Timothy Ryan, Director of the Division of Business and Economic Research of the University of New Orleans. Dr. Ryan discussed the impact of the decline in oil prices and the resulting decline in the oil industry on Louisiana's economy. As a result of the oil and gas industry dominating the State's economy, Louisiana has experienced drastic unemployment since the downturn of that industry. The percent change in total employment decreased drastically in the 1981-1986 period compared to the figures from 1976-1982, when the percent change in total employment increased while the oil industry was at its peak. For example, petroleum and coal products manufacturing increased from 1976-1981 by 38%, whereas from 1981-1986 total employment in this sector decreased by 16.5%. As a result of this tremendous decrease in the Louisiana labor force, and if it continues as expected, the reduction in labor force could have impacts on many other sectors of the economy, such as retail sales. In addition from 1976-1981, personal income grew by 94%, and during that same time period the United States figure was only 74%. From 1981-1986, personal income grew by 20% in Louisiana and 38% in the United States. Figures show that prior to 1981, Louisiana's personal income increased much faster than the average in the United States. A temporary increase in 1984 in personal income could have been due to one of two factors: a slight upswing in oil prices preceding that period and the Louisiana's World Fair.

The sixth speaker was Dr. Harold Gross from Southern Methodist University. He discussed the impact of oil and gas prices on the Texas economy. The economy in Texas is based primarily on commodities (such as oil and gas) and defense. Through the 1970's, Texas experienced an economic growth rate three times that of the nation as a whole. Texas has received many contracts from the Department of Defense, which have sustained the economy in some regions of Texas. It is not known whether this will continue.

The oil and gas industry sustains two regions in Texas: the Permian Basin in West Texas and the Gulf Coast. The state has encountered two immediate impacts of falling prices. The first is the state is dealing with a budget deficit for the first time due to the fact that the tax structure is heavily tied to oil and gas severance taxes which have declined. The second is a political fallout due to the state's economy. There are two long-term impacts of falling oil and gas prices. The first is a serious need for tax reform resulting from the budget deficit. The second is Texas has been redlined by the national financial community. Investors are afraid to invest in the state.

In the Gulf Coast region (from Corpus Christi to Beaumont), processing, manufacturing equipment, and offshore production are the sectors the oil and gas industry are involved with. For a period of time, it was believed that, unlike the Permian Basin, the lower feed fuel costs used in refining and manufacturing would not cause any problems in the region. So far, however, 175,000 jobs have been lost in Houston alone. Job losses are higher in the Gulf Coast region than in the Permian Basin region. This has resulted in a tremendous loss in purchasing power from the tertiary sector. In addition, the Gulf Coast region is leading the nation in the decline of new business start-ups and increase of small business failures.

Ms. Vicki Zatarain is an economist with the Leasing Activities Section of the Gulf of Mexico OCS Region. She earned an MA degree in economics and a BS degree in marketing from the University of New Orleans and a BS degree in computer information systems from Tulane University. As an economist, she is instrumental in analyzing employment, population, and income impacts resulting from OCS lease sales.

Ms. Janet Reinhardt is an Environmental Protection Specialist with the Environmental Assessment Section of the Gulf of Mexico OCS Region. In that capacity, she is responsible for analyses involving the federal offshore oil and gas industry. She earned a BA degree in geography from the University of New Orleans.

Oil and Gas Price Forecast

Dr. Karen M. Blanford
Data Resources Inc.

The current oil and gas price forecast is substantially unchanged from last quarter's outlook. The imported price of crude oil has been revised for 1986 to reflect the actual data year-to-date. The average refiners acquisition cost of crude is slightly lower over the 1986-1990 period, reflecting the return of the average cost of domestic crude oil to its traditional relationship to the average imported crude oil price.

Crude prices are projected to hover near today's level for the next eighteen months before turning up in 1988. Imported crude oil prices are projected to recover to 1985 levels in inflation- adjusted terms by the late 1990's.

Petroleum product prices generally follow the projected crude price path. In 1986, product prices lagged behind the fall in crude oil prices by one to two months, resulting in average price declines of 27% to 39%, versus a crude price decline of 41%. Due to this phenomenon, most product prices continue to show a decline through 1987. Beginning in 1988, all petroleum prices escalate at rates above inflation. The forecast is shown in Figure 8.1.

Natural gas prices have begun to follow oil prices down. The current forecast reports a $1 per thousand cubic feet (mcf) drop in the average acquisition price of gas this year. The reported drop in price may overstate what the gas industry is capable of achieving. While the gas industry had responded to the continuing downward pressure of prices during the 1982-1985 period, the 40% drop in oil prices the first quarter of 1986 seemed to overwhelm the industry. The combination of long-term contracts for gas at above-market prices and federal regulations that require nondiscriminatory pricing held gas prices above competitive levels during the first four months of this year.

During the second quarter of 1986, gas prices became steadily more responsive as producers and pipelines scrambled to find ways to make gas more competitive as sales plummeted. The transition to acquisition costs of $1.50-$1.60 per mcf is well underway. Spot prices for natural gas have hovered in this range since March 1986, and anecdotal evidence reports more contracts being negotiated to this level. Given the outlook for residual fuel prices, it is only a matter of "when" gas acquisition costs drop to this level.

In the current forecast, we have assumed that gas prices drop to competitive levels sometime in the third quarter of 1986. Under this assumption, the gas industry sales would be expected to recover the sales that have been lost to residual fuel oil. Without this correction, gas sales will continue their lackluster performance.

While gas acquisition costs have remained sticky, end-use prices have reacted to the competition with varying degrees of success. Of the four consuming sectors, the electric utility sector has been the most price responsive. The average price in this sector is dominated by sales in the West South Central region and the California market. As these regions are very price-sensitive and have access to gas from multiple sources, the price has dropped. The other sectors have been much slower to respond. While data on these sectors is less timely, preliminary estimates show the residential and commercial markets experiencing only a 3% to 5% decline during the first quarter of this year. Industrial gas prices have fallen at about half the rate of the price paid by electric utilities.

Declining prices for all gas should be felt by these sectors the second half of 1986. However, residential and commercial prices are likely to experience less of a price drop as they are forced to bear more of the fixed cost in this highly competitive market. Figure 8.2 displays the current gas price forecast.

Coal prices have been declining over the last eighteen months, and this is reflected in the current forecast. The average price paid by electric utilities is now projected to drop 5% this year. Lower coal prices are the result of several factors. First, current contracts contain escalation clauses that allow for adjustment when petroleum prices change. The clauses were introduced to protect coal suppliers when oil prices were escalating, but have worked to the consumers' benefit over the past few years. Second, "flexibility" has been the goal of most utilities to take advantage of lower prices through a combination of spot and contract purchases. The combination of these two factors has resulted in a significant downward movement in the delivered price of coal to utilities. As markets recover, coal prices are projected to move at a slightly faster pace than previously forecast, as shown in Figure 8.3.

The forecast electricity prices are also essentially unchanged from last quarter. Prices are projected to decline an average of 6.3% this year. This decline is predominantly due to the 17.7% decline in fuel cost. Over the next five years, electricity prices are projected to escalate with the rate of inflation as fuel costs recover to 1985 levels, offsetting the higher rates of escalation for depreciation, operation, and maintenance charges.

In the long run, slowing capacity costs offset rapidly rising fuel costs resulting in a real escalation of 1.9% per year in total expenses. This increase is met by a 1.9% rise in electricity demand which results in a 0.4% decline in the average price of electricity.

Dr. Blanford is a senior economist with the DRI Energy Division of the McGraw-Hill Publications Company. She is currently a member of the Energy Modeling and Development Group and directs special projects and forecasts using the DRI's Energy Model. She has also served as a member of DRI's U.S. Energy Forecasting Group with particular responsibility for forecasting petroleum demand. In addition, she was responsible for maintaining the transportation sector of the energy model.

Prior to joining DRI in 1984, Dr. Blanford served as an assistant professor in the Economics Department at the University of Lowell. She has also served on the faculty at Colby College. Dr. Blanford's educational background includes a B.S. degree with honors in economics from the University of Delaware and a Ph.D in economics from Boston College.

Sensitivity of Leasable Resources in the Gulf of Mexico to Changing Prices

Mr. Lawrence J. Slaski
Minerals Management Service

An economic analysis was performed by the Minerals Management Service (MMS) for the Department of the Interior's proposed 5-year Outer Continental Shelf (OCS) oil and gas leasing program. At the time the analysis began, oil prices were about $29 per barrel. However, since that time, oil prices have fallen precipitously to about $14 per barrel.

An effect of the falling prices is a decrease in the quantity of unleased OCS oil and gas resources that have private values greater than zero and, therefore, are considered "leasable." The decline in oil prices from about $29 to $14 per barrel greatly reduced the leasable resources in Alaskan and Atlantic OCS planning area. However, in the Gulf of Mexico, the effects of lower prices are far less dramatic.

Although leasable resources declined about 14% in the Gulf of Mexico as oil prices declined from $29 to $14 per barrel, the Gulf of Mexico's share of total OCS resources increased relative to other planning areas (see Figure 8.4 for the change in leasable resources in the GOM with price). With oil priced at $29 per barrel, the Gulf of Mexico accounted for 67% of all leasable OCS oil and gas resources. However, with oil priced at $24, $19, and $14 per barrel, the Gulf of Mexico accounts for, respectively, 71%, 82%, and 87% of remaining leasable OCS resources. Clearly, because the Gulf of Mexico is a proven, relatively low-cost area, sensitivity of leasable resources to price changes is not as great as in other OCS planning areas.

Therefore, even though recent sales have shown declining leasing interest in the Gulf of Mexico, the area remains the most promising for continuing OCS activity.

Mr. Slaski is an economist with MMS. Most recently he was instrumental in conducting economic analyses for the Department of the Interior's proposed 5-year OCS oil and gas leasing program. Prior to coming to MMS, Mr. Slaski was employed by the U.S. Fish and Wildlife Service and The Research Foundation of the State University of New York.

Mr. Slaski has an undergraduate degree in economics from the State University of New York at Buffalo and a graduate degree in urban affairs from the University of Delaware.

Direct Oil and Gas Related Employment

Mr. G. Allen Brooks
Offshore Data Services, Inc.

The importance of determining the direct employment related to offshore oil and gas activities is shown by the problems of the Texas and Louisiana economies in recent years. Generally, the number of people working offshore is in direct relation to the amount of capital flowing into the petroleum industry and how much of that capital is designated for the offshore. Historically, the percentage of money going offshore has been rising, but that appears to be leveling out and possibly declining, although determining trends in today's disoriented times is difficult.

For the Coastal States, the multiplier of offshore employment is important. However, the most important consideration today is the outlook for the future. This paper discusses the forces that will determine the level of offshore activity in the near future.

Offshore petroleum activity is composed of a number of subsets of oil and gas industry activity. These subsets are Exploration, Development, and Production. This latter category includes everything from the time the field is brought onto production until it is finally abandoned.

Each of the subsets of activity has its own subset of businesses active in the marketplace. For example, within the Exploration phase, there are seismic vessels, mobile drilling rigs, divers and diving support vessels, supply vessels, and drilling support services. Each of these businesses have a complement of people engaged in the actual work offshore, plus additional support people onshore.

The Development phase of industry activity probably has the most intense employment impact since the number of workers involved in fabricating and installing offshore platforms is very large, although some of their work time is rather short -- days and weeks rather than months for construction barges which may employ 200 to 400 people. The businesses involved in the Development phase include platform fabrication, platform installation, supply vessels, divers and diving support vessels, construction barges, hook-up crews, and drilling support services.

The Production phase, which has the longest life of all the phases of offshore activity, also has the least impact on employment. The phases of the business require oil company personnel, maintenance and repair workers, occasionally, hook-up people, divers and diving support vessels, and regular supply vessels.

Employment levels in the offshore industry have fallen over the past few years. A study done by Loren Scott of LSU based on the Louisiana input/output model suggested that some 52,000 employees in the oil and gas extraction and maintenance and repair/construction industries were dependent on offshore activity in Louisiana. This study includes oil company employees. A study by Centaur Associates for MMS suggested that almost 29,000 employees worked primarily offshore in 1984. An Offshore Data Services study done in early 1984 suggested that about 31,000 employees worked offshore in 1983.

All three of these studies are reasonably consistent, albeit different in both methodology and scope. The two closest studies are the Centaur and ODS ones which are also more narrow in scope. The consistency of these studies' conclusions is shown by the level of offshore equipment and activity in each year (see Table 8.1).

What the table shows is that the employment estimates fit generally with the level of offshore activity. Today, with the level of activity substantially below past years, there are fewer people working offshore. Nothing is surprising. The problem for the industry is that current work levels are equal to those of the mid-1970's. However, since that time, the supply of equipment offshore grew to support the levels of business represented by 1981's activity. Given the present outlook for oil and gas markets, the amount of offshore activity will not change appreciably in 1987.

Therein lies the problem for the United States offshore industry. Too much equipment is chasing too little work, resulting in too low day rates. The final result is a bankrupt industry.

The outlook for this industry depends on the price of oil, the condition of the natural gas market, and how oil companies and service companies adjust operations to live in a world of low oil and gas prices.

Mr. G. Allen Brooks is a vice president of Offshore Data Services, Inc. In this capacity, Mr. Brooks serves as a senior analyst in Offshore Data's research division as well as a member of the company's governing board. Recently, Brooks has been the lead author of two important studies published by the firm: "Offshore Mobile Rig Outlook to 1990" and "Gulf of Mexico Opportunities, 1984-86." Prior to joining Offshore Data Services in 1982, Mr. Brooks spent 10 years as a petroleum investment analyst for Underwood, Neuhaus, and Co. and Citicorp. Mr. Brooks is a Certified Financial analyst and holds an M.S. degree in economics in Cornell University and a BA degree in economics from the University of Connecticut.

Socioeconomic Impact of OCS Oil and Gas Development in the Gulf of Mexico, Year II Study

Dr. F. Charles Lamphear
and
Dr. James R. Schmidt
University of Nebraska-Lincoln

The oil embargo of the mid-70's and the boom-bust situation that has followed the embargo have had both a profound impact on the development of the OCS oil and gas activities in the Gulf of Mexico and on the development of the coastal economies.

The socioeconomic impact associated with the growth side of the oil and gas activities in the Gulf of Mexico is now being investigated for MMS in a study entitled "Analysis of Indicators for Socioeconomic Impact Due to OCS Oil and Gas Activities in the Gulf of Mexico, Year II." In brief, this is a two-part study. The first part involves the development of techniques and software programs for identifying and measuring socioeconomic impacts. The second part involves the use of these techniques and programs to estimate the socioeconomic effects associated with a number of OCS oil and gas development scenarios for the Gulf of Mexico. These scenarios numerically describe the growth and development period of oil and gas activities in the Gulf of Mexico, which are being prepared by MMS.

The first part of the study has been completed with the development of socioeconomic databases and software programs. These databases and programs have been used to construct a regional input-output model for each of the ten MMS Study Areas. MMS has defined ten Study Areas that include seventy-four counties from Dade County, Florida to Cameron County, Texas. The ten Study Areas are indicated by county in Table 8.2.

Basic to the construction of regional input-output models is the accounting of all economic activity as industry types. One hundred and sixteen industries were used to classify regional economic activity for the MMS study. Briefly put, the formulation of the 116 industries features the Study Areas' businesses that are most linked to OCS oil and gas activity in the Gulf of Mexico.

The construction of regional input-output models for the ten Study Areas makes it possible to identify and measure the socioeconomic impacts associated with OCS oil and gas development in the Gulf of Mexico. The measurement of socioeconomic impacts is based on the derivation of so-called industry output multipliers from the regional input-output models. An industry output multiplier for an industry (e.g., Petroleum Refining in Table 8.3) is defined as the total value of production in all industries of the region's economy and is necessary in order to satisfy a dollar's worth of final demand for that industry's output. The output multiplier of 2.2260 for Petroleum Refining in Study Area W2 (Table 8.3) means that a total of (approximately) $2.23 of total value of production (impact) is generated by a one-dollar change in the final demand for the Petroleum Refining Industry in W2. assuming a proportional relationship between a change in industry final demand and the corresponding change in the total value of production, an industry output multiplier can be used to estimate the total economic impact for any dollar amount of change in industry final demand. Thus, industry output multipliers can be used to measure the total economic impact associated with any postulated or known change in industry final demand. The change in final demand can either be positive or negative and, as a result, the associated total economic impact is positive or negative.

Output multipliers for selected industries and selected Study Areas are given in Table 8.3. The variation in industry output multipliers by industry type, as indicated in Table 8.3, is due to the extent of interindustry relationships (linkages) within the Study Areas. Simply put, high multipliers reflect a high degree of interindustry linkages. Conversely, low multipliers reflect a low degree of interindustry linkages.

For the second part of the study, industry output multipliers of the type noted in Table 8.3 and the MMS scenarios, which numerically describe OCS oil and gas development in the Gulf of Mexico, will be combined to estimate total economic impact. These total economic impacts, by Study Area, will then be used to estimate the related employment and population impacts. Employment-to-earnings ratios and, also, employment-to-population ratios, which reflect certain known labor and demographic characteristics, have been prepared to accomplish the employment and population estimates. These estimates will complete the socioeconomic impact study of the growth of OCS oil and gas activity in the Gulf of Mexico.

Dr. F. Charles Lamphear is Professor of Economics at the University of Nebraska-Lincoln. **Dr. James R. Schmidt** is associate professor of Economics at the same institution. They have been involved in research activities that span several fields of economics including regional economics, regional econometric modeling, energy economics, and monetary economics. Both are participants in the MMS Year II Socioeconomic Impact study for the Gulf of Mexico Region.

The Impact of the Oil and Gas Industry on the Louisiana Economy

Dr. Timothy P. Ryan
University of New Orleans

It is hard to overestimate the importance of the Oil and Gas Industry for the Louisiana economy. This is specially true over the past ten years.

During this time period, the boom and subsequent bust in the worldwide oil market has caused a massive restructuring in the Louisiana economy.

The major cause was the very rapid increase in prices that occurred in the period from 1978 to 1982 and the just as rapid decline in prices that occurred in early 1986. These price changes were followed by corresponding increases and decreases in the oil and gas drilling activities in the State.

The wholesale price of crude oil over the period from 1970 to the present, utilizing quarterly data was traced. Most of the volatile activity occurred during two time periods--from 1978 to 1982 and from late 1985 to mid 1986. During the oil boom period of the late 1970's, the price of oil more than quadrupled during a three-year period. Over a six-month period at the beginning of 1986, the price of oil was reduced by half.

Since Louisiana is not national headquarters for the major oil and gas firms, the Louisiana economy is dominated by drilling and exploration activities in the Gulf of Mexico. The offshore rig count for Louisiana over the period from 1970 to the present was also traced. Although rig activity does not move nearly as smoothly over time as does the price of oil, the same pattern emerges. There was a tremendous increase in the number of working rigs in the late 1970's and a precipitous drop in 1986.

This report analyzes the effects of these factors on the Louisiana economy. The effect of the oil and gas industry on personal income, employment, and labor force were studied. The overall effect of the boom and bust in the oil industry has been to completely restructure the Louisiana economy.

As indicated earlier, the roller coaster ride that the oil industry has taken over the past has had a profound effect on the Louisiana economy, especially over the last ten years. Over the period from 1976 to 1981, personal income in Louisiana grew by 94.1%. During that same time period, the United States economy grew at a rate of only 74.7%. Thus, the Louisiana economy grew at a rate that was more than 20% higher than the United States average. During the period from 1981 to 1986, personal income increased by 20.9% in

Louisiana and 38% in the United States as a whole. Thus, from 1981 to 1986, the situation was completely reversed; the State economy grew at a rate almost 18% below the United States average.

The annual change in personal income in Louisiana from 1970 to 1986, using quarterly data, has a very similar pattern to that for crude oil prices and the Louisiana offshore rig count. Personal income grew at a relatively slow rate during the early 1970's, grew at a rapid rate from 1978 to 1982, and dropped off sharply after 1982. There was a temporary increase in 1984. This could be caused by two phenomena: the slight upswing in oil prices preceding that period and the Louisiana World's Fair.

Just as personal income experienced significantly different growth from 1976 to 1981, as compared to the period from 1981 to 1986, employment followed the same pattern.

From 1976 to 1981 (Table 8.4), total employment in The United States increased by 15%; during that same period, total employment in Louisiana grew by almost 24%. This same pattern is repeated in almost every category. One would expect employment in oil and gas related jobs to increase rapidly during that period. But it is somewhat surprising that employment in manufacturing, construction, transportation, and public utilities grew faster in Louisiana than in the nation as a whole. The increase in government employment is very interesting: In Louisiana, State and local government employment increased almost five times faster than in the United States as a whole.

From 1981 to 1986 (Table 8.5), the pattern is reversed. Total employment in the United States increased by almost 10%; in Louisiana, total employment decreased by over 3%. Although manufacturing employment decreased all over the United States (this is referred to as the "deindustrialization" of America), manufacturing employment in Louisiana decreased three times as much. In the United States, construction employment increased by 19.6% from 1981 to 1986; in Louisiana, construction employment decreased by almost 40%.

The only surprising result is the effects of the changes in crude oil prices and Louisiana offshore rig count on the unemployment rate. From 1976 to 1981, one would have expected the unemployment rate to increase. But the opposite happened. The unemployment rate in Louisiana actually increased by 1.5% over this time. The explanation for this is that as total employment was increasing rapidly, the labor force was increasing even more quickly. The next section will analyze changes in the labor force.

Any state that has experienced an economic boom has experienced a large in-migration of workers to compete for these jobs. As expected, the labor force grew every year during the 1970's at a large rate. In some years the increase in the labor force was as high as 80,000 workers. After 1982, the growth in the labor force dropped off sharply, but was still positive. From 1985 to 1986, the labor force actually decreased. If the oil and gas depression continues, this decrease in the labor force is likely to increase. This spells further economic troubles for the State as these workers leave and take their consumer and housing spending with them.

Dr. Ryan received his Ph.D. in Economics at the Ohio State University in 1978. His doctoral dissertation was in the area of State and Local public finance. He has been on the faculty in the Department of Economics and Finance at the University of New Orleans since 1976. In June of 1984 he was appointed Director of the Division of Business and Economics Research at UNO.

Dr. Ryan won the UNO Alumni Association Excellence in Teaching Award in 1982. He is currently on the editorial board of the Research Director at UNO; he has published the results of that research in the Louisiana Business Survey. The Research Division, under his direction, is currently preparing an econometric forecasting model for the New Orleans metro area.

Falling Oil Prices and Their Impact on the Texas Economy

Dr. Harold T. Gross
and
Dr. Bernard L. Weinstein
Southern Methodist University

On Monday, January 20, 1986, New York Mercantile Exchange futures and spot crude oil prices began a sharp fall to their lowest levels since before the 1979 Iranian revolution. On Thursday, January 30, 1986, contracts for March 1986 delivery of West Texas Intermediate crude, the United States benchmark grade, closed at $19.66 per barrel, compared to $25.10 per barrel only two and a half weeks previously. Also on Thursday, January 30, 1986, spot prices for West Texas Intermediate closed at $19.50 per barrel while another important benchmark grade, British North Sea Brent, closed at $18.50 per barrel. "Posted" prices for West Texas Intermediate range from $22.50 per barrel to $27.00 per barrel, with an average of approximately $24.86. Of course, the growing importance of the spot market, which now accounts for nearly 40 percent of the world's commerce in crude oil, renders the "posted" price increasingly meaningless.

The decline in oil prices from their peak in 1981 of roughly $35 per barrel results generally from a persistent worldwide glut of oil that reflects over-production on the part of producing nations and declining consumption among consumer and industrial users. This glut was exacerbated by OPEC's decision at their December 1985 meeting in Geneva to increase production beyond previously agreed-upon quotas in an effort to maintain market share and, hence, maintain foreign currency markets. The Saudis, in particular, seem determined to regain control over the oil market, and have doubled their daily production. Moreover, on Thursday, January 30, 1986, the Indonesian oil minister commented that OPEC would probably increase its crude oil production ceiling to 18 million barrels per day, up 2 million from the current limit. Given the persistence of these trends, the decline in oil prices is likely to continue through Spring 1986 to a low of $15 to $18 per barrel.

For the national economy as a whole, a drop in crude oil prices is a boon: each $1.00 decrease in the price of oil reduces the inflation rate approximately two-tenths of one percent and increases gross national products by roughly one-tenth of one percent. Lower oil prices may also result in lower interest rates, as suggested by recent declines in yields on Treasury securities. Among subnational regional economies, however, the impacts of lower oil prices vary considerably. For State and regional economies, whose dependence on oil is limited principally to the consumption of refined products, lower oil prices are a stimulus to growth. Indeed, much of the Northeast's and Midwest's recent economic recovery, particularly with respect to manufacturing, is attributable to lower oil prices. For State and regional economies that depend more on oil production than consumption, however, lower oil prices result in the contraction of basic industries, reduced output, and a significantly subdued overall level of economic activity.

Texas has been especially hard-hit by the decline in oil prices. In retrospect, the State's comparatively rapid economic growth during the late 1970's was an outcome principally of escalating oil prices. Higher oil prices, particulary in the aftermath of the Iranian revolution, prompted a flurry of drilling activity in Texas; the subsequent demand for drilling rigs, oil field machinery, drilling pipe and valve, and instruments stimulated rapid employment growth in the State's manufacturing sector. Because of its strong supply and demand linkages to other sectors of the economy, as well as the comparatively high wages received by its workers, manufacturing, in turn, supported the rapid expansion of services, trade and other tertiary sectors. Perhaps the greatest beneficiaries of energy-induced economic growth were Texas' financial institutions who loaned extensively to energy producers in Texas and abroad. Moreover, both State and local governments in Texas experienced tremendous revenue windfalls through income derived from severance taxes on oil and gas, sales taxes on energy-related manufactured goods, and property taxes on industrial plants.

The approximate $10 per barrel decrease in crude oil prices to $25.10 per barrel between 1981 and early January 1986 was accompanied by a virtual halving of Texas' active drilling rigs from the 1981 peak of roughly 1,300. As a consequence, the once-strong demand for drilling-related manufactured goods has dried up, prompting the contraction of the State's manufacturing sector. Since 1981, in fact, Texas has suffered a net loss of 118,000 manufacturing jobs in addition to the 33,000 jobs lost in the drilling industry. Employment and output growth in the State's non-industrial sectors has also slowed considerably, with the greatest weakness in financial services where many banks and savings and loans, in sharp contrast to the oil-driven boom years, carry a large volume of non-performing assets and post lower earnings or net losses.

Job and income losses in the industrial sector have returned Texas to the ranks of the "low-income" states; after rising to slightly over 102 percent of the national average in 1982, Texas' per capita personal income fell two points below the national norm in 1984. Finally, in sharp contrast to previous years, and at a time when most states are boasting substantial budget surpluses, Texas faces a severe fiscal crisis, precipitated by the inability of its tax structure to respond to the dramatic changes in its economy. With the Texas Comptroller currently projecting a revenue shortfall of $2 to $3 billion for the fiscal 1988-89 biennium, taxing and spending issues are sure to dominate the next legislative session.

The events of the past four years suggest three benchmarks that are useful in gauging the probable impacts on Texas of the more recent sharp declines in oil prices. Generally, each dollar decrease in the yearly average oil price costs Texas:

- 25,000 jobs;
- $3 billion in gross State output; and
- $100 million in State and local tax revenue.

Three oil price scenarios warrant consideration: (1) impacts to the Texas economy if the yearly average oil price stabilizes at approximately

$20 per barrel; (2) impacts in the case of a further deterioration of prices to an average of $18 per barrel; and (3) impacts of $15 per barrel oil.

Scenario 1: $20. A stabilization of oil prices at an average of $20 per barrel, down roughly $5 from the 1985 average would

- cost Texas roughly 125,000 jobs, reducing expected total nonagricultural employment growth by approximately one third for the next three years; and
- remove approximately $15 billion in purchasing power from the State economy, sharpening Texas' recent declines in gross State output.

Scenario 2: $18. A further deterioration of oil prices to a yearly average of $18 per barrel, a decrease of $7 from the 1985 average would

- cost Texas 175,000 jobs, reducing expected total nonagricultural employment growth by approximately 50 percent per year for three to five years; and
- remove approximately $21 billion in purchasing power from the State economy.

Scenario 3: $15. $15 per barrel oil, a drop of $10 would

- cost Texas 250,000 jobs over the next three to five years, likely resulting in an overall contraction of nonagricultural employment; and
- remove $30 billion in purchasing power.

Several additional and more general impacts apply in varying magnitudes to each of the scenarios. First, industrial sector job losses occurring as a result of the latest round of oil price cuts are likely to involve white collar workers or small business failures rather than the customary blue collar cutbacks. The just-announced layoffs by ARCO in Dallas may be the first of many on the administrative side of the oil and gas business. Furthermore, non-industrial sectors may increasingly experience underemployment or layoffs as they adapt to the more subdued level of economic activity. Second, lower oil prices will expose further weaknesses in the State's financial institutions. For those institutions heavily exposed in energy, non-performing assets are likely to rise and earnings likely to fall. Large losses should not come as a surprise, nor should the continual downgrading of many institutions' debt ratings. Finally, the State's fiscal condition will worsen considerably and deficits will remain a chronic problem until the tax structure is modified to de-emphasize its present reliance on the energy sector.

Dr. Harold Gross has co-authored with **Dr. Bernard L. Weinstein** a major report entitled "Current Conditions and Long Term Prospects of the Oil Industry" for the Joint Economic Committee of Congress. This is the last of a series of reports. Dr. Gross received a Ph.D in economics from the University of Texas.

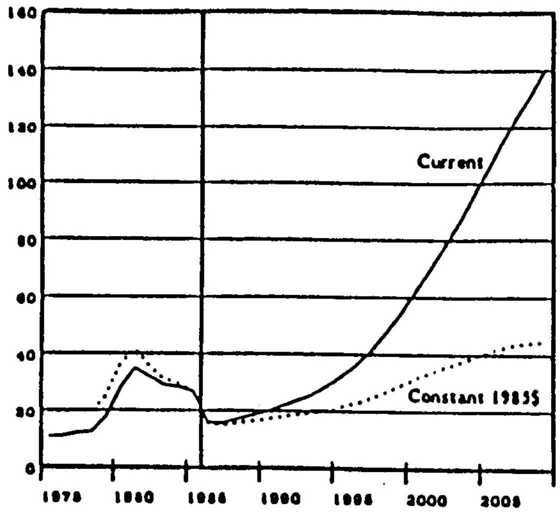

Figure 8.1.--Average refiners' acquisition price of crude oil (dollars per barrel).

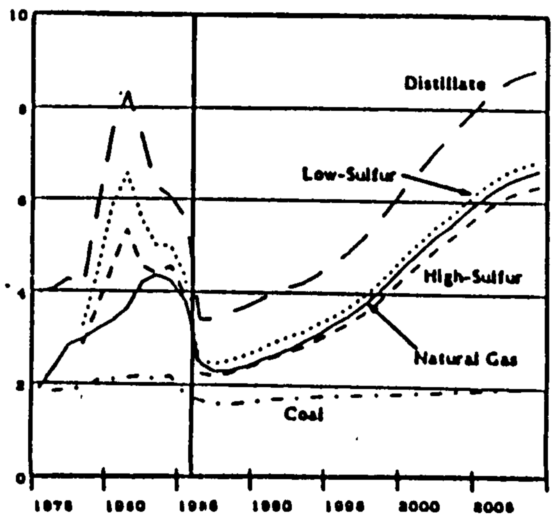

Figure 8.2.--Energy prices to the industrial sector (dollars per million btu).

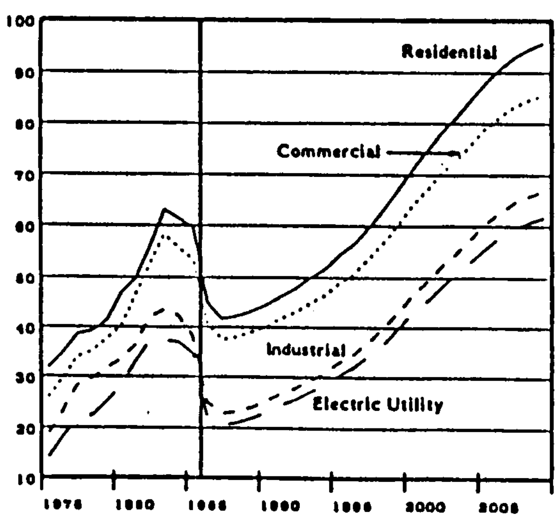

Figure 8.3.--Delivered price of natural gas by sector (constant 1985 dollars per million btu).

Source: General Review, Autumn 1986.

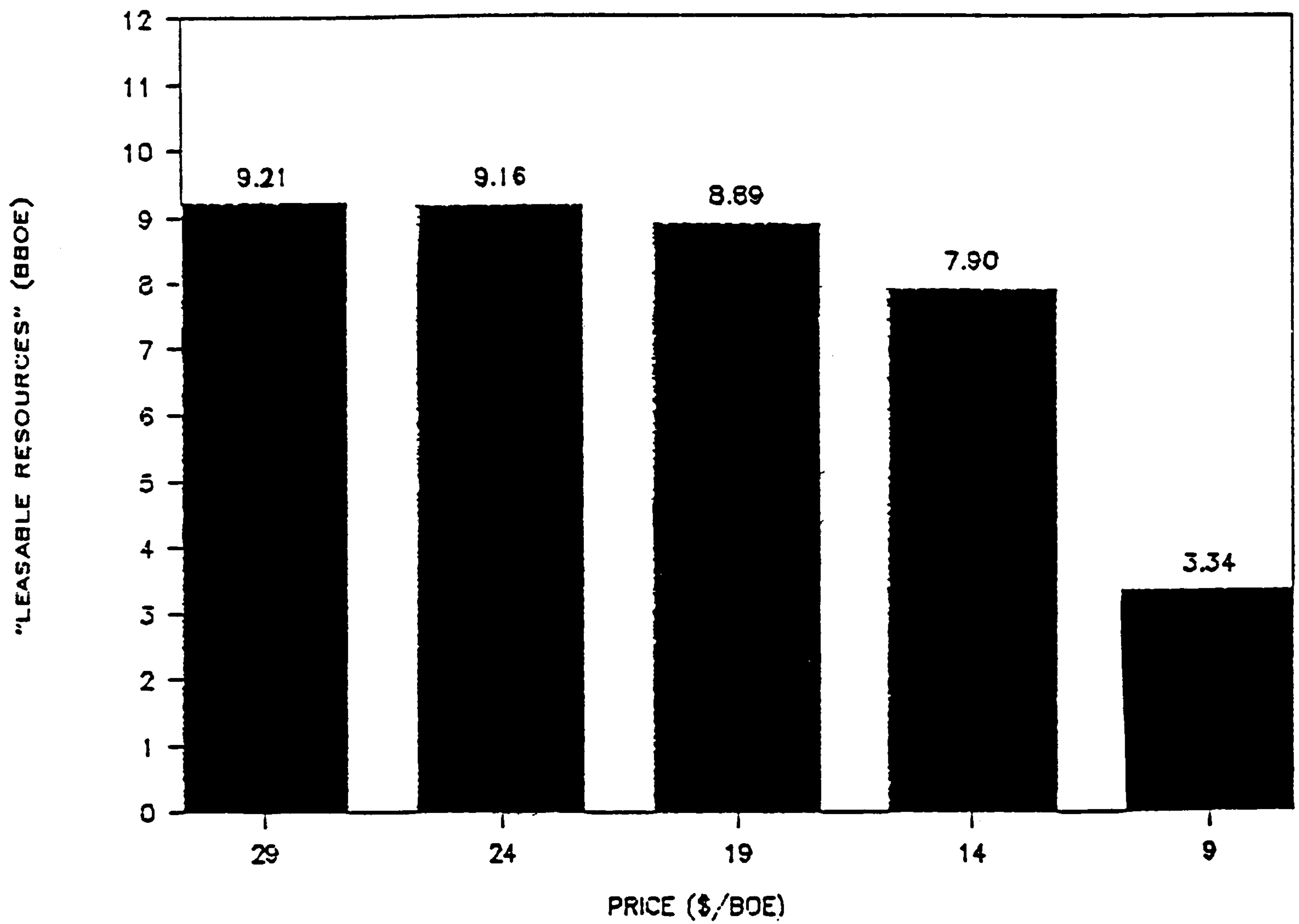

Figure 8.4.--Change in "leasable resources" in Gulf of Mexico with price.

Table 8.1

Level of Offshore Equipment and Activity Each Year

Year	Mobile Rigs	Platform Rigs	Platforms Installed
1981	169	155	139
1983	138	99	119
1984	182	90	141
Today	73	42	(est.) 65

Table 8.2

MMS Study Areas, by County

Study Area	Counties
F1	Florida: Bay, Escambia, Okaloosa, Santa Rosa, Walton
E2	Florida: Dixie, Franklin, Gulf, Jefferson, Levy, Taylor, Wakulla
E3	Florida: Charlotte, Citrus, Collier, De Sota, Hernando, Hillsborough, Lee, Manatee, Pasco, Pinellas, Sarasota
E4	Florida: Dade, Monroe
C1	Louisiana: Calcasieu, Cameron, Iberia, Lafayette, Vermilion
C2	Louisiana: Ascension, East Baton Rouge, Lafouche, Livingston, St. Charles, St. James, St. John the Baptist, St. Mary, Terrebonne, West Baton Rouge
C3	Louisiana: Jefferson, Orleans, Plaquemines, St. Bernard, St. Tammany
C4	Mississippi and Alabama: Hancock, Harrison, Jackson, Stone, Baldwin, Mobile
W1	Texas: Aransas, Calhoun, Cameron, Jackson, Kenedy, Kleberg, Nueces, Refugio, San Patricio, Victoria, Willacy
W2	Texas: Brazoria, Chambers, Fort Bend, Galveston, Hardin, Harris, Jefferson, Liberty, Matagorda, Montgomery, Orange, Waller

Source: Derived as part of the socioeconomic impact study

Table 8.3

Industry Output Multipliers for Selected Industries and Selected Study Areas

Industry	Study Areas				
	W2	C2	C3	F1	E2
Crude Petroleum & Natural Gas Mining	1.7723	1.6337	1.7136	1.4896	1.4179
New Petroleum & Natural Gas Well Drilling	2.9895	2.7057	2.7314	2.2880	1.9950
New Petroleum, Natural Gas and Solid Mineral Explor.	2.4609	2.2566	2.4118	2.1858	2.0240
Petroleum Refining	2.2260	2.0662	2.1274	1.4512	1.3029
Maintenance & Repair of Petroleum Pipelines	3.3192	2.8576	2.9497	2.8122	2.4135
Maintenance & Repair of Petroleum & Natural Gas Wells	2.6277	2.4213	2.5532	2.3049	2.1550
Industrial Inorganic & Organic Chemicals	2.9675	2.6174	2.5070	2.2755	2.2536
Ready-mixed Concrete	3.1054	3.0952	3.1704	2.7668	2.4173
Steel Pipes & Tubes	3.0759	2.8218	2.2957	2.1073	2.0773
Fabricated Structural Steel	2.8424	2.5976	2.4304	2.1416	2.0550
Pipe, Valves & Pipe Fittings	2.6447	2.3378	2.3543	2.1189	2.0121
Oil Field Machinery	2.6770	2.3507	2.4048	1.5440	1.9748
Banking	2.7940	2.5733	2.7874	2.6219	2.3208
Insurance Carriers	3.3144	2.8322	3.3618	3.0295	2.4175
Accounting, Auditing & Bookkeeping & Misc. Serv.	2.5370	2.3368	2.5612	2.3943	2.1403

Source: Derived as part of the socioeconomic study

Table 8.4

Percentage Change in Total Employment
July, 1976 to July, 1981

	UNITED STATES	LOUISIANA
TOTAL EMPLOYMENT	15.06%	23.85%
MANUFACTURING	7.61%	9.18%
DURABLE GOODS	11.16%	13.38%
LUMBER & WOOD PRODUCTS	13.08%	-15.48%
STONE, CLAY AND GLASS PRODUCTS	2.22%	0.00%
FABRICATED METAL PRODUCTS	16.16%	19.59%
MACHINERY, EXCEPT ELECTRICAL	21.78%	34.12%
TRANSPORTATION EQUIPMENT	10.95%	34.56%
OTHER DURABLE GOODS	-1.18%	-15.38%
NONDURABLE GOODS	2.67%	5.68%
FOOD & KINDRED PRODUCTS	-2.04%	-7.19%
APPAREL & OTHER TEXTILE PRODUCTS	-4.05%	-17.27%
PAPER & ALLIED PRODUCTS	1.77%	-10.81%
PRINTING & PUBLISHING	17.52%	10.59%
CHEMICALS & ALLIED PRODUCTS	7.45%	16.10%
PETROLEUM & COAL PRODUCTS	7.43%	38.10%
OTHER NONDURABLES	NA	200.00%
MINING	47.72%	51.75%
CONSTRUCTION	23.92%	35.11%
TRANSPORTATION & PUBLIC UTILITIES	15.05%	24.56%
WHOLESALE & RETAIL TRADE	17.43%	18.70%
WHOLESALE TRADE	26.11%	23.35%
RETAIL TRADE	14.65%	16.92%
FINANCE, INSURANCE & REAL ESTATE	23.51%	19.84%
SERVICES	27.35%	25.24%
GOVERNMENT	6.51%	28.05%
FEDERAL	1.98%	14.98%
STATE & LOCAL	6.29%	31.22%
STATE	NA	38.01%
LOCAL	NA	27.58%
UNEMPLOYMENT RATE	-0.8%	1.5%

Source: Louisiana Department of Labor, monthly reports for July, 1976 to July, 1981

Table 8.5

Percentage Change in Total Employment
July, 1981 to July, 1986

	UNITED STATES	LOUISIANA
TOTAL EMPLOYMENT	9.69%	-3.49%
MANUFACTURING	-6.17%	-22.54%
DURABLE GOODS	-7.86%	-28.22%
LUMBER & WOOD PRODUCTS	5.42%	-6.34%
STONE, CLAY AND GLASS PRODUCTS	-8.23%	-30.34%
FABRICATED METAL PRODUCTS	-10.93%	-29.94%
MACHINERY, EXCEPT ELECTRICAL	-17.49%	-27.19%
TRANSPORTATION EQUIPMENT	2.08%	-33.56%
OTHER DURABLE GOODS	-12.89%	4.55%
NONDURABLE GOODS	-3.61%	-17.44%
FOOD & KINDRED PRODUCTS	-1.91%	-20.30%
APPAREL & OTHER TEXTILE PRODUCTS	-11.71%	-29.57%
PAPER & ALLIED PRODUCTS	-0.58%	-12.12%
PRINTING & PUBLISHING	16.72%	5.32%
CHEMICALS & ALLIED PRODUCTS	-7.66%	-22.12%
PETROLEUM & COAL PRODUCTS	-25.35%	-16.55%
OTHER NONDURABLES	NA	2.56%
MINING	-33.93%	-37.67%
CONSTRUCTION	19.57%	-39.68%
TRANSPORTATION & PUBLIC UTILITIES	2.05%	-17.31%
RAILROAD TRANSPORTATION	NA	-32.94%
WHOLESALE & RETAIL TRADE	15.66%	3.87%
WHOLESALE TRADE	8.78%	-18.36%
RETAIL TRADE	18.08%	12.82%
FINANCE, INSURANCE & REAL ESTATE	19.19%	12.22%
SERVICES	24.61%	10.57%
GOVERNMENT	4.74%	-3.32%
FEDERAL	4.86%	-5.59%
STATE & LOCAL	4.71%	-3.01%
STATE	NA	-5.27%
LOCAL	NA	-1.70%
UNEMPLOYMENT RATE	-0.3%	4.3%

Source: Louisiana Department of Labor, monthly reports for July, 1981 to July, 1986

SEAGRASSES: IMPACTS AND MITIGATION

Session:	SEAGRASSES: IMPACTS AND MITIGATION
Co-chairs:	Ms. Laura Gabanski Dr. Robert Rogers
Date:	November 5, 1986

Presentation	Speaker/Affiliation
Seagrasses: Impacts and Mitigation Session Overview	Ms. Laura Gabanski Minerals Management Service Gulf of Mexico OCS Region
Chemical Dispersants and Their Role in Mitigating Oil Spill Impacts on Seagrass Habitats	Mr. Kenneth W. Fucik Consultant
Impact of Drilling Fluids on an Experimental Seagrass Community	Dr. Thomas W. Duke U.S. Environmental Protection Agency Gulf Breeze Environmental Research Laboratory
The Restoration and Creation of Seagrass Meadows in the Southeast United States	Mr. Roy R. Lewis III Mangrove Systems, Inc.
Seagrass Restoration Along the Texas Coast	Mr. Donald R. Deis and Mr. E. A. Kennedy Continental Shelf associates, Inc.
Seagrass Restoration Management in South Texas: Aspects of the Rate of Natural Colonization and Other Regional Management Considerations	Mr. Paul D. Carangelo Island Botanics

Seagrasses: Impacts and Mitigation Session Overview

Ms. Laura Gabanski
Minerals Management Service

The purpose of the session was to highlight the research on possible impacts of OCS activities on seagrasses and to assess current seagrass mitigation efforts. The research that was discussed included the effects of oil, dispersed oil, and drilling fluids on seagrasses. Current mitigation and restoration efforts in Florida and Texas were assessed.

The first presentation entitled, "Chemical Dispersants and Their Role in Mitigating Oil Spill Impacts on Seagrass Habitats", was given by Mr. Kenneth Fucik, a private consultant. He stated that oil could impact seagrass ecosystems by lowering productivity and ecological value. Of the small number of studies on seagrass habitats following oil spills, only a few effects on seagrasses have been observed. This is probably due to their subtidal nature. Results from a field study conducted in Panama on the effects of dispersed oil on seagrass beds indicated no effects on the grass itself, but there were effects on associated fauna. Guidelines for dispersant use near seagrass habitats are difficult to develop due to the proximity of seagrasses to other critical habitats, i.e., coral reefs, mangroves, and marshes. Factors such as seasonal sensitivity, scarcity, and restoration potential of the affected habitats need to be considered when deciding on the use of dispersants.

Dr. Thomas Duke, of the Environmental Protection Agency, presented a paper entitled, "Impact of Drilling Fluids on an Experimental Seagrass Community." Dr. Duke et al. (in press) developed a laboratory ecotoxicity test (42-day) that determines the effects of drilling fluids on the structure and function of seagrass communities. Results from the test showed that invertebrates were adversely affected by treatments of drilling fluids containing ca. 1% diesel oil and clay at a concentration of 15 mg/l. There were significantly fewer individuals of the dominant species and half the number of organisms in the treated microcosms than in the control. Thalassia leaves exhibited a significant reduction in chlorophyll a/dry weight tissue when exposed to drilling fluid and clay. Thalassia epiphytes showed significant reductions in biomass and photosynthetic potential in drilling fluid treatments. Finally, there was a significant decrease in the rate of decomposition of dried Thalassia in the drilling fluid treatments.

The next presentation entitled, "The Restoration and Creation of Seagrass Meadows in the Southeast United States," was given by Mr. Roy R. Lewis of Mangrove Systems, Inc. Mr. Lewis stated that seagrass meadow restoration is generally unsuccessful. The success rate has not been measured in a uniform way. Usually a survival rate of the planting units at the end of a period of time, e.g., 80% after one year, is used. Fonseca et al. (1984) recommend a plant coverage that equals or exceeds the impacted meadow as being a measure of success. Mr. Lewis indicated that this is a more realistic determination of success because rates of asexual reproduction vary with species and location. Finally, he recommended that nondestructive sources of plant material be used due to the increasing demand.

Mr. Donald Deis of Continental Shelf Associates, Inc., gave a presentation entitled, "Seagrass Restoration Along the Texas Coast." He discussed an ongoing restoration project that was required mitigation for dredging an oil and gas canal and basin in Laguna Madre. An experimental approach which included monitoring for conditions that promote growth was used to create a shoalgrass (Halodule wrightii) habitat. The site was contoured to a depth of 3.5 feet and allowed to stabilize for one year. Approximately 3.3 acres were planted with 16,500 Halodule plugs, averaging 4.5 apical meristems per plug, on 0.9-meter centers. Monitoring after 3 months showed an average of 88.9% survival and an average spread of ca. twice the plug size. Further monitoring will be conducted after 6 and 12 months.

The final presentation entitled, "Sea Grass Restoration Management in South Texas: Aspects of the Rate of Natural Colonization and Other Regional Management Considerations," was given by Mr. Paul Carangelo of Island Botanics. He stated that the rate of natural revegetation of disturbed sites exceeds that of seagrass restoration efforts when predisturbance elevation and surface sediments are restored. However, the rate is dependent on, among other factors, the presence of live rhizomes in sediments used to restore the elevation and proximity to undisturbed grass beds which provide a source of vegetative growth and seed. Seagrasses, primarily Halodule, have doubled in areal extent in the Texas Coastal Bend area from 1956-1974. Mr. Carangelo hypothesized that the extent and distribution of seagrasses in this region are at an historic maximum. Regarding seagrass restoration management, he recommended a standardized approach for a region or bay system. In addition, he suggested development of a multilateral regional policy by lead regulatory agencies and wildlife organizations for habitat creation.

In summary, there were some interesting recommendations brought forth in the presentations and discussion. It was suggested that drilling fluids without diesel oil be used in the seagrass ecotoxicity test, as diesel oil contributes the most to toxicity, and discharge of diesel oil-based drilling fluids is prohibited. Mr. Lewis stated that impacts to donor seagrass beds ought to be studied. Mr. Carangelo indicated that Thalassia may not be transplantable in lower Texas as that is the limit of its distribution. Finally, Lewis, Deis, and Carangelo stressed the importance of collecting environmental data from the proposed planting site to determine restoration potential.

Ms. Laura Gabanski is an oceanographer with the Environmental Assessment Section of the Minerals Management Service's Gulf of Mexico OCS Regional Office. Her duties include the review of seagrass study proposals and reports. Ms. Gabanski received her B.A. degree in biology from Lake Forest College and M.S. degree in oceanography from Old Dominion University.

Chemical Dispersants and Their Role in Mitigating Oil Spill Impacts on Seagrass Habitats

Mr. Kenneth W. Fucik
Consultant

Seagrasses are found throughout the coastal regions of the Gulf of Mexico. The greatest development of the seagrass habitats is in those coastal regions characterized by minimal river inflow and generally clear waters. In the northern Gulf, these areas tend to be along the Florida coast and in the bays of south Texas. In these areas, seagrasses are a major contributor to the primary productivity of the region.

The importance of seagrasses to coastal regions is severalfold.

Seagrass habitats are among the most productive of natural ecosystems. The high productivity of the seagrasses leads to the formation and transport of large quantities of detritus and dissolved organic matter and contributes to the secondary productivity of a region. The extensive root and rhizome systems of the plants help to stabilize and trap inorganic and organic matter in the grass beds. The leaf blades support large numbers of epiphytes which can equal the biomass of the plant and which are fed upon by other fish and invertebrates. Dense seagrass beds also provide cover for foraging marine fauna as well as shelter and protection for larval and juvenile forms. Given the importance of seagrass habitats to coastal environments, it is important that they be protected from catastrophic impacts from oil spills.

Seagrass ecosystems can be impacted by oil in a number of ways. These include direct impacts which result in decreased productivity as well as lowered ecological value. Fish and invertebrates associated with the seagrasses can be indirectly impacted due to the loss of food and habitat. Oil in the seagrass system can also affect the associated faunal organisms directly through mortality or reduced physiological functions.

Studies in seagrass habitats following oil spills have generally documented few effects on seagrasses from oil. This may be at least partly due to the subtidal nature of the systems and the fact that the greatest biomass of the plants is located within the sediments. The major impacts that have been observed seem to be reflected in the associated faunal communities. The most serious effects on the seagrasses themselves has been in those communities that are intertidal or marginally subtidal and subject to occasional exposure. Some laboratory studies have shown that seagrass photosynthesis can be significantly reduced by exposure to water soluble fractions of aromatic hydrocarbons. Nevertheless, this would suggest that where an oil slick passes over a seagrass bed, and where there is little dissolution of the toxic hydrocarbon fractions into the water column, damage from an oil spill would probably be minimal.

Information on the effects of dispersed oil on seagrasses is practically non-existent. Preliminary results from a recently completed but as yet unpublished study conducted in Panama found no effects on the seagrasses from either treated or untreated oil. However, some impacts were observed on the associated fauna. Water depths in these studies were approximately 0.5-1.0 m. Previous studies have shown that dispersed oil probably mixes only a few meters into the water column so that most effects would probably be observed on seagrasses in waters less than 10 m.

It is difficult to provide definite guidelines for the use of dispersants near seagrass habitats because of the lack of available data. For the immediate future, any decisions to use the dispersants near seagrass systems will have to be based on best scientific judgment. However, there are various pieces of information which should be used to input into this decision.

In the initial decision process, consideration should be given to the location of the spill, the type of oil spilled, and physical transport parameters. For example, it is probably safe to disperse an oil slick in offshore waters to prevent the oil from passing over the seagrass bed. This assumes that the seagrass beds and other shoreline environments are the primary habitats for protection and that the offshore waters do not support commercially important egg and larval fish and invertebrates.

For spills which occur nearby or in the immediate vicinity of seagrass beds, decisions on the use of dispersants are less clearcut. Where seagrass beds are found in fairly dynamic areas with high rates of water exchange, the use of dispersants may be justified. In such cases, hydrocarbon exposures in the water column may be sufficiently short so that impacts to the seagrass and associated organisms would be minimal. Mechanical methods should, however, be considered the first line of defense unless physical conditions prevent their use.

In enclosed bays and lagoons where tidal energy and/or flushing rates are minimal, mechanical cleanup methods are probably the preferred course of action. Such methods will minimize the amount of oil entering the water column and potentially impacting shallow seagrass habitats. However, disposal of the collected oil will be a problem and the potential exists that some of this oil will not be collected at sea and will eventually impact shoreline environments.

Where seagrass habitats are the only critical habitat requiring protection during an oil spill, decisions on the use of dispersants can be resolved fairly easily. However, there are few locations around the Gulf where seagrass beds are not also found in close proximity to other sensitive or critical habitats (e.g. marshes, mangrove forests, coral reefs). Existing coastal sensitivity indices developed for oil spill response priorities rank mangroves and marshes as the most vulnerable intertidal habitats to oil spills. Preliminary results from simulated spills in Panama suggest that mangroves were damaged when untreated oil was allowed to wash ashore but dispersed oil did not appear to affect the mangroves. Therefore, if a decision to use dispersants is based solely on the presence of one habitat (e.g. seagrasses), then significant impacts could occur in some other sensitive environment. In such cases where more than one sensitive and critical habitat could be affected by the use or non-use of dispersants, a decision must be made as to which habitat should receive priority protection.

When making decisions to use dispersants in the vicinity of seagrass beds to protect other coastal habitats, various factors should be considered. For example, the use of dispersants during periods outside the growing season of the seagrasses may have little initial impact. Similarly, if sufficient time elapses before the start of a new growing season, then any residual hydrocarbons may be flushed from the system before they can impact new seagrass growth. The scarcity or abundance of a particular habitat type compared to other sensitive habitat types in an area should also be considered in making the decision on dispersant use and possible impacts. Therefore, if there are abundant seagrass beds but few marshes, then dispersant use should be considered to protect the latter.

Giving equal value to the critical habitat types in an area also complicates decisions on the use of the dispersants. In such cases, the ease or difficulty in rehabilitating damaged habitats should be considered. For example, while there have been some marked improvements in techniques for rehabilitating damaged seagrass beds in recent years, success in replanting seagrass beds remains more of a science than a proven technology. By contrast, marsh revegetation experiments have been highly successful in many cases.

In summary, then, it can be said that there are no easy answers for deciding on the use of dispersants in the vicinity of seagrass beds. Much of this is due to the fact that there is very little information currently available on the effect of dispersants used in such habitats. For the foreseeable future, decisions to use dispersants will have to be made on a case-by-case basis and will probably involve trade-offs such that effects may be increased at one site in order to eliminate or decrease effects at another site. These compromises will have to be made on the basis of the relative importance of, and projected impacts on potentially affected habitat types.

Mr. Kenneth Fucik is a private consultant. His current work includes developing guidelines for dispersant use near coral reefs and seagrass beds. Mr Fucik has become involved with this as a member of the American Society for Testing and Material's Subcommittee on Chemical Treatment of Oil Spills.

Impact of Drilling Fluids on an Experimental Seagrass Community

Dr. Thomas W. Duke
U.S. Environmental Protection Agency

Seagrasses form productive, stabilizing communities in many shallow waters of the Gulf of Mexico. These communities are relatively sensitive to turbidity, excess nutrients, and pollutants such as crude oil. Consequently, the health of a seagrass community is often used as an indicator of health of the coastal zone in which it occurs.

It has been suggested that drilling fluids discharged from offshore oil and gas platforms near state waters could be transported to seagrass communities and adversely affect them. The purpose of the research described herein was to develop a relatively rapid (42-day) ecotoxicity test that demonstrates the effects of drilling fluid on the structure and function of seagrass communities maintained in microcosms in the laboratory.

The methods and results of this research are explained in detail in Morton et al., 1986.[1] Generally, cores of seagrass (Thalassia testudinum) were removed from Santa Rosa Sound, Fl., and brought to the laboratory. The cores were than placed in Plexiglas[R] cylinders (15.9-cm inside diameter, 50-cm height) and exposed to either used drilling fluid that contained about 1% diesel oil, or clay, added to flowing seawater from Santa Rosa Sound (Figure 9.1). Clay was tested to indicate effects due to physical impact of particles. Controls were exposed to flowing seawater only. Suspended particulate phases of drilling fluid and clay were added continually at a concentration of approximately 15 milligrams per liter. At the end of 12 weeks, the cores were harvested and analysed, including comparison of treated and control microcosms in relation to numbers and kinds of invertebrates, growth and production of seagrass and epiphytes, and decomposition of seagrass leaves. The flow diagram (Figure 9.2) indicates the sequence of collecting, testing, and analyzing samples.

Exposure to drilling fluid or clay for 42 days adversely affected structure of the invertebrate population. There were significantly fewer individuals of four numerically dominant species in microcosms exposed to drilling fluids or to clay, than in the control. Perhaps the most striking effect was the overall reduction in the number of numerically dominant individuals per microcosm in both drilling fluid and clay treatments. Treated microcosms contained approximately one-half the number of organisms as control microcosms.

Drilling fluid and clay also adversely affected some aspects of production and health in Thalassia and epiphytes. Plants exposed to drilling fluids and clay showed significant reduction in chlorophyll a/dry weight leaf tissue. There were also significant reductions in epiphyte biomass (ash free dry weight/cm^2) and epiphytic photosynthetic potential (chlorophyll a/ cm^2) in drilling fluid treatments. Drilling fluid caused a significant decrease in rate of decomposition of dried Thalassia contained in small-mesh bags (litter bags). Decomposition was defined as loss of weight of the bags from treatment microcosms when compared with weight of bags from control microcosms. Since clay treatment did not affect decomposition, the effect probably was not caused by physical impact alone.

The test method fulfilled the requirement for a relatively rapid ecotoxicological test sensitive enough to reveal impacts on structure and function of a seagrass community. Additional tests must be conducted to determine no-effect concentrations of a particular drilling fluid and to evaluate ecological relevance of results.

Dr. Thomas W. Duke is a Senior Research Scientist at the United States Environmental Protection Agency's at Gulf Breeze, Florida. He has conducted marine ecotoxicological research with pesticides, radioactive material, drilling fluids and other environmental contaminants.

Dr. Duke received a B.S. degree in zoology and a M.S. and Ph.D. in oceanography from Texas A & M University.

[1]Morton, R.D,. T.W. Duke, J.M. Macauley, J. R. Clark, W.A. Price, S.J. Hendricks, S.L. Owsley-Montgomery, and G. R. Plaia. Impact of Drilling Fluids on Seagrasses: An Experimental Community Approach (In Press) ASTM Multispecies Testing Conference.

The Restoration and Creation of Seagrass Meadows in the Southeast United States

Mr. Roy R. Lewis III
Mangrove Systems, Inc.

Seagrass meadows in the southeast United States, particularly Florida, are a critical marine habitat for many species of importance to commercial and recreational fisheries, including scallops, spotted seatrout, snook, redfish, and pink shrimp (Tabb and Manning, 1961: Thayer et al., 1979: Zieman, 1982; Gilmore, 1983). Seagrasses are also important as a food source for the endangered West Indian manatee (Hartman, 1979). Historical losses of seagrass meadows have been substantial: in Florida, 43% of the original seagrass cover has been lost in northern Biscayne Bay (Harlem, 1979), 81% in Tampa Bay (Lewis et al., 1985a), and 29% in Charlotte Harbor (Harris et al., 1983);in Mississippi Sound, a 59% loss has been documented (Eleuterius, 1976).

The reasons for these declines include dredging and filling for waterfront property and port development (Taylor and Saloman, 1986; Lewis, 1977; Harlem, 1979), and water quality degradation due to silt resuspension and eutrophication which reduce light penetration (Harris, et al., 1983; Lewis et al., 1985a). The former problem is now largely regulated while the latter is not, and further losses of seagrass meadows due to general eutrophication of Florida's marine waters can be expected. In Mississippi, freshwater diversion reduced salinities (average of 4 ppt for a 3-month period during 1973) in much of Mississippi Sound have decimated existing seagrass meadows (Eleuterius and Miller, 1976). Partially as a result of these large-scale losses of seagrass habitat, marine productivity in Florida, as defined by the commercial harvest of estuarine dependent species, has declined (Harris et al., 1983: Lewis et al., 1986). Impacts to recreational fisheries are probably substantial, but are unquantified. When asked in interviews, saltwater recreational fishermen generally believe that their harvests have declined (Bell et al., 1982).

Because of the above, there has been keen interest in restoring lost marine habitat in general, and tidal marshes, mangrove forests, and seagrass meadows, in particular (Lewis, 1982a). The technology to restore or create tidal marshes and mangrove forests in the southeast has been under study for over 10 years, using techniques developed in North Carolina and Maryland for tidal marsh restoration (Lewis, 1982a, b, c). The technology is quite feasible and results have been successful (Kruczynski, 1982; Hoffman et al., 1985). Unlike tidal wetland restoration and creation, seagrass meadow restoration and creation is not presently generally successful. The reasons for this and the direction we need to take to improve the success rate of these efforts are the subjects of this paper.

TERMINOLOGY

There exists some confusion as to the terminology used to describe seagrass restoration efforts. Most recent papers use the word "transplanting" to describe seagrass restoration efforts, even if the actual mechanics of the restoration effort did not really involve transplanting (Thorhaug and Austin, 1976; Phillips, 1982; Phillips and Lewis, 1983; Fonseca et al., 1984). The use of this term to describe seagrass restoration efforts in general is understandable since transplanting planting units from an existing seagrass meadow to a site without seagrass has been, until recently, the most commonly available technique (Darovec et al., 1976; Van Breedveld, 1975; Phillips, 1982).

Recent advances in the techniques of seagrass restoration and the need for clarity in describing methods require better terminology. Webster's New Collegiate Dictionary (Bethel, 1961) defines "transplant" as "remove and plant in another place; to lift and reset in another soil or situation [p. 904]." The same source defines "restore" as "to bring back to, or put back into the former or original state; to repair; renew; ... re-establish [p. 722]." "Create" is defined as "to bring into being; to cause to exist [p. 195].

For purposes of clarification, the following definitions apply as used in this paper. Restoration is defined as the re-establishment of a seagrass meadow at a site that is documented to have supported a seagrass meadow in the recent past. Creation is defined as the establishment of a seagrass meadow on a site that is not documented to have supported a seagrass meadow in the recent past. Examples of the latter would be the excavation of uplands to create a wetland area, or the deposition of dredged material in water too deep to normally support seagrasses in order to crate a shallow submerged shoal. In both of these cases, the seagrass meadow may be created through natural colonization by seagrass propagules (either sexual or asexual), or by active planting of propagules.

If the planted propagules consist of plugs removed from another meadow, then transplanting has occurred. On the other hand, if the propagules are cultivated seedlings (grown from seeds or seedlings), it would be incorrect to refer to the planting effort as transplantation, as is often done (Phillips, 1982; Phillips and Lewis, 1983). A better term in this case would be planting, or installation. While these differences in terminology may seem minor, it is a major thesis of this paper that the future of seagrass restoration and creation efforts will increasingly depend on the availability of planting units that do not produce damage to existing healthy seagrass meadows (non-destructive plant material sources), or represent a "salvage" effort (*sensu* Phillips and Lewis, 1983). Classic transplantation methods are predicted to cease to be the best available technology to solve the problem of seagrass restoration.

Mitigation is another word frequently misused in discussing seagrass restoration. Mitigation refers to decreasing or compensating for the impact of some proposed activity and includes a variety of management efforts ranging from not undertaking a project at all to providing substitute resources for those being lost. Seagrass mitigation thus refers to a wide variety of possible management techniques, only one of which may be seagrass meadow restoration or creation.

The success of an attempt to restore or create a seagrass meadow has not been measured in any uniform way in past projects. This has led to confusion as to whether in fact seagrass restoration projects have been successful (Fonseca *et al.*, 1984). The usual practice is to define a certain survival rate of planting units at the end of a period of time (*e.g.* 80% survival at the end of one year), and to call a project successful if that goal is met. However, as noted by Fonseca *et al.* (1984), simply measuring planting unit survival does not indicate whether the restored meadow is biologically similar to adjacent, or near, undisturbed meadows. These authors state that, "Plantings should be considered successful if surviving planting units exhibit a coverage rate similar to data presented here [population growth model data], if the coverage generated equals or exceeds the impacted meadow acreage, and if that coverage persists through time".

These authors recommend a minimum of three years of unassisted endurance (no replanting) or a planting as a minimum requirement. The emphasis on coverage as a criterion is important because population growth model data indicate that the three common species used in restoration efforts (in Florida) have different rates of asexual reproduction; thus, increase in number of shoots of established planting units varies widely with location and species used.

RECOMMENDATIONS

1. Seagrass meadow restoration/creation designs should be based upon the best scientific information available.
2. Salvage of seagrass plant material from sites of permitted destruction should be given higher priority.
3. The excavation of seagrass plant material from healthy meadows to provide planting material should be discouraged.
4. The use of seagrass population growth models, up-front mitigation where feasible, and more rigorous compliance monitoring are encouraged (Fonseca *et al.*, 1984).
5. Before planting unvegetated existing sites, it is essential to understand why it

is unvegetated, and either rectify that condition or discard the site.

6. Future restoration efforts will require large amounts of plant material; consideration should be given to non-destructive plant material sources, including cultured planting units (see Table 9.1).

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Seagrass Restoration Along the Texas Coast

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and
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In February 1985, the Texas General Land Office (TGLO) commissioned a study to identify areas of the coastal zone where improvements to existing habitat could help minimize development-related impacts to wildlife and fisheries. The study had two phases: (1) identification of sites for habitat improvement, and (2) planting of seagrass at a recommended site. Potential sites were initially located on U. S. Geological Survey and National Wetland Inventory Maps prior to field surveys. All sites considered were within TGLO jurisdiction. Sites were to be selected so as to maximize habitat diversity, both locally and regionally; to increase habitat that was historically abundant but has since been degraded; to maximize habitat for particularly important or sensitive species; and to maximize the probability of conducting a successful restoration project. Several sites for seagrass restoration were identified in the lower Laguna Madre and Land Cut area. Many of the sites had been affected by impacts of oil and gas exploration.

In the second phase of the study, a site in the Land Cut area was planted with shoalgrass (Halodule wrightii). In this area, the Department of the Army issued permits approving maintenance dredging of an existing channel, dredging of a new slip and basin, and drilling of exploratory wells for oil and gas. Permit holders agreed to implement a mitigation plan that included the creation of seagrass habitat at a depth conducive to growth of shoalgrass.

Previous seagrass planting attempts have demonstrated the importance of using an experimental approach and monitoring for conditions that promote seagrass growth. In 1985, a small, shallow-draft hydraulic dredge was used to prepare the site so that it would mimic conditions within adjacent seagrass beds. The site was allowed to stabilize for one year prior to the planting. During this interval, the adjacent seagrass beds were monitored for growth characteristics. Shoalgrass in the donor area was found to be in a high-growth phase (3 to 5 new growth shoots per rhizome) during April 1986. The prepared site was planted with 16,500 planting units on 0.9-m centers (total area: approximately 3.3 acres). Each planting unit consisted of a portion of a sod taken from an adjacent donor bed. Random counts of apical meristems yielded 4.5 apical meristems per planting unit.

A monitoring program was designed to document survival and coverage of the transplanted shoalgrass after 3-month, 6-month, and 12-month intervals. Randomly selected planting rows were examined for percent survival and transect counts of surviving transplants within the full length of six rows (i.e., approximately 5% of the total transplants). Thirty randomly selected planting units were measured for bottom coverage by placement of a 0.5 m^2 grid with 5 cm^2 squares and counting the squares filled with seagrass. Unit numbers planted at time 0, survival percentage, and average area coverage per transplant give an estimate of actual area of grassbed that has been generated. At the end of the monitoring program, growth and coverage models from other systems were used to interpret the data in an evaluation of this project. The 3-month monitoring interval showed an average of 88.9% survival and an average spread of approximately twice the planting unit size.

Mr. Donald R. Deis is a coastal ecologist with Continental Shelf Associates, Inc. He specializes in user conflict resolution in the coastal zone and has been attempting to develop the concepts of mitigation and habitat restoration as a tool for conflict resolution. Many of his ideas on the potential of mitigation and habitat creation are found in the recent U.S Fish and Wildlife Report, "Mitigation Options for Fish and Wildlife Resources Affected by Port and Other Water Dependent Developments in Tampa Bay, Florida".

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Sea Grass Restoration Management in South Texas: Aspects of the Rate of Natural Colonization and Other Regional Management Considerations

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Experimental transplantation of marine angiosperms has been conducted in southern Texas since 1974. In recent years, sea grass plantings have been conducted on a larger scale to compensate for sea grass habitat loss resulting from coastal development, including OCS activities.

While sea grass restoration or habitat creation is a successful aquabotanical culture technique for which substantial demonstration exists, the rapid rate of non-induced revegetation of disturbed sites by Halodule and Ruppia in Texas waters has often been observed to exceed the rate of growth and colonization induced by Halodule transplants. These observations, as well as other regional characteristics of the sea grass system, suggest that managers should consider the selective application of a "hands-off" approach as a method to restore damaged or create new Halodule dominated systems in south Texas.

Four projects relating to impacts to Halodule type sea grass beds as a result of OCS related activities in southern Texas waters were examined as they concerned aspects of colonization by Halodule or Ruppia (Figure 9.3). Photographic evidence and study-site documentation was collected at the selected project sites within a period from 1977 to 1983. Additional photographs and field observations were acquired in 1986. File and recent data, and some engineering, environmental, and edaphic factors which regulate revegetation, are presented as Table 9.2.

The database is representative of those circumstances where natural colonization could be prudently employed to restore a damaged Halodule --dominated system regionally. The generalized results of these studies indicate that if the predisturbance elevation was restored and the original surface sediment (texture) replaced -- even in the cases where severe damage to rhizomes had occurred or they had been completely destroyed -- depending on the size of the area affected, most low-to moderate-energy Halodule and Ruppia grass flats were restored within a one-to five-year period following disturbance. The data and observations at the study sites indicated the rate of colonization or invasion is linked to time from disturbance to backfilling; occurrence in disturbed sediments of pieces of live rhizome from plants present before the disturbance; proximity of undisturbed grass beds to supply vegetative growth and seed; the similarity of pre-and post disturbance sediments; shallow water generally less than .4 meter deep mean sea level; topography; and protection from wave action.

Proposed recommendations focusing on sediment or substrata management as a means to enhance the natural capacity of Halodule to recolonize following disturbance in south Texas are:

1. Partition and stockpile surface "topsoil" from parent or underlying sediments. This is crucial when the underlying texture would be inimical to plant colonization.
2. Back fill underlying sediment and return "topsoil" to surface.
3. Conduct work as rapidly as possible to preserve live pieces of meristem.
4. Calculate volume of sediment loss from handling and import clean fine sandy material to make up for loss plus compaction.
5. Final grades must be level with or slightly higher than adjacent grass beds.

Data by other workers indicate sea grasses in selected study areas in south Texas have more than doubled in areal extent in the period 1956 to 1974. These increases were largely of the Halodule type. The spread of marine grasses has been at the expense of unvegetated wind-tidal flats and subaqueous flats (Figure 9.4). The processes responsible for these environmental changes were reported as related to compactional subsidence and eustatic rise in sea level (White et al 1983).

Based on field observations of the author, and supported by communicated observations by other scientists, the above trend has continued to the present date. Although the trend rate may have changed, it is hypothesized that the extent and distribution of marine angiosperms (principally Halodule) are presently at a historic maximum in the Coastal Bend.

Both factors of rapid recovery of disturbed systems and extensive new development regionally over the last 20 years should be considered when impacts are being addressed or when mitigation is proposed as a condition of permitted activities. The data and the historical trends presented suggest the planting of Halodule may not be an appropriate primary element in a submergent restoration or creation strategy in south Texas. Rather, it could be considered a secondary element in a proposal to be applied later during plan life if natural colonization has not been satisfactory. The study data strongly suggest that Halodule will rapidly invade even newly exposed sites when proper site selection criteria are met, and controlling environmental conditions of depth as a function of light quality, sediment texture, temperature, salinity, and low to moderate current energies are provided.

In addition to transferring information on the preceding subject, the application of a standardized approach to site selection, project plan and design, monitoring criteria, and predictable cradle-to-grave responsibility of the applicant or agency for their impact is forwarded as an essential aspect of south Texas sea grass management. Also, the time and resource commitment an applicant or agency has given to a compensation project may be considerably longer than that which is presently anticipated. In any event, this commitment may be at least as long as that noted in the literature for sea grass community recovery: 1 to 5 years for Halodule and 5 to 15 years for Thalassia. This fact should be communicated to the responsible party when impacts to sea grasses, or their restoration or creation, are proposed. It is emphasized that there is a need for a clearinghouse for regulatory and compliance activities in sea grass resource management. A procedure should be developed to assure institutional memory. An essential part of this procedure is the development of regional or bay system standards which provide not only a data-base on restoration need (in-kind or out-of kind), but a standardized approach to determine if the goal of the compensation effort is met -- the development of permanent and functional marine aquatic habitat. Elements of this mechanism should include the following tasks:

1. Obtain current inventory of existing habitat, the spatial distribution on a bay system level, and historic trend analysis through the present;
2. Determine degree of heterogeneity or extent of patchiness within the existing sea grass habitat and clarify the need for more or less habitat spatial diversity;
3. Compile Habitat Suitability Index sea grass species models and distribute them for adaptation to each bay system;
4. Develop a proper site selection evaluation form. This should build on existing models but with regional system parameters as applied limits;
5. Verify the suitability of a compensation plan and the appropriateness of its design and construction methodology to the findings 1-4;
6. Verify that permitted or proposed activity is conducted on schedule and that design and functional compliance is met;
7. Develop a standardized monitoring program to be followed by applicants or their consultants to obtain data from cradle-to-grave on restoration/creation projects. The program will be designed to measure created vegetative

structural and habitat functional complexity in comparison to selected natural habitat while recognizing differences in age;
8. Develop field procedures to verify that the habitat has been recovered or created. These procedures will follow the standardized monitoring program data-base;
9. Provide enforcement and penalty for noncompliance.

Lastly, a holistic approach in managing coastal systems including sea grass systems has been considerably discussed and positive steps should be taken in that direction. The author recommends that a "summit" meeting of lead regulatory agencies and wildlife organizations be held to execute a multilateral policy of habitat creation goals which go beyond the piecemeal case-by-case strategy of the present. The driving force behind this effort is not only the need to compensate for losses from proposed projects, or to remedy effects of past engineering works, but to meet perceived social and political demands of the future. A suggested concept to bear in mind is that it will take large scale engineering projects to mitigate the effects of large scale engineering works. The successful final product from this "summit" would be execution of a memorandum of understanding defining regional or bay system habitat creation/ preservation goals and agreeing to the sharing of all agency resources and capabilities to meet those goals.

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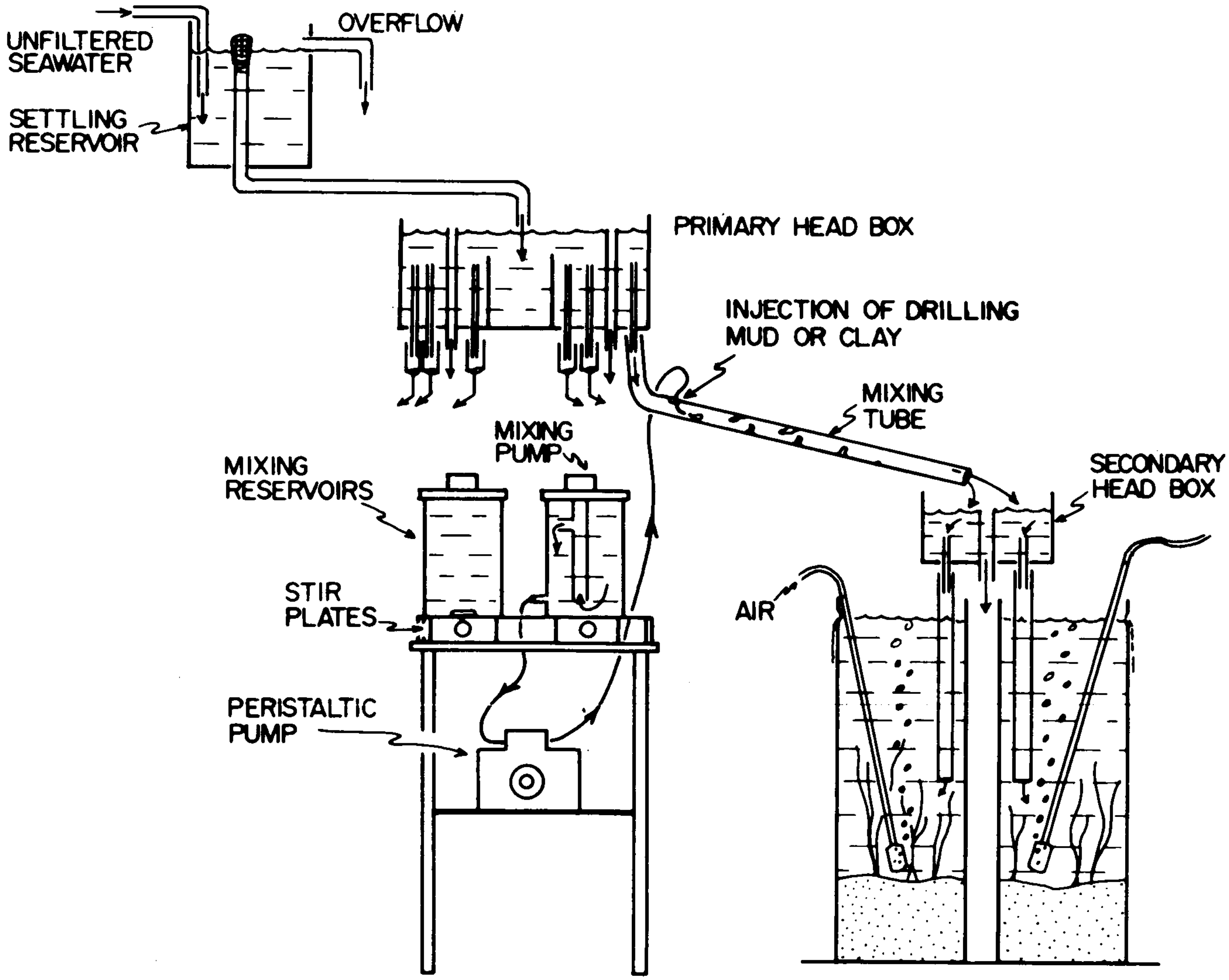

Figure 9.1.--Seawater and test material delivery system (Morton et al., 1986).

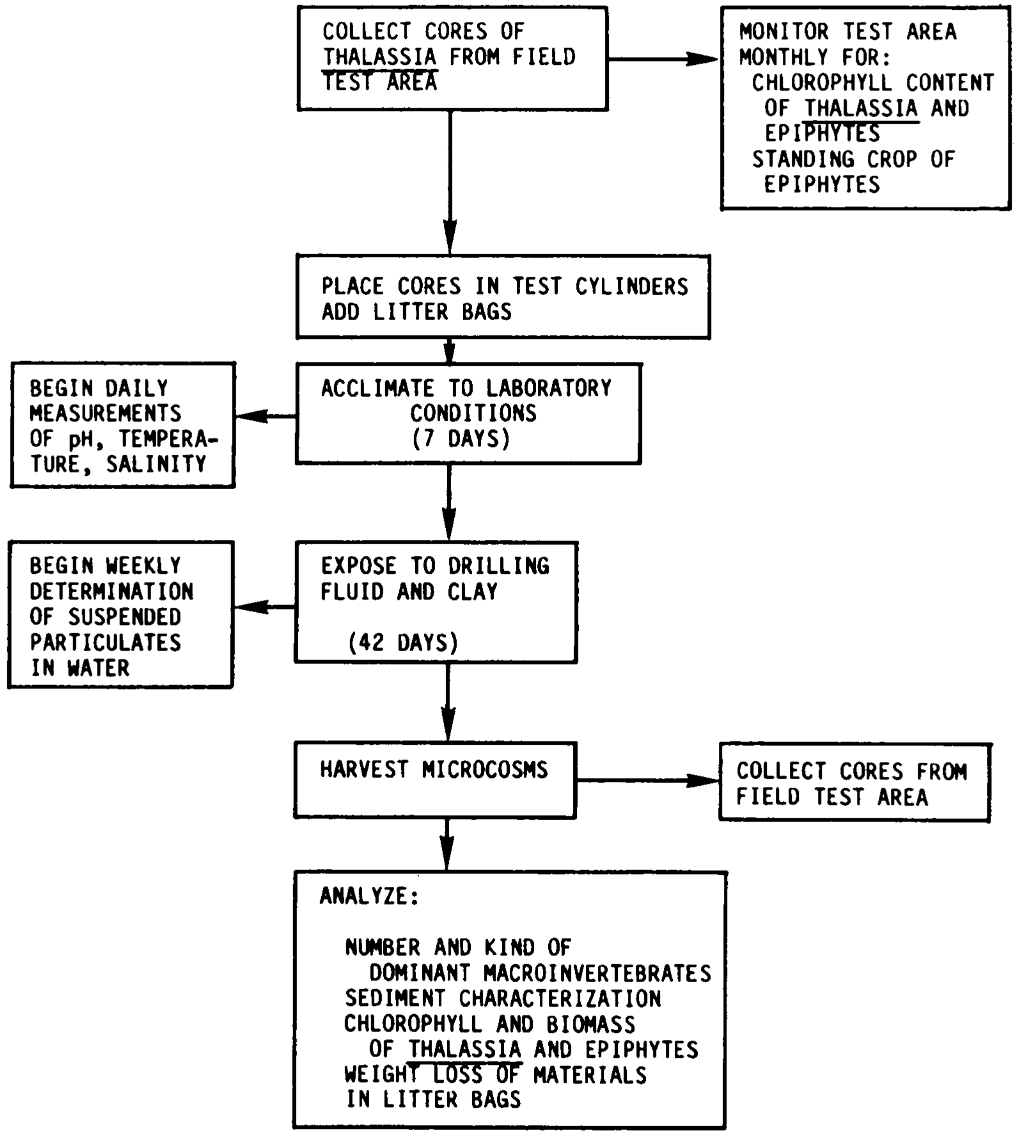

Figure 9.2.--Flow diagram showing the sequence of collecting, testing, and analyzing samples (Morton et al.,1986).

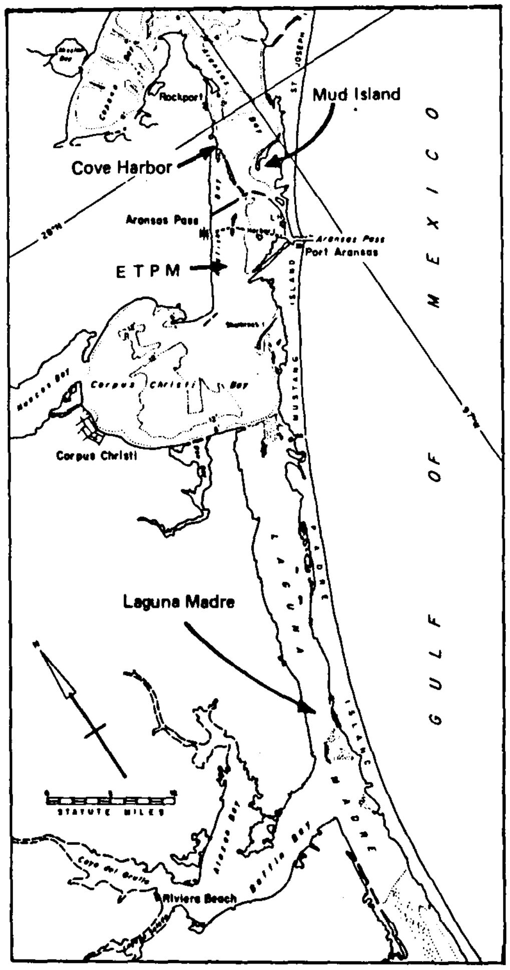

Figure 9.3.--Location of project sites in the south Texas Coastal Bend region.

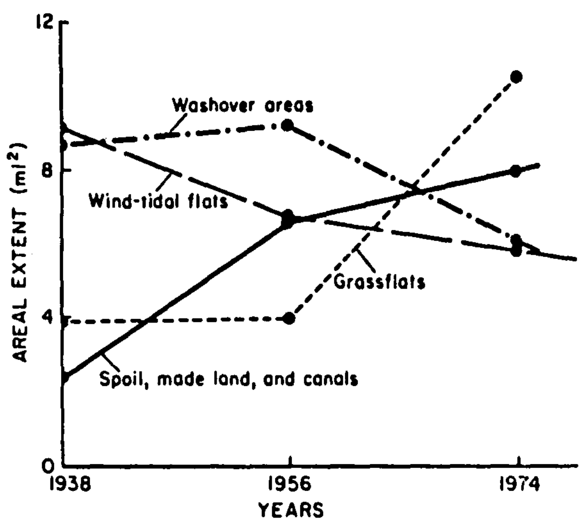

Figure 9.4.--Changes in areal extent of selected environments based on historical monitoring analysis of Mustang and northern Padre Islands, Nueces County, Texas (1938-1974). (Adapted from White et al., 1978).

Table 9.1

Summary of Existing and Proposed Seagrass Restoration Plant Material Sources

	Source	Advantages	Disadvantages
A.	Harvested, unattached rhizomes	- available year-round - culture not required	- presently available for *Halodule wrightii* and *Syringodium filiforme* only, in the Florida Keys
B.	Harvested fruits	- no sediment disturbance	- seasonal availability - locating fruiting plants - high cost of collection - presently available only for *Thalassia*
C.	Collected seedlings	- no sediment disturbance - salvage of plant material that would normally die - low collection costs	- seasonal availability - presently available only for *Thalassia* - culture may be required
D.	Beach drift-line salvage	- available year-round - salvage of plant material that would normally die - no sediment disturbance - low collection costs	- culture may be required
E.	Impact site salvage	- intact plug removal helps ensure success	- replanting site needs to be prepared prior to salvage

References:
A - Derrenbacker and Lewis, 1983; B - Thorhaug and Austin, 1976; C - Lewis and Phillips, 1980; C, D, E - Phillips and Lewis, 1983.

Table 9.2

Locations of Selected OCS Impact Study Sites in South Texas
The table provides regionally representative data on rate and extent of natural recolonization by Halodule or Ruppia observed under site specific and various environmental or edaphic conditions

Location	Mud Island - Aransas Bay, Tx		Cove Harbor - Aransas Bay, Tx			
	Control	Disturbed	Control		Disturbed	
No. years post impact	2.5	2.5	1.5	2.5	1.5	2.5
% presence (cover)	80-86	46-66	96	99	67	72
Relative Density % sparse	33-34	20-35	no data			
moderate	26-26	21-22	no data			
lush	19-21	8-11	no data			
Standing Crop g/m2	no data		no data			
% Short Shoots/m2	no data		no data			

	Mud Island - Aransas Bay, Tx	Cove Harbor - Aransas Bay, Tx
Data source	Nessmith 1980, MS	Holt et al 1980 unpublished
Type OCS activity - impact	prop wash/exploratory work	gas pipeline installation
Impact date	February 1977	February 1977
Total area impacted	2.2 hectares	0.71 hectares
Previous seagrass system ?	yes; five local species	yes; Halodule predominant
Damage level to plants	severe damage to rhizomes	severe damage to rhizomes
Date return of sediment to excavation	n/a - not applicable	within month
Similar or original profile returned ?	yes	yes with heavy equipment
Date return of original profile	n/a	January 1978
Original texture returned ?	yes	yes
Original topsoil returned ?	no	yes
Live meristem in sediment?	no	yes: 2 - 20 pieces/20 cm2
Avg water depth disturbed (range)	18 to 66 cm	31 to 45 cm
Avg water depth control (range)	11 to 66 cm	40 to 50 cm
Exposure - wind/wave climate	moderate - faces SE	low - protected by berm
Period of observation - photographs	1977 to 1980; 1986	1978 to 1979; 1986
Period of field data aquisition	1978 to 1979; 1986	1978 to 1979
Transplantation performed ?	yes	yes
Citation	Carangelo et al 1979	Holt op cit; This paper
Recolonization overwhelm transplants ?	yes: within one year	yes: plantings yeild 14% cover
Rate of non induced recovery	1977 1978 1979	1978 1979
% of study area per observation	16 34 40	67 5
predominant species recolonizing	Ruppia & Halodule	Predominantly Ruppia
Distance from edge of vegetation to farthest point of disturbance	1977 - 83 meters	1978 - less than 59 meters
Seed sources limiting ?	no data	no data (assumed nonlimiting)
Textures or depth not recolonizing ?	yes: > 80 - 100 cm depth	< 30 cm; marine clay/sandstone

Table 9.2 (cont'd)

Locations of Selected OCS Impact Study Sites in South Texas
The table provides regionally representative data on rate and extent of natural recolonization by Halodule or Ruppia observed under site specific and various environmental or edaphic conditions

Location	E T P M - Redfish Bay, Tx		Upper Laguna Madre, Tx					
	Adjacent Beds	Scrapedown	Control			Disturbed		
No. years post impact	1986	8	1	2	3	1	2	3
% Presence (Cover)	92	42	55.9	53.3	46.9	9.5	35.5	46.4
Relative Density % sparse	19.4	53.0			6.6			16.6
moderate	34.7	31.0			40.0			47.6
lush	45.8	16.0			53.3			35.7
Standing Crop g/m2	no data		492	439	169	127	340	409
# Short Shoots/m2	no data		3863	4548	3215	2271	5029	5561

Data source	Carangelo, unpublished data	Carangelo, unpublished data
Type OCS activity - impact	compensation for fabrication yard	20 inch OCS gas pipe line crossing
Impact date	1978	October - November 1980
Total area impacted	1.25 hectares	5.44 hectares
Previous seagrass system ?	no; emergent spoil island	yes: Halodule
Damage level to plants	n/a: new surface	severe damage to rhizomes
Date return of sediment to excavation	n/a	December 1980
Similar or original profile returned ?	n/a	no; 80 % higher, 20 % depressions
Date return of original profile	1978	n/a backfilled December 1980
Original texture returned ?	no data	yes
Original topsoil returned ?	n/a	no
Live meristems in sediment?	no	no data
Avg water depth disturbed (range)	96 cm	93 cm
Avg water depth control (range)	71 cm	117 cm
Exposure - wind/wave climate	low - open shallow bay w/berms	low - open shallow bay/ non shoreline
Period of observation - photographs	1986	1981 1982 1983; 1986
Period of field data aquisition	1986	1981 1982 1983
Transplantation performed ?	no	no
Citation	this paper	this paper
Recolonization overwhelms transplant ?	n/a	n/a
Rate of non induced recovery	1978 to 1986	1980 1981 1982 1983
% of study area per observation	0 to 42	0 9.5 26.0 10.9
predominant species recolonizing	94 % Halo; 6% Syring; Trace Thal	Halodule
Distance from edge of vegetation to farthest point of disturbance	1978 - less than 80 meters	1981 - 39 meters
Seed sources limiting ?	no data - unlikely	no data - unlikely
Textures or depth not recolonizing	yes:) 98 cm avg depth	yes: depressions and unfilled trench

MARINE ARCHAEOLOGY: A PROBLEMATIC APPROACH TO RESOLUTION OF UNIDENTIFIED MAGNETIC ANOMALIES

Session:	MARINE ARCHAEOLOGY: A PROBLEMATIC APPROACH TO RESOLUTION OF UNIDENTIFIED MAGNETIC ANOMALIES
Chair:	Mr. Richard J. Anuskiewicz
Date:	November 6, 1986

Presentation Title	Speaker/Affiliation
Marine Archaeology: A Problematic Approach to Resolution of Unidentified Magnetic Anomalies: Session Overview	Mr. Richard J. Anuskiewicz Minerals Management Service Gulf of Mexico OCS Region
Summary of Thoughts of Theoretical and Practical Considerations for the Improvement in the Interpretations of Magnetic Survey Data	Dr. John W. Weymouth University of Nebraska
Resolution of Unidentified Anomalies and Related Matters	Mr. J. Barto Arnold III Texas Antiquities Committee
An Analytical Consideration of Three Interpretative Anomaly Parameters - Amplitude, Signature, and Duration	Dr. Ervan G. Garrison Texas A&M University
Response to a Problematic Approach to Resolution of Unidentified Magnetic Anomalies	Mr. Allen R. Saltus, Jr. Southeastern Louisiana University
Geophysical Search Techniques for Distinguishing Shipwrecks from Trash	Dr. Bruce W. Bevan Geosight

Marine Archaeology: A Problematic Approach to Resolution of Unidentified Magnetic Anomalies: Session Overview

Mr. Richard J. Anuskiewicz
Minerals Management Service

Every year Minerals Management Service (MMS) archaeologists review hundreds of geophysical - archaeological reports containing geological interpretations and an archaeological assessment of lease blocks located in Federal OCS waters of the Gulf of Mexico. As a part of the archaeological review for these lease blocks, a historic analysis is conducted to assess the potential impact of future oil and gas development on possible historic shipwrecks located within these lease blocks. In the process of reviewing the geophysical - archaeological reports yearly, MMS archaeologists look at thousands of unidentified magnetic anomalies recorded during marine magnetometer surveys presented in these reports. These thousands of unidentified anomalies are scrutinized and an attempt is made to discriminate between a potential historic shipwreck and modern marine debris.

In order to attempt to develop a better analytical capability to discriminate between potential historic shipwrecks and modern marine debris, a panel of experts--experienced in theory, method, instrumentation deployment, and data interpretation of magnetometer remote sensing -- was formulated.

The panel members were given two geophysical - archaeological lease block survey examples for review, and copies of MMS's Notice to Lessees (NTL 75-3, Revision No. 1), and Letters to Lessees (July 17, 1984 and March 5, 1986) which detail MMS's magnetometer survey requirements for OCS archaeological surveys.

The marine archaeology sessions focused on specific analytical factors that provide the existing interpretive framework in MMS's analysis of magnetometer data for archaeological reports. MMS archaeologists have been reviewing magnetometer data and using these analytical factors in an attempt to discriminate between potential historic shipwrecks and modern debris. Hopefully, these sessions will expand the present state of knowledge in marine magnetic interpretive skills to better increase discriminative capabilities. Listed below are the analytical factors used in MMS's present archaeological interpretive framework: (a) anomaly amplitude in gammas; (b) signature width and/or duration in time; (c) signature asymmetrical characterization; (d) sensor height above the seafloor; (e) spatial occurrence of anomaly due to existing oil and gas production facilities, designated anchorage areas, shipping fairways, and military warning areas; (f) the existence of predetermined high- and low-probability zones for the occurrence of historic shipwrecks; and (g) whether or not the anomalies correspond to existing geologic features.

Given MMS's 150-meter magnetometer survey line spacing interval, the panel discussants began the session.

Dr. John W. Weymouth, University of Nebraska, had several thought provoking suggestions for both magnetic data acquisition and data interpretation of survey data. Within the existing 150-meter survey methodology, Dr. Weymouth suggested: a) providing copies of all chart recordings of magnetic anomalies; b) all information available to include, factor translating time on charts to horizontal distance, time at the start of each run, magnetic amplitude, and horizontal distance between readings to estimate size and nature of the magnetic source; c) use of the "full width, half maximum" (FWHM) number which is obtained from a simple profile by measuring the width of the profile at an amplitude halfway between the maximum value and background; d) the concept of "anatomy of anomalies" should be studied within the framework of an examination of anomalies produced by actual shipwrecks and non-shipwrecks that have been tested by excavation and by model calculations using realistic sources and simulating the survey methods being used; and e) within the existing survey methodological framework add another magnetometer in a side-by-side array at a separation distance roughly comparable to the anticipated sensor-to-source distance.

J. Barto Arnold III, the state marine archaeologist for Texas, pointed out a basic flaw in plan in MMS's existing 150-meter line spacing methodology, and drew on his past experience, suggesting that the distance between lines is too great to develop patterns of readings on neighboring survey tracks which are essential in recognizing a shipwreck. He further stated that even assuming adequate coverage by close survey tracks, it may be there are too many independent variables to ever be completely sure about anomaly causes without physical visual inspection. Current MMS survey line spacing requirements present an insurmountable barrier to better interpretation of the magnetic records. There are, nonetheless, some actions that should be taken to immediately vastly improve the (archaeological) reports. A gathering and analysis of anomaly signatures which have subsequently been ground truthed would be a big step towards seeing what can be done and how far we can go with our interpretations and the confidence level appropriate in those interpretations. In addition, the section of magnetometer strip chart showing every anomaly recorded should be submitted with the archaeological report for review and interpretation.

Dr. Ervan G. Garrison, Texas A&M University, talked about an experimental magnetometer survey he conducted over a 19th century historic shipwreck. This well-known and diver-surveyed Civil War shipwreck, the "Will O' Wisp," lies approximately 300 meters off Galveston Island, Texas. A total of six survey transects, one directly over the wreck and thence out to 150 meters at 25-meter line spacing intervals, was run. The six separate transects were then analyzed for the relative discriminatory power of the three parameters of amplitude (intensity), signature (shape), and duration (period). The set of magnetic survey data, taken with high precision, was evaluated using these three parameters. Typically used in MMS's standards for evaluatory purposes, these parameters were analyzed for their relative discriminatory power in characterizing magnetic anomalies. Based on the preliminary results of the study, only one--duration--was instrumentally significant over survey transects a hundred meters distant from the anomaly source: in this case, a 19th century historic shipwreck.

Professor Allen R. Saltus said that MMS archaeologists should be commended for their attempt to utilize all available data to the fullest, but their interpretive framework should not be used in formulating a final determination as to the cause of any magnetic occurrence, including debris from shipwrecks. In doing so they could be writing off cultural resources without knowing anything of their nature or significance. However, given sufficient data, the interpretive factors could be useful for planning purposes. The only method of determining cause and significance of magnetic data is through ground truthing (i.e., diver verification, underwater television, and sometimes die scan sonar). This statement is based on a discussion of survey methodology used to gather this magnetic data and the seven interpretive factors used by the MMS archaeologists.

He continued by saying that the magnetic data gathered to fulfill the MMS guidelines is generated at 150-meter (492.39 feet) line spacings. Using this methodology, no known pre-World War II watercraft is guaranteed to be detected. Actually, most vessels have less than a one in four (25%) chance of being located. Smaller watercraft have less than a one in five (20%) chance of being located. At 150-meter line spacing, the survey can only be considered an exploratory or sample survey from which further investigations can be determined and/or planned, and budgetary needs established for the next phase of investigation. The MMS archaeologists are attempting to short cut this process using analytical methods which do not seem to have any acceptable degree of significance or reliability regarding their criteria for differentiating debris from shipwrecks.

In summary, Professor Saltus suggested that he hoped that the criteria established by the MMS archaeologists will not be used. To do so could create a situation in which a Federal agency may write off significant cultural resources by using both an unacceptable database and manipulating this data using criteria which do not have an acceptable degree of reliability or significance. Using this approach would lend credence to the term used by critics of this program, "Archaeofolly."

Dr. Bruce W. Bevan of Geosight stated that magnetic surveying has been a successful procedure for locating shipwrecks, but many false indications from modern discarded iron are also found. It is possible that changes from current survey techniques could increase the reliability of distinguishing shipwrecks from trash on the seafloor. Triaxial vector magnetic measurements have greatly aided the search for magnetic materials from boreholes. These same procedures could be applied to estimating the depth of iron in the sediment and therefore could suggest its age.

Handheld metal detectors have been applied to search for artifacts at shipwrecks, but other instruments could be more suitable for large area investigation of insulators and conductors. Electrical resistivity measurements can be made on the seafloor by dragging an electrical cable with several connection points exposed to the seawater. Magnetotelluric surveys typically measure to a great depth, but might be suitable for this survey.

Old iron could be significantly different from modern iron in its magnetic properties. An electromagnetic induction system which measures the electrical conductivity of the seafloor could also determine its AC magnetic susceptibility. Measurements at one or more frequencies might allow different ferrous materials to be distinguished. With the vector magnetometer mentioned above, it could be possible to separate the remnant and inducted magnetization of iron objects by determining the net direction of polarization. The ratio of remnant to inducted magnetization, the Koenigsberger ratio, might distinguish old iron from modern steel.

Richard J. Anuskiewicz obtained a B.A. in 1972 and an M.A. in 1974 in anthropology/archaeology from California State University at Hayward. He was employed with the U.S. Army Corps of Engineers from 1974 to 1984 as a terrestrial and marine archaeologist and worked in San Francisco, New England, and Savannah Corps of Engineers District Offices before accepting a position with the Minerals Management Service Gulf of Mexico OCS Regional Office in 1984. Mr. Anuskiewicz took a year's leave of absence for graduate school at the University of Tennessee in Knoxville, and in February 1982 he was advanced to doctoral candidacy. His current research interests are marine remote sensing and underwater archaeological site reconstruction in a blackwater environment.

Summary of Thoughts of Theoretical and Practical Considerations for the Improvement in the Interpretations of Magnetic Survey Data

Dr. John W. Weymouth
University of Nebraska

The meeting was a panel and audience discussion of theoretical and practical considerations for the guidance and improvement in the acquisition and interpretation of magnetic survey data of lease blocks for the purpose of mitigating the impact on archaeological resources.

1. Within Existing Methodology

Although the present form of obtaining magnetometer data (running traverses 150 m apart with one magnetometer and side scan sonar) can only provide anywhere from 10% to 30% coverage of possible shipwreck indications, it is realized that there are severe economic restrictions to providing greater coverage. Within this framework, several things can be done to improve the interpretation potential of the data that are obtained.

a. Copies of all chart recordings of magnetic anomalies should be provided. In order to extract the fullest possible information from the data, it is not sufficient to have just the maximum and total length of the anomaly. It is necessary to see the shape and structure of the anomaly profile. Having the original profile will aid in separating simple sources from complex sources.
b. Full information should be provided, and this includes sensor distance above bottom, factor translating time on charts to horizontal distance, and time at the start of each run. The magnetic amplitude and horizontal distance between readings can be used to estimate size and nature of source. The time of recording the anomaly can be used in conjunction with the geomagnetic information provided by NOAA (Preliminary Report and Forecast of Solar-Geophysical Data) to account for possible deviations from the normal magnetic diurnal curve.
c. If a "width" number is going to be used, it should be the "full width, half maximum" or FWHM. This number is obtained from a simple profile by measuring the width of the profile at an amplitude halfway between the maximum value and background. The width should be expressed in horizontal distance along the traverse. This measure is less ambiguous than duration of anomaly and is widely used (M. Aitken, Physics and Archaeology, 2nd Edition, 1974, p. 217; J. Weymouth, Chapter 6, Advances in Archaeological Method and Theory, M. Schiffer, Ed, Vol. 9, 1986, p. 344).
d. The "anatomy of anomalies" should

be studied in relation to these data. This should include 1) an examination of anomalies produced by shipwrecks and non-shipwrecks that have been subsequently tested by excavation, 2) model calculations using realistic sources and simulating the survey methods being used.

e. Within the framework it should be possible to add another magnetometer without a large increase in cost. The two sensors should be run side-by-side at a separation distance roughly comparable to the anticipated sensor to source distance. This should provide valuable information as to the lateral direction of sources as well as some clues as to the size of the sources.

2. Beyond the Existing Methodology

a. Obviously the single most important step beyond the present method would be to reduce the distance between traverses. In fact, the ideal would be to have that spacing equal to the sensor-to-source distance. This is unrealistic, but any reduction in distance would be an improvement.

b. Bruce Bevan's suggestion of using vector measurements of the anomalous field should be examined, first with mathematical model calculations, then with testing, to see what additional information this would provide.

c. I do not think that a base station is needed in most situations. Such a station would be operated continuously on the shore in the general area of the survey. This would provide data for correcting the temporal variations in the magnetic field during the time of the survey. This would eliminate spurious or false anomalies that could arise from brief, sharp spikes in the magnetic field occurring during a survey. This would not happen very frequently, and considering the nature of the data that is obtained, it probably is not urgent. If the expense of establishing a base station is not great, it could be tried, and the results obtained on geomagnetic active days could be examined for any improvement.

Dr. Weymouth obtained his B.S., M.S. and Ph.D. degrees from the University of California, Berkeley (Ph.D. in 1952). He is currently a Professor in the Department of Physics and Astronomy, University of Nebraska. He also holds an appointment in the Anthropology Department at UN. His original field of research was solid state physics, but in 1971 he turned to archaeometry. After some work with x-ray diffraction and x-ray fluorescence, he concentrated particular emphasis on magnetics. He has been involved in surveys in over ten states in the USA, plus surveys in Japan, France, and Hungary.

Resolution of Unidentified Anomalies and Related Matters

Mr. J. Barto Arnold III
Texas Antiquities Committee

Several factors cause a problem relating to the identification of the causes of magnetic anomalies when we are limited to only the magnetometer records in making the interpretation. For the OCS surveys the first and foremost problem is the lane spacing. The 150 m distance required is too great to develop the patterns of readings on neighboring tracks which are essential in recognizing a shipwreck. Many marine archaeologists have pointed this out through the years in various articles and papers including previous MMS-ITM meetings (Arnold 1982 Appendix I). Given this basic flaw in the survey design, the only conclusion one can draw is that any anomaly could be caused by an historic shipwreck. Indeed, cases exist demonstrating that anomalies from substantial shipwrecks might be missed altogether at 150 m track spacing (Arnold 1982 -Appendix I, Arnold 1982 - Appendix II). Nevertheless, there are things to look for in the data that would indicate a more promising anomaly. A large multipeaked anomaly would be indicative of a possible wreck (Arnold 1982 - Appendix III). The trouble is that small single peak anomalies cannot be discounted due to the overly wide lane spacing. And, of course, a multipeaked anomaly could just as possibly be caused by a complex assemblage of modern debris.

Even assuming adequate coverage by close survey tracks it may be that there are too many independent variables to ever be completely sure about anomaly causes without physical visual inspection. The orientation of an object in the vertical and horizontal planes relative to the earth's field causes variation in the anomaly and, therefore, the magnetometer strip chart signature. So does the direction of the sensor as it crosses the object or the anomaly. There are also indications that anomalies produced by historic wrecks may not be detectable at as great a distance as one would predict from the inverse cube rule (Arnold, in press-Investigation of a Civil War Anti-torpedo Raft - Appendix II).

It must be said, however, that an experienced marine archaeologist <u>can</u> and does develop a sense of which anomalies look more promising than others.

To improve this situation there is at least one step that could be taken immediately. The section of magnetometer strip chart showing every anomaly reported in an OCS-CRM report should be illustrated. The same is true for side scan targets and subbottom profiler features. The reports would then become useful. The data analysis could be easily checked. In the past, original remote sensing data has not been archived like other archaeological data must be. Now many survey and oil companies have disappeared due to the decline of the domestic oil and gas industry. What has become of the data gathered by those companies? I fear that much of the data has been disposed of and, therefore, can never be reanalyzed or rechecked.

An urgent effort to salvage and retrieve the data gathered by now-defunct firms should be a top priority of the MMS.

In addition to this new report requirement, there should be an additional new requirement to archive a legible copy of all data with the MMS.

Another idea productive of a better interpretive situation vis-a-vis magnetometer strip chart data would be to gather the anomaly records of sites that have subsequently been ground-truthed by diver examination and/or test excavation. An example of a paper presenting such data is presented in full in Appendix III (Arnold 1982). Many underwater archaeologists have such data. It should be systematically gathered by the MMS or a contractor and then analyzed.

A minor matter that could easily be improved involves the references required for use in preparation of OCS-CRM reports (cited in Sieverding letter of 17 July 1984 - (LE-51 LE-2)). A number of additional later publications than the Calusen and Arnold article cited are included in Appendix II. These should be added along with others by other authors.

I noticed in the advanced material for this meeting that a copy of one of the Archaeological Report Reviews prepared by the MMS staff archaeologists was sent to the appropriate SHPO. Is this done regularly, and is a copy of the report itself sent? They should be.

In conclusion, current OCS survey lane spacing requirements present an insurmountable barrier to better interpretation of the magnetic records. There may be too many independent variables to ever get very far with or be very confident of interpretations based on the magnetometer alone. There are, nonetheless, some actions that should be taken to immediately vastly improve the reports. A gathering and analysis of anomaly signatures which have subsequently been ground-truthed would be a big step toward seeing what can be done and how far we can go with our interpretations and the confidence level appropriate in those interpretations.

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Arnold, J. Barto, III, Tom Oertling and Herman A. Smith. 1986. Investigations of a Civil War Anti-torpedo Raft on Mustang Island, Texas. International Journal of Nautical Archaeology Academic Press, Inc., New York and London.

J. Barto Arnold III is a native of San Antonio, Texas. He received his B.A. and M.A. in anthropology/archaeology from the University of Texas at Austin. He is the State Marine Archaeologist for Texas and has served in that position since 1975.

An Analytical Consideration of Three Interpretative Anomaly Parameters - Amplitude, Signature, and Duration

Dr. Ervan G. Garrison
Texas A&M University

A set of magnetic survey data taken with high precision was evaluated using these three parameters. Typically used in Minerals Management Service (MMS) standards for evaluatory purposes, these parameters were analyzed for their relative discriminatory power in characterizing magnetic anomalies. Based on the results of the study, only one--duration--was instrumentally significant over survey transects a hundred meters distant from the anomaly source: in this case, a 19th century historic shipwreck.

EXPERIMENTAL CONDITIONS

A set of magnetic survey data representing six separate transects over a 19th century shipwreck was analyzed for the relative discriminatory power of the three parameters--amplitude (intensity), signature (shape) and duration (period). The data were obtained under optimized conditions of environment and survey. Every attempt was made to maximize the precision of the data in terms of repeatability for survey and instrumental conditions over the study. The anomaly was a well-known and diver-surveyed Civil War shipwreck, the Will O' The Wisp, lying 300 meters off Galveston Island, Texas, in three meters depth of water.

A total of six survey transects, one directly over the wreck and thence out to 150 meters, were run. The data appear in Tables 10.1, 10.2, 10.3, 10.4, 10.5 and 10.6 and represent a sequence of survey lines of 0, 50, 75, 100, 125 and 150 meters distance, respectively, from the wreck. These data were evaluated graphically and numerically for the discriminatory value as regards the characterization of a magnetic anomaly by amplitude, signature or duration.

ANALYSIS AND RESULTS

1. Amplitude -- The maximum intensity of the anomaly was scaled to the earth's field value for that time and plotted versus distance (in meters) from the wreck. Table 10.7 shows these values.

   The data show an expected fall in the intensity, roughly on the order of magnitude, expected for relation of amplitude to the inverse cube of the distance. Intensity falls markedly after 50 meters.
2. Signature -- These data were graphically analyzed at the same scale, +3000 to -3000 nanoteslas (lines 1-6), and a scale of +50 to -50 nanoteslas for lines 2-5. The key element examined was signature shape in the relatively scaled lines. Inclusion of lines 1-6 data showed the large dipolar signature of the line 1 anomaly at the expense of the clear visualization of the anomaly on lines 2-6. The removal of the line 1 trace allowed a better appreciation of these signatures at an equivalent scale.

   Individually, scales were adjusted to maximize shape discrimination, and each line's signature was evaluated.

   The results are summarized in Table 10.8. The results show delineation of a repeatable signature up to 50 meters. The signature at 75 meters is clearly discernible, but showed little similarity to that seen on lines 1 and 2.
3. Duration -- Again plotted graphically, duration of the anomaly was scaled from first detection of a consistent instrumental deflection to the loss of same. The total time of the anomaly was plotted as the duration and is shown in Table 10.9.

   Examined statistically, there was no significant difference between the values seen for duration over lines 1-4. Taken with the values for lines 5 and 6, the fall-off in the value of duration is significant at the .95 level.

CONCLUSIONS

Of the three variables examined,

1. Amplitude was found to be not diagnostic after 75 meters.
2. Signature repeatability was not observed after 75 meters.
3. Duration was observed at the same level of repeatability at 100 meters.

Duration was found to be the most reliable variable in detecting the anomaly over distance.

Dr. Ervan G. Garrison is an archaeologist and a lecturer and associate research scientist of civil engineering at Texas A&M University. His research interests include the application of geophysical instrumentation to the study of archaeological problems onshore and offshore.

Response to a Problematic Approach to Resolution of Unidentified Magnetic Anomalies

Mr. Allen R. Saltus, Jr.
Southeastern Louisiana University

Archaeologists for the Minerals Management Service (MMS), Gulf of Mexico Region have been reviewing magnetometer data and have proposed to use analytical factors in an attempt to discriminate between historic shipwrecks and modern debris. The analytical factors used for this interpretive framework include

1. Anomaly amplitude, in gammas.
2. Signature width and/or duration in time.
3. Signature asymmetrical characteristics (i.e. dipole and monopole).
4. Sensor height above seafloor.
5. Associated anomaly occurrence (anchorage, shipping fairway, military warning areas, gas- and oil-producing facilities and pipelines).
6. Anomalies corresponding with geological features.

The MMS archaeologists should be commended for their attempt to utilize all available data to the fullest, but the above criteria should not be used in formulating a final determination as to the cause of any magnetic occurrence. In doing so, they could be writing off cultural resources without knowing anything of their nature or significance. However, given sufficient data, the above factors could be useful for planning purposes. The only method of determining cause and significance of magnetic data is through ground-truthing, i.e., diver verification, underwater television and, sometimes, side scan sonar. This statement is based on the following discussion of survey methodology used to gather this magnetic data and the seven factors used by the MMS archaeologists.

The magnetic data gathered to fulfill the MMS guidelines is generated at 150 meter (492.39 feet) lane spacings. Using this methodology, no known pre-World War II watercraft is guaranteed to be detected. Actually most vessels have less than a one in four (25%) chance of being located. Smaller watercraft have less than a one in five (20%) chance of being located. Table 10.10 is a list of selected magnetic anomalies for which we have fully executed magnetic contour maps of magnetic source areas and amplitudes. The table includes single magnetic sources, multiple magnetic sources, and wrecks. The table lists the height of sensor from the object(s) being detected, size of object(s) being detected, magnetic area being magnetically affected at that sensor height, and maximum magnetic inflection produced by the object(s) being detected. At 150 meter lane spacing, the survey can only be considered an exploratory or sample survey from which further investigations can be determined and/or planned, and budgetary needs established for the next phase of investigation (Murphy 1980; Murphy and Saltus 1981). The MMS archaeologists are attempting to short-cut this process using analytical methods which do not seem to have any acceptable degree of significance or reliability regarding their criteria for differentiating debris from shipwrecks.

The seven MMS criteria for determining wreckage from modern debris using the magnetic data generated at these line spacings all have varying degrees of problems. These problems will become apparent by discussing each criterion's limitations, using the table of selected magnetic anomalies and other pertinent magnetic examples.

The anomaly's amplitude, in gammas, is a function of both the distance of the sensor from the object(s) being detected and the chance occurrence of the transect over the magnetic field. The amplitude is not only determined by the distance of the sensor head to the magnetic source, the mass of the object, and the magnetic quality of the magnetic source, but also by the magnetic sources orientation in the earth's magnetic field. This last factor has particular importance for linear objects. If the linear object is lying in an east/west direction opposed to a north/south direction, then the area below the earth's ambient magnetic field (magnetic low) could increase and constrict the area above the earth's magnetic field (magnetic high), thus making the detection of the "full" magnetic amplitude even harder to detect even if closer lane spacing were used. The chance of the transect passing in the area to record the maximum magnetic high and low area is far greater than the chance of detecting the material itself. In reviewing Table 10.10, it is apparent that single objects can produce a far greater and sometimes smaller magnetic amplitude than some shipwrecks. Without knowing over what portion of the magnetic field the transect was run and how far the sensor is from the source, the size of the mass cannot be determined, much less whether the mass is a shipwreck or debris.

The signature width and/or duration in time may also be a function of chance depending upon where the survey transect crossed the magnetic field along with the unknown factors of: (a) orientation of the object(s) within the earth's magnetic field; (b) magnetic quality or qualities of the material being detected; and (c) the accumulative magnetic effect of the association and orientation of cultural material to the survey transect. An examination of the selected magnetic anomalies in Table 10.10 indicates an apparent spatial overlap in the size of the magnetic field areas produced by single and multiple objects, by multiple objects and shipwrecks, and by single objects and shipwrecks.

Signature asymmetrical characteristics (i.e., monopole or dipole) are, again, a function of chance determined by location of the transect over the magnetic field, orientation of the source of the magnetics, and nature of the source single object, multiple objects, orientation and association of these objects. In the case of the Star of the West (Saltus 1976) and the schooner James Stockton (Saltus 1985) there are areas below the ambient magnetic field on either side of an area of above the ambient readings. If on a single pass, one of these magnetic low areas were encountered there would be no way of anticipating, predicting, or knowing the nature of the total magnetic area, and it would have to be classified as a monopole when it is neither a monopole or a dipole but a complex magnetic anomaly area. Also there would be no way of determining on which side of the magnetic low (below ambient magnetic field) the magnetic high (above the magnetic ambient field) is located as in the cases of the two above mentioned wrecks.

Sensor height above the seafloor as a criteria is also a function of sensor distance from the magnetic source. If there is collaborating data such as a feature on the side scan sonar record, then analytical interpretation may be possible, but using the magnetic data alone, there is no way to know the sensor-to-magnetic-source distance, therefore, making any type of analysis futile for the above-mentioned rationale regarding amplitude.

Associated unidentified magnetic anomaly occurrences which may be located in anchorage areas, shipping fairways, military warning areas, and gas and oil field and pipeline production areas, represent a broad interpretative category. Gas and oil field pipeline production areas provide an existing magnetic anomaly data base of large and/or liner magnetic fields represented by well heads, platforms and pipelines and oil field platforms which could very easily mask historic shipwrecks. Elimination of anomalies related to shipping fairways could also eliminate possible shipwrecks lying in one of the high wreck probability areas.

Anomalies corresponding with geological features can also mask the presence of cultural material when viewed on a single pass. When the magnetics of the steamer Spray, 1852 construction date, is examined it is apparent that its magnetic field is incorporated with the magnetic field caused by pyrite nodule refuse. Only through a magnetic contour map is the vessel apparent (Saltus 1982). Hematite nodules found in remnant stream channels could conceivably produce low magnetics (J. Harding, personal communication). These magnetics could be within the magnetic amplitude and spatial area range of smaller shipwrecks. Drainage channels in some forms of clay with magnetic qualities have been observed producing 15 to 20 gamma anomalies (D. Bryant 1986). This too could be mistaken for a shipwreck using the MMS lane spacing.

There is no apparent degree of significance to any of the MMS criteria to differentiate debris from shipwrecks. Any such determination is subject to probability and chance, inherent in both the present methodology and the nature of magnetics as it applies to cultural material and, more specifically, multiple cultural material which occur in shipwrecks. If all the variables for interpretation were known, i.e., magnetic moments of the material(s) causing the anomaly, orientation of this material, masses of this material, distance of this material from one another, and the magnetic sensor head, etc., then we could better address the problem as to whether the nature of the magnetics was caused by debris or shipwreck. In almost all cases the anomalies, would have to be ground-truthed even if this agency were to use the 30-meter lane spacing developed by another federal agency, the National Park Service, as adequate for their needs to protect and manage cultural resources (Murphy 1982). Examples of magnetic conflicts between debris and shipwreck occur in fully mapped and contoured magnetic areas. An archaeological river landing site, 16EBR68, produced significant magnetic anomaly areas all of which upon diver investigation produced modern trash and debris while another river landing site, 16LV71, produced one anomaly which was considered relatively less significant than those produced at 16EBR68. Upon diver investigation, this less significant anomaly revealed three watercraft. A keeled vessel, scow barge, and section of a raft, were found, all more or less lying in a pile (Saltus 1986). A small coastal vessel found in the Wando River has less magnetic spatial area and magnetic amplitude than an anchor found in the same survey. Both of these historic materials were magnetically dwarfed by a World War II naval refuse, debris, located and diver identified (Watts 1979).

For the above reasons, it is hoped that the criteria established by the MMS archaeologists will not be used. To do so could create a situation in which a federal agency may write off significant cultural resources by using both an unacceptable database and manipulating this data using criteria which do not have an acceptable degree of reliability or significance. Using this approach would lend credence to the term used by critics of this program, "Archaeofolly."

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Allen R. Saltus, Jr. obtained a B.A. in history in 1967 from Florida Atlantic University, Boca Raton, Florida, and a M.S. in anthropology in 1972 from Florida State University, Tallahassee, Florida. He has worked for the Florida Department of State, Division of Archives, History and Records Management, Bureau of Historic Sites and Properties, Underwater Archaeological Research Unit for seven years and for Gulf South Research Institute for five years. In May 1978, he founded his own firm, Archaeological Research and Survey. ARS has consulted with numerous local, state, and federal agencies as well as with private firms. Mr. Saltus joined the faculty of Southeastern Louisiana University in 1984. He holds an appointment as researcher-in-residence in the Center for Regional Studies and is Curator of Collections. During this period, he has received three grants to study the submerged cultural material in the Maurepas Basin.

Geophysical Search Techniques for Distinguishing Shipwrecks from Trash

Dr. Bruce W. Bevan
Geosight

There are several possible ways of distinguishing old shipwrecks from recent trash on the sea floor. Several ideas are presented here; these ideas are not necessarily original and may not be practical.

It is possible that the AC magnetic properties of old iron are different from modern steel. Steady magnetic fields would almost surely not aid this distinction.

The depth of iron below the sediments could approximate its age. Vector magnetic measurements along a single tow line might allow a determination of the distance of iron below the sensor.

If individual iron artifacts or clusters could be detected, identification of a shipwreck would be more certain. The spatial resolution of the magnetic survey would probably have to allow separation of objects spaced by 1-2 m.

High electrical resistivity could be associated with earlier wrecks having wood and ballast stone. This could be measured with a drag cable resistivity system, electromagnetic induction, or magnetotellurics. A single-source, multiple-sensor electromagnetic system could give high resolution measurements of conductivity and magnetic susceptibility.

Magnetic surveying has been a successful procedure for locating shipwrecks (Arnold and Clausen 1975; Hall 1972), but many false indications from modern discarded iron are also found. It is possible that changes from current survey techniques could increase the reliability of distinguishing shipwrecks from trash on the sea floor.

The high spatial frequency caused by the many iron artifacts at a wreck could aid its identification; the depth of burial within the sediments could be another guide. A wreck could also contain nonmagnetic, but conductive, metals and could have electrically resistive material such as ballast stone. It is also possible that old iron can be distinguished from recent steel trash by differences in magnetic properties resulting from differences in chemical composition and metallurgical structure.

Current magnetic search procedures have a sensor height of 3-6 m above the sea floor and a measurement interval of about 1 m. If the sediment surface is flat and unobstructed, it could be possible to lower the magnetic sensor and decrease the measurement spacing to allow objects 1-2 m apart to be separately resolved.

Triaxial vector magnetic measurements have greatly aided the search for magnetic materials from boreholes (Silva and Hohmann 1981). These same procedures could be applied to estimating the depth of iron in the sediment and, therefore, could suggest its age.

Handheld metal detectors have been applied to search for artifacts at shipwrecks (Colani 1966), but other instruments could be more suitable for large area investigation of insulators and conductors. Electrical resistivity measurements can be made on the sea floor by dragging an electrical cable with several connection points exposed to the seawater (Orellana 1982, p. 386; Terekhin 1962). Magnetotelluric surveys typically measure to a great depth (Moose 1981, Gregori and Lanzerotti 1979), but might be suitable for this survey. Other techniques for measuring sea floor conductivity are also possible (Bannister 1968, Coggon and Morrison 1970).

Old iron could be significantly different from modern iron in its magnetic properties. An electromagnetic induction system which measures the electrical conductivity of the sea floor could also determine its AC magnetic susceptibility. Measurements at one or more frequencies might allow different ferrous materials to be distinguished. With the vector magnetometer mentioned above, it could be possible to separate the remnant and induced magnetization of iron objects by determining the net direction of polarization. The ratio of remnant to induced magnetization, the Koenigsberger ratio (Parasnis 1979, p. 13), might distinguish old iron from modern steel.

While all of the ideas mentioned here have been applied in geophysics, further investigation will be needed to see if any of them could really aid the geophysical search for historic shipwrecks.

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Bruce Bevan is a geophysicist who does terrestrial surveys for archaeological and geotechnical engineering applications. Through his company, Geosight, he applies magnetics, electromagnetics, and ground-penetrating radar to high resolution, shallow depth surveys. He has an M.S. degree in electrical engineering and a Ph.D. in geology.

Table 10.1

Line #1 - Run Directly Over Wreck of Will O' Wisp*

#	Amplitude (nanoteslas,nt)	Time (sec)	Duration (sec)
1	0	0	0
2	0	10	0
3	0	20	0
4	0	30	0
5	0	40	0
6	+6	50	10
7	+7	60	10
8	+7	70	20
9	+18	80	30
10	+56	90	40
11	+216	100	50
12	+2659	110	60
13	-311	120	70
14	-122	130	80
15	-33	140	90
16	-14	150	100
17	-6	160	110
18	-3	170	120
19	-4	180	130
20	0	190	0
21	0	200	0

*Tow depth: surface
Target depth: 3 meters
Tow speed: 3.5 knots
Sensitivity: ± 1 nt

Table 10.2

Line #2 - 50 Meters South of Will O' Wisp

#	Amplitude (nanoteslas,nt)	Time (sec)	Duration (sec)
1	0	0	0
2	0	10	0
3	0	20	0
4	-1	30	0
5	-4	40	10
6	-9	50	20
7	-9	60	30
8	-3	70	40
9	+18	80	50
10	+48	90	60
11	+46	100	70
12	+25	110	80
13	+18	120	90
14	+11	130	100
15	-4	140	110
16	-3	150	120
17	-4	160	130
18	-5	170	140
19	0	180	0
20	0	190	0
21	0	200	0

Table 10.3

Line #3 - 75 Meters South of Will O' Wisp

#	Amplitude (nanoteslas,nt)	Time (sec)	Duration (sec)
1	0	10	0
2	0	20	0
3	0	30	0
4	0	40	0
5	-2	50	0
6	0	60	10
7	0	70	20
8	-3	80	30
9	-5	90	40
10	+3	100	50
11	+2	110	60
12	+9	120	70
13	+11	130	80
14	+8	140	90
15	+8	150	100
16	+6	160	110
17	+4	170	120
18	+7	180	130
19	+5	190	140
20	+3	200	150
21	0	210	0

Table 10.4

Line #4 - 100 Meters South of Will O' Wisp

#	Amplitude (nanoteslas,nt)	Time (sec)	Duration (sec)
1	0	10	0
2	0	20	0
3	0	30	0
4	0	40	0
5	0	50	0
6	-2	60	0
7	-5	70	10
8	-9	80	20
9	-4	90	30
10	-2	100	40
11	-1	110	50
12	0	120	60
13	-3	130	70
14	0	140	80
15	-1	150	90
16	0	160	100
17	+1	170	110
18	+1	180	120
19	+1	190	130
20	+2	200	140
21	+1	210	150
22	+1	220	160
23	0	230	0

Table 10.5

Line #5 - 125 Meters South of Will O' Wisp

#	Amplitude (nanoteslas,nt)	Time (sec)	Duration (sec)
1	0	0	0
2	0	10	0
3	0	20	0
4	0	30	0
5	0	40	0
6	+6	50	10
7	+7	60	10
8	+7	70	20
9	+18	80	30
10	+56	90	40
11	+216	100	50
12	+2659	110	60

Table 10.6

Line #6 - 150 Meters South of Will O' Wisp

#	Amplitude (nanoteslas,nt)	Time (sec)	Duration (sec)
1	0	10	0
2	0	20	0
3	0	30	0
4	0	40	0
5	0	50	0
6	+1	60	10
7	+2	70	20
8	0	80	30
9	+2	90	40
10	-1	100	0
11	0	110	0
12	0	120	0
13	0	130	0
14	0	140	0
15	0	150	0

Table 10.7

Amplitude Values

Line #	Amplitude (nanoteslas)	Distance (meters)
1	2659	0
2	46	50
3	11	75
4	9	100
5	4	125
6	2	150

Table 10.8

Signature Values

Line #	Signature	Distance (meters)
1	dipolar	0
2	dipolar	50
3	monopolar	75
4	dipolar(?)	100
5	monopolar	125
6	monopolar	150

Table 10.9

Duration Values

Line #	Time (sec)	Distance (meters)
1	2659	0
2	130	50
3	140	75
4	150	100
5	70	125
6	40	150

Table 10.10

Selected Magnetic Anomalies

SINGLE OBJECTS

Sensor Height in feet	Object	Size of Object in feet	Magnetic Area in feet	Inflection in Gammas
3	cable	70 x 1 in.	173 x 89	380
15	camshaft	20 x 2 in.	50 x 45	45
4	cast iron soil pipe	10; 100 lbs.	65 x 45	1407
4	anvil	150 lbs.	26 x 26	598
4	kettle	22 in. dia.	26 x 26	59
16	anchor	6 foot shank	270 x 80	30
3	pipe	3 in. dia.	45 radius	550*
8	pipe	20 x 10 in. dia. 10 in. dia.	160 x 90	180

MULTIPLE OBJECTS

Sensor Height in feet	Object	Size of Object in feet	Magnetic Area in feet	Inflection in Gammas
5	pipe & bucket	8 x 1 in. dia.	60 x 50	250
15	cable & chain	60 in. @	50 x 40	30
5	burn pile charcoal	8 dia. x 3 in.	40 x 30	20
6	burn area charcoal	30 x 20 x 1	120 x 70	15
10	pyrite	noduals	350 x 150	310
10	metal stairs & "I" beam	14 x 3 x .8 10 x 1	150 x 140	100
15	scattered ferrous metal	90 lbs.	110 x 90	100
20	WW II naval refuse (paint buckets, 55 gal drums, mop pails, cable, etc.)	mixed	550 x 450	361

Table 10.10 (cont'd)

Selected Magnetic Anomalies

WRECKAGE

Sensor Height in feet	Object	Size of Object in feet	Magnetic Area in feet	Inflection in Gammas
4	Star of the West ocean going side-wheel steamer	228 x 32	350 x 350	7650
16	Wando River wreck coastal trader	90 x 20	250 x 150	35
8	gas sternwheel boat	50 x 10	200 x 140	450
12	Lotawana river steamboat	180 x 47	350 x 300	310
20	Constante merchant sail	128 x 26	250 x 150	60
10	Steamer Spray	140 x 19	180 x 160	520
8	James Stockton schooner	55 x 19	130 x 90	80
20	CSS Tuscaloosa ironclad	150 x 40	300 x 200	4000
3	segment of a shrimp boat	27 x 5	90 x 50	350
12	keeled barge	92 x 22	250 x 250	180
8	river trader sail	44 x 13	120 x 100	100
12	1840's tow boat	65 x 13	110 x 60	110

All values in feet unless otherwise noted. * Denotes monopole; all other anomalies are dipolar (A.R. Saltus 1986).

PHYSICAL OCEANOGRAPHY OF THE WESTERN GULF OF MEXICO

Session: PHYSICAL OCEANOGRAPHY OF THE WESTERN GULF OF MEXICO

Co-Chairs: Dr. Murray Brown
Mr. Joe Perryman

Date: November 6, 1986

Presentation Title	Speaker/Affiliation
Physical Oceanographic Studies of the Western Gulf of Mexico: Session Overview	Dr. Murray Brown Minerals Management Service Gulf of Mexico OCS Region
Overview of the Western Gulf of Mexico Physical Oceanography Study	Dr. Evans Waddell Science Applications International Corporation
The Interaction of a Loop Current Ring with the Continental Slope in the Western Gulf of Mexico	Dr. David A. Brooks and Mr. Frank J. Kelly Texas A&M University
MMS Drifting Buoy Studies in the Gulf of Mexico	Dr. James K. Lewis and Ms. Maria R. Giuffrida Science Applications International Corporation
Remote Sensing Studies in the Western Gulf of Mexico	Dr. Fred M. Vukovich Research Triangle Institute
Fresh Water on the West Louisiana and Texas Shelves	Mr. Scott P. Dinnel and Dr. William J. Wiseman, Jr. Louisiana State University
Circulation on the Louisiana/Texas Shelf	Mr. John D. Cochrane and Mr. Frank J. Kelly Texas A&M University
Drifting Buoy Studies in the Western Gulf of Mexico	Dr. George Z. Forristall Shell Development Company
Hurricane-Generated Currents on the Continental Slope	Mr. Cortis Cooper Conoco R&D
Circulation Modeling Progress: (A) The Topographic Intersection Problem, and (B) Thermodynamics	Dr. Alan J. Wallcraft JAYCOR, Inc.
Plans for Future Work in the North Central Gulf of Mexico	Dr. Evans Waddell Science Applications International Corporation

Physical Oceanographic Studies of the Western Gulf of Mexico: Session Overview

Dr. Murray Brown
Minerals Management Service

The Offshore Studies Program of the Minerals Management Service (MMS) includes a very active series of physical oceanography studies, concentrating on two areas of work: field measurements and numerical circulation modeling. Since January 1983, the Gulf of Mexico OCS Region has been supporting a five-year cycle of field efforts designed to characterize the circulation in the southeastern Gulf (Years 1, 2 and 4), the northwestern Gulf, offshore Texas (Year 3), and the north-central region, offshore Louisiana (Year 5). This session focused on the results of the Year 3 work, which concluded in May 1986. Other, closely related work, including the coordinated modeling study and independent work by oil companies, has always been taken into account in the planning of the MMS contracts; presentation by investigators from these other studies were included. By chance, two landmark papers have recently appeared in the journal literature synthesizing much existing data on the adjacent continental shelf. The authors of these papers were included in the program, as their findings relate directly to the recent results of the MMS contractor. The presentations concluded with a brief overview of planned field measurements for Year 5.

Dr. Evans Waddell of Science Applications International Corporation, the major contractor for field measurements, opened the meeting with an overview of the various data sets collected during the Year 3 schedule, lasting from June 1985 to May 1986. They included subsurface currents, temperature, and pressure at a mooring array in the northwestern Gulf, regional-scale hydrographic surveys using both ship and aircraft platforms, satellite-tracked Lagrangian drifters, satellite thermal imagery, and extensive ship-of-opportunity measurements of temperature. The principal focus of the work was to capture the sequence of events following the breakoff of a major anticyclonic (clockwise circulation) eddy from the Loop Current, i.e., the westward movement of the eddy, its interaction with the western boundary, and the possible generation of other closed circulation features. Fortunately, an eddy did form during the subject period, and its trajectory took it to the area of the MMS moorings. Through the close cooperation of the Mexican Navy it was possible to gather data throughout the interaction period.

Dr. David Brooks and Mr. Frank Kelly of Texas A&M University gave a joint presentation on the results of both the hydrographic work and the current meter data. The eddy, which detached from the Loop Current in early July 1985, reached the general area of the moorings by late October, when it was estimated to have a roughly circular shape with about a 4-degree diameter. By mid-November the eddy had begun to interact with the shelf along its northwestern side. The formation of weak cyclones (counterclockwise circulation) was indicated, with an intermediate front, similar to those observed by earlier workers. A drifting buoy that had been placed in the eddy in July exhibited a trajectory tightly coupled to the geometry calculated from hydrography. By February 1986, the eddy was highly distorted due to shelf-edge interaction, and the cyclones were noticeably more intense. In subsequent surveys, the original anticyclone and its major cyclone partner had moved to a more southern location, an action predicted by previous modeling work. It is apparent from the results of this study that the dispersion products of Loop Current rings play an important role in determining the time-varying and complicated current patterns over the continental slope in the western Gulf of Mexico. An improved understanding of the eventual decay of Loop Current rings is thus of central importance to such practical issues as pollutant trajectories, biological productivity, and resource management in the western Gulf.

Dr. James Lewis of Science Applications International Corporation reported on the analyses he has performed, with Maria Giuffrida, of drifting buoy trajectories from two deployments attempted in the summer of 1985. The first of the two was intended to be deployed within a structure that appeared to be a recently detached eddy, in June 1985. Both satellite sea-surface temperature data and ship-of-opportunity data strongly indicated complete separation, but the buoy's subsequent movement was toward the southeastern Gulf, or the main body of the Loop Current. The buoy's later movements were of great interest, as it remained within the Loop Current for six complete anticyclonic revolutions before exiting the Gulf in late summer. The trajectory of the buoy appeared to reflect a regrowth of the Loop Current, initiated within a closed anticyclonic "kernel" off northwest Cuba. Lewis reflects that the time-scale of the regrowth activity appears to be much shorter than the approximately one-year cycle often recognized in the literature.

The path of the second buoy, deployed in July 1985, was clearly related to the movement of the eddy, as it described smooth anticyclonic loops toward the west. That buoy was joined within the eddy, during the winter of 1986, by a previously deployed buoy that had strayed from the southwestern Gulf. The paths of the two buoys within the eddy, as it interacted with the western Gulf slope and shelf, closely followed hydrographic contours.

Dr. Fred Vukovich of the Research Triangle Institute reported on the results of his analyses of remote imagery, performed both to aid in logistics planning during the field measurements phase of the above work and to provide a unifying element in the synthesis of the hydrographic, trajectory, and current meter datasets.

NOAA-9 infrared data were integrated with _in situ_ data in the period November 1985 to March 1986 to study the near-surface effects of warm ring interacting with the western slope wall of the Gulf of Mexico. The satellite data indicated that a massive but narrow, zone of relatively warm water stretched from about 24°N to about 28°N along the far western portion of the Gulf of Mexico when the ring reached the western wall. The satellite and _in situ_ data suggested that there was a transport of heat, mass, and momentum northward and southward when the ring reached the wall. Part of the northward transport may be due to the interaction of this ring with another ring that current meter data and the NOAA satellite data suggested to be located in the northwestern corner of the Gulf. The existence of this ring has not been confirmed to date.

Mr. Cort Cooper of Conoco Research and Development reported on the results of his work modeling hurricane-generated currents on the continental slope. His model is a layered formulation, utilizing 0.2-degree resolution over the entire Gulf, time steps on the order of a minute, and realistic topography, excepting the shallow shelf. Using existing data from Hurricanes Eloise and Frederic, Cooper has achieved favorable comparisons between his own hindcasts and the archived data. At one location the model reproduced 90% of the observed variance. Three major current responses were observed in the model simulations: convergence zones, coastal jets, and shelf waves. The first two exhibited typical velocities on the order to two knots and disappeared within 10-20 days. The third type had peak velocities of about one knot.

Dr. George Forristall of Shell Development Company presented the results of many drifting buoy trajectory analyses, including industry and Federal deployments. His data include striking examples of buoy motion within anticyclonic eddies, along the Loop Current front, and within the Loop Current, and the occasional translation of a buoy into an eddy from a remote location. This later behavior is not now thought to be unusual, as it has occurred several times. Dr. Forristall emphasized that nearly all buoy deployments yield valuable information, even when their initial target has not been realized. The data shown demonstrate that in a basin the size of the Gulf of Mexico, a relatively small number of drifting buoys can give a reasonably clear view of the major features of the circulation. Compared to other sources of data, they are also quite economical.

Dr. Bill Wiseman of Louisiana State University reported on an analysis he has performed, with Scott Dinnel, of the freshwater balance on the western Louisiana/Texas shelf. They obtained a database of salinity measurements performed in this area in 1963-1965 and were able to elucidate the effects of riverine discharge on regional hydrography. The freshwater volume on the shelf, estimated for each data set, exhibits an annual cycle that is dominated by the spring flood of the Mississippi and Atchafalaya Rivers. During the winter, shelf freshwater content is low, with the highest content appearing as a discontinuous band along the inner shelf. In summer, an isolated high-content region is present in the center of the shelf. This high content region dissipates and the pattern migrates toward the southeast in the late summer. By late fall, the winter distribution pattern is again present. Due to the non-climatological nature of two of the study years, however, these results may not be applicable to periods of very large river discharge.

Dr. John Cochrane of Texas A&M University reported on work he has been doing, with Mr. Frank Kelly, to synthesize various data on the mean circulation on the Texas/Louisiana shelf. West of approximately Cameron, Louisiana, they find that existing current measurements clearly show a strong response of coastal current to the winds. They hypothesize that an anticlockwise circulation (gyre) is set up in this way. The inshore limb of the gyre is the westward or southwestward (downcoast) component which prevails along much of the coast, except in July-August. Because the coast is concave, the shoreward prevailing wind results in a convergence of coastal currents at a location where the winds are normal to the shore, which marks the downcoast extent of the gyre. A prevailing countercurrent toward the northeast along the outer edge of the shelf constitutes the outer limb of the gyre. The convergence at the southwestern end of the gyre migrates seasonally with the direction of the prevailing wind, ranging from Cameron in July to a point south of the Rio Grande in the fall. The gyre is normally absent in July, but reappears in August-September when a downcoast wind component develops.

Dr. Alan Wallcraft of Jaycor, Inc., reported on recent progress in the four-year circulation modeling effort supported jointly by MMS and the U.S.

Navy. A major thrust of the third year program, in progress, is the development of a layered ocean model that will allow layer interfaces to effectively intersect the bottom topography, thus, removing what is probably the most serious deficiency of the model, namely that the topography is m. When intersection occurs in a conventional layer model, the layer thickness becomes negative which is clearly unphysical any leads to unrealistic results. If the situation persists, catastrophic failure of the run due to undamped instabilities occur. One promising approach to the layer intersection problem is to insure positive layer thicknesses via 'flux corrected transport' (FCT), a technique that was originally developed for fluid problems with shocks. Two dimensional (x-z) versions of a two-layer hydrodynamic model that uses FCT to allow layers to intersect the bottom have been tested on sections across the Gulf of Mexico on a 0.2 degree grid. Initial tests in three dimensions are in progress for the Gulf of Mexico on a 0.4 degree grid. A fully explicit model's timestep would be controlled by the external gravity wave speed (about 150 m/s), but here the depth averaged flow is treated implicitly so the timestep depends on the internal gravity wave speed (about 3 m/s). The existing ocean model, with topography confined to the lowest layer, treats both external and internal gravity waves implicitly and can use a timestep 3 to 5 times longer than the FCT code.

The second major element of the third year is the addition of bulk layer thermodynamics to the model. The existing model is 'hydrodynamic', i.e., the density in each layer is constant and fixed for all time, with the fixed densities and the density different between layers set to realistic mean values for the Gulf of Mexico. The addition of thermodynamics allows the density to vary in space and evolve with time under the control of an equation of state and a temperature equation, forced by heat fluxes and the density of inflow water. Mixing of denser fluid from the layer below into each layer is also allowed and this can prevent the layer interface surfacing due to upwelling, i.e., the layer gets denser rather than getting thinner. In hydrodynamic models there is no exchange of fluid between layers.

Initial thermodynamic experiments use the simple, one-active, layer-reduced gravity version of the model, which defines the lower layer to be infinitely deep and at rest. This model does not allow topographic steering, but is a useful test bed for more realistic Gulf simulations. Instead of forcing the model with heat flux data, which is still being prepared, the model is required to relax back to a monthly density climatology based on sea surface temperature maps from historical ship observations. The relaxation period is about 360 days in the center of a Loop Current eddy, but is only 90 days over the continental shelf where rapid winter cooling is important.

In the final presentation, Dr. Evans Waddell outlined the data gathering efforts to be supported during the final (fifth) year of the physical oceanographic field measurements program. The general program objective is to develop an appropriate database to be used in isolating and describing the circulation patterns and processes in the study region. An additional program concern involves documenting aspects of the optical properties of the shelf waters and relating these to circulatory patterns.

Measurements and observations to be made or used during this study include

a. Subsurface current/temperature
b. Transmissivity (shelf only)
c. Hydrography and water quality
d. Satellite thermal imagery
e. Satellite tracked drifting buoys
f. Ship-of-opportunity program (SOOP)

In addition, several optional aerial expendable bathythermograph (XBT) surveys have been proposed.

There will be four shelf moorings between approximately 15 m and 150 m (the shelf break) water depths containing current meters and transmissonmeters, as well as three slope moorings in 1000, 1500, and 3000 m of water. In addition, two inverted echo sounders (IES) will be deployed in deep water near and beyond the end of the mooring transect. Gulfwide and study area-specific, satellite imagery will be used during cruise planning and data synthesis. Five to six drifting buoys will be released in various features such as Loop Current eddies and possibly the Loop Current proper to document further dynamic and kinematic characteristics of these oceanographically important features.

Focus for the various members of the scientific team is on processes and environments rather than on types of observations. As such, each principal investigator (PI) or group of PI's will be working with the full range of appropriate and relevant data. Key focus will be on

a. Shelf dynamics and water quality
b. Slope circulation
   - Eddy related
   - Non-eddy induced circulation patterns
c. Sea-Surface temperature patterns
   - Gulfwide
   - North-central eddies
d. Loop Current eddies
   - Lagrangian perspective

At present, the plans call for a 12-month measurement program beginning in early Spring 1987.

In summary, the general period 1985-1986 was one of significant progress in understanding the overall circulation in the Gulf of Mexico, but especially so in the northwestern part of the basin. It is clear that anticyclonic eddies detached from the Loop Current constitute a powerfull mechanism for the transport of heat, salt, and momentum into the western area. The currents measured within these eddies, on the order of one knot or better, are of practical concern to both environmental assessment activities and to oil and gas interests. They have been confirmed to generate "daughter" cold-core and warm-core eddies as they interact with the shelf and slope, with important implications for the nutrient budget in this area. Additionally, the coupling between the northwest Gulf and the southwest quarter, below the U.S.-Mexico border, is now seen to involve both northward and southward movement of eddies. On the shelf, adjacent to these mesoscale events, the circulation pattern, elucidated from both hydrographic and current data, confirms an older hypothesis of convergence offshore Texas.

Dr. Murray Brown received his Bachelor of Science degree in chemistry at Duke University in 1969, and his Licentiate (Ph.D.) in marine chemistry from the University of Copenhagen in 1975. He has worked for the U.S. Army Corps of Engineers in a variety of assignments, and, since 1978, within the Offshore Studies Program, of BLM and MMS. At present, he is project officer for the physical oceanography study series and has special interests in information management.

Overview of the Western Gulf of Mexico Physical Oceanography Study

Dr. Evans Waddell
Science Applications
International Corp.

In 1982, MMS initiated a sequence of regional scale physical oceanographic measurement programs in the Gulf of Mexico. Program Years 1, 2 and 4 emphasized the eastern Gulf while Program Year 3 emphasized the western Gulf. Specifically, the Year 3 program was to focus on processes associated with the interaction of Loop Current (LC) eddies as they migrate generally westward and eventually interact with the slope in the western Gulf. It is important to note that the overall success of this project was dependent on the excellent cooperation and assistance provided by the Mexican Navy.

The primary Year 3 field measurements which were started in 1985 included

- Subsurface currents/temperature/pressure
- Regional hydrographic surveys (ship and plane based)
- Satellite-tracked lagrangian drifters
- Satellite thermal imagery
- Ship-of-opportunity program (SOOP)

The principal investigators and their general area of focus includes

- Dr. David Brooks and Mr. Frank Kelly: Subsurface currents and hydrography
- Dr. James Lewis: Drifting buoys
- Dr. Fred Vukovich: Satellite imagery

The general program design included using thermal imagery and SOOP data to determine when a LC eddy separated. At that time an XBT survey was made and drifting buoys were released in the feature. As it revolved around the LC eddy, the buoys provided not only dynamical information but also helped track the eddy location as it translated westward. Prior to reaching the slope in the western Gulf, a hydrographic survey was made. Subsurface current moorings were deployed to further document circulation patterns as the eddy interacted with the adjacent slope. When the interaction was occurring, a second hydrographic survey was made. During the westward movement and interaction, satellite imagery helped document eddy configuration and position.

Clearly, aspects of the program were dependent upon an eddy detaching at an appropriate time and moving westward along a trajectory which allowed our <u>in-situ</u> instrument placement to provide measurements at appropriate locations within the eddy. Planning paid off. An eddy detached at the beginning of the measurement period and followed a path which resulted in its moving directly into our fixed instrument arrays. All the desired regional surveys were made. Through further cooperation with the Mexican Navy, additional, valuable XBT transects were obtained.

An overview of some of the measurements made is shown in Figures 11.1 and 11.2. The movement of the primary eddy is well documented in Figure 11.1. Its eventual movement into the fixed mooring array is clearly illustrated. Station location for two surveys, one prior to and one following interaction with the slope, are shown in Figure 11.2. In addition to these surveys, supplemental surveys were made.

The results of the Year 3 measurements will provide a unique picture of a LC eddy during the various phases of its life cycle.

Dr. Evans Waddell is Division Manager for Marine Science and Engineering with Science Applications International Corporation (SAIC). AT present, he is also Program Manager for the MMS-funded Physical Oceanography Program in the Gulf of Mexico. He received his Ph.D. in marine science (physical oceanography) from Louisiana State University in 1972. His recent research involvement emphasizes shelf and shallow-water physical oceanographic processes.

The Interaction of a Loop Current Ring with the Continental Slope in the Western Gulf of Mexico

Dr. David A. Brooks
and
Mr. Frank J. Kelly
Texas A&M University

With the collaboration of the Mexican Navy, a comprehensive program was recently begun to study the interaction of Loop Current (LC) rings with the bottom topography of the western Gulf of Mexico. In June 1985, the Mexican naval vessel Altair deployed an L-shaped array of current meter moorings on the continental slope in the western Gulf of Mexico. The array was designed to intercept a westward-drifting eddy or ring after it became separated from the LC in the eastern Gulf. In July, such a ring was seeded by a satellite-tracked drifter. The ring moved approximately westward in deep water along the edge of the Texas-Louisiana slope, and by October, the ring's western limb was interacting with the outermost mooring of the array. Figure 11.3 shows the depth of the 8°C thermal surface, estimated from a limited CTD/XBT survey by R/V Pelican. Also shown are part of the track of the drifter and 3-day averaged currents at several depths from the moorings. The ring structure was judged to be roughly circular, based mainly on the complete drifter tracks. The strong central depression of the 8°C surface is associated with the anticyclonic (clockwise) circulation in the ring that also affected the shallow (300 m) currents at mooring Q and possibly at mooring T.

In November 1985, an AXBT (air-dropped expendable bathythermograph) survey was conducted to determine the state of the ring and its interaction with the bottom topography in the northwestern Gulf. Figure 11.4 shows that by the second week of November the northern and western periphery of the ring's thermal and current structure was distorted over the steep slope. A shoaling or doming of the 8°C surface on the northern edge (and possibly also on the offshore edge) of the ring indicates the formation of weak cyclones (counter-clockwise circulation) in regions of offshore flow into deeper water, as would be expected from simple vorticity arguments. The currents at moorings P and Q reflect an inclined frontal zone between the anticyclone and the northwestern cyclone, with the shallow current at mooring Q associated with the anticyclone and the other currents associated with the cyclone. During November, the drifter was tightly coupled to the circulation in the center of the anticyclone.

By early February 1986, the anticyclone was highly distorted into an ellipse with an aspect ratio of about 2, with major axis oriented northeast-southwest. Both cyclones, especially the northwestern one, were greatly intensified over the intervening 2.5 months, and a third but weaker cyclone can be seen on the south side of the ring. Figure 11.5 shows the 8°C topography determined from a CTD/XBT survey carried out by R/V Altair, with the cooperation of the Mexican Navy. The currents and the drifter track generally reflect the strong anticyclonic circulation of the ring.

Another XBT survey (Figure 11.6) was conducted by R/V Altair in April-May 1986. The 8oC topography shows that the original anticyclone and its initial cyclonic partner moved to a more southern location along the slope. The second, northeastern cyclone affected the currents at moorings P and Q, which were located in the depression separating the two cyclones. The southern mooring T was in the strong front between the anticyclone and the cyclone immediately to its north. Trajectories of two drifters are shown; number 3353 circuited the northern cyclone and number 3378 passed northward along the western edge of the anticyclone. Analysis of the drifter trajectories during February to May suggests that the anticyclone-cyclone pair moved southeastward from its February position and then moved westward again to the position shown in early May. Both the southeastward (offslope) motion and the subsequent onslope motion are predicted by nonlinear models of rings in the western Gulf.

While the analysis of the full current and hydrographic data sets has only begun, it is clear that the combined data sets give an unprecedented history of the life cycle of a LC ring in the western Gulf of Mexico. It is significant that the cyclonic eddies formed as parasitic dispersion products as the ring interacted with the topography of the western Gulf, and that they did not migrate westward in the company with the ring from the eastern Gulf. Rather, the cyclones appeared to form as the ring became elongated over the steep outer slope region, probably due to a combination of vortex stretching in the offslope flow regions and instability of the ring as its aspect ratio exceeded some critical value. While the full complexity of the region has yet to be appreciated, recent model results are basically consistent with the observed cyclogenesis in the ring front and with the subsequent offslope and then southward motion of the ring and its dispersion products.

It is apparent from the results of this study that the dispersion products of LC rings play an important role in determining the time-varying and complicated current patterns over the continental slope in the western Gulf of Mexico. An improved understanding of the processes that control and affect the dispersion and eventual decay of LC rings is thus of central importance to such practical issues as pollutant trajectories, biological productivity, and resource management in the western Gulf.

Dr. David A. Brooks is Associate Professor of Oceanography at Texas A&M University, College Station, Texas. He earned a Ph.D. in physical oceanography from the University of Miami, Florida. His present research interests include field studies of the circulation in the Gulf of Mexico and the Gulf of Maine, and theoretical studies of ocean currents and their instabilities.

Mr. Frank Kelly is an Assistant Research Scientist with the Environmental Engineering Division of the Civil Engineering Department at Texas A&M University. His interests are the circulation of the Gulf of Mexico, the effect and fate of Loop Current eddies in the western Gulf of Mexico, and the dynamics and circulation of the Texas-Louisiana Shelf. He received an A.B. in physics from the University of California, Berkeley, in 1972 and an M.S. in oceanography from Texas A&M University.

MMS Drifting Buoy Studies in the Gulf of Mexico

Dr. James K. Lewis
and
Ms. Maria R. Giuffrida
Science Applications
International Corp.

PROJECT HISTORY

The unique data base used in this investigation enables the identification and kinematic characterization of the mechanisms by which Loop Current (LC) eddies are generated. In the summer of 1985, an attempt was made to put a drifter into a ring about to pinch off from the LC in the Gulf of Mexico (GOM). Argos drifter 3354 was seeded in the ring at 25.9°N, 87.9°W on 18 June 1985. However, the ring had not totally separated from the LC and the drifter remained in the LC proper for approximately three months before leaving the GOM through the Florida Straits. The trajectory of drifter 3354 is shown in Figure 11.7. A second drifter with Argos identification number 3378 was seeded in the original ring at 26.4°N, 89.3°W on 18 July 1985. By that time, the ring had totally separated from the LC. The trajectory of this second drifter is also given in Figure 11.7. These Lagrangian observations, together with XBT data from the eastern GOM during May - September 1985 and weekly SST charts of the entire GOM, comprise the data base used in this investigation. The Lagrangian data sets obtained from the two drifters provided a unique opportunity for simultaneous investigations of the kinematics of the LC as it extends northward and of a LC ring, the final product of such an extension.

PROJECT STATUS

Drifter trajectories were drawn on weekly SST contour charts and used, together with XBT data, to gain insight into the location, structure, and motion characteristics of the LC and ring 3378. The kinematics of the LC and ring 3378 were compared for the time period during which they coexisted. The kinematics of the ring before and after it broke off from the LC were also investigated. The rotational characteristics of the LC and the ring were determined by kinematic analysis of the two drifter paths.

SIGNIFICANT RESULTS

One of the most interesting points indicated by the drifter data concerns the anticyclonic characteristics of the LC. The drifter data showed that, at the same time that ring 3378 was breaking off from the LC, another anticyclonic feature existed in the southern portion of the LC off the northwest coast of Cuba. Time histories of position data showed that this flow field moved only slightly northwest at first while ring 3378 was still connected to the LC. After ring 3378 pinched off, however, the vortex pushed northwestwardly to about 26.5°N. Figures 11.8, 11.9 and 11.10 clearly indicate this northwestward progression with time, and show that the rotational field is at this point an integral component of the LC. The LC had now become reconfigured for another ring breakoff within only 1.5 months after the previous ring had separated. It is, therefore, proposed that a new generation mechanism has been identified for the vortices which eventually can become LC rings in the GOM. The northward flow of the LC west of the tip of Cuba, together with its southeasterly flow along the north-central coast of Cuba, will produce negative vorticity off Cuba's northwestern shore. Vortex generation would, therefore, be induced by lateral shearing all along the northwest to the north-central coast of Cuba. This realization, together with results of the kinematic analyses, indicates that the basic kinematic characteristics of GOM rings are established as the LC pushes northwestwardly off the shore of Cuba. If it takes 1.5 months for a ring to separate, these results imply that up to four rings per year can be generated.

RECOMMENDATIONS

The discovery of vortex formation off the northwest coast of Cuba leads to questions concerning its role in the reconfiguration of the LC for a ring breakoff, its effect on the time scale of LC ring shedding, and its importance in LC kinematic characterization. To address these questions, it is recommended that hydrographic coverage of the LC be increased. This will provide insight into the characteristics of the LC at different stages in the development of a ring, the time of ring separation, and the location and structure of the anticyclonic feature off Cuba. In addition, we suggest drifter seedings before and after a ring separation to provide another data base for use in making kinematic and dynamic comparisons among phases of the ring's lifecycle. The hydrographic data, together with the LC drifter seedings, will provide direct observations of the vortex phenomena and allow one to more closely scrutinize its character. Because numerical models do not reveal this feature, drifter and hydrographic data are essential to us in examining its role in the generation of LC Eddies.

Dr. James K. Lewis is a Senior Scientist in Oceanography and Manager of the SAIC Office in College Station, Texas. Dr. Lewis received his B.S. in mathematics from Oklahoma State University, his M.A. in marine science from the College of William & Mary, and his Ph.D. in physical oceanography from Texas A&M University.

Maria R. Giuffrida is a research scientist in Physical Oceanography with SAIC, College Station, Texas. Ms. Giuffrida received her B.A. in mathematics, physics, and chemistry from the College of the Holy Cross and her M.S. in physical oceanography from Texas A&M University.

Remote Sensing Studies in the Western Gulf of Mexico

Dr. Fred M. Vukovich
Research Triangle Institute

NOAA-9 infrared data were integrated with _in situ_ data in the period November 1985 to March 1986 to study the near-surface effects of a warm ring interacting with the western slope wall of the Gulf of Mexico. The satellite data indicated that a massive, but narrow, zone of relatively warm water stretched from about 24°N to about 28°N along the far western portion of the Gulf of Mexico when the ring reached the western wall. The satellite and _in situ_ data suggested that there was a transport of heat, mass, and momentum northward and southward when the ring reached the wall. Part of the northward transport may be due to the interaction of this ring with another ring that current meter data and the National Environmental Satellite Services' analysis of NOAA satellite data suggested to be located in the northwestern corner of the Gulf. The existence of this ring has not been confirmed to date.

Dr. Fred M. Vukovich, Director of the Office of Geoscience Programs at Research Triangle Institute, has studied applications of satellite data to meteorology and oceanography, specializing in combining satellite data with _in situ_ data to study physical phenomena. He has been involved with the application of free-drifting buoys to study ocean features, including efforts to study cold rings in the Sargasso Sea and to study Gulf Stream frontal events and Loop Current structure.

Fresh Water on the West Louisiana and Texas Shelves

Mr. S.P. Dinnel
and
Dr. W.J. Wiseman, Jr.
Louisiana State University

Hydrographic data collected on monthly cruises over the West Louisiana and Texas Shelves during 1963-1965 were analyzed, and the volume of fresh water on the shelf was estimated for each data set. The freshwater volume exhibits an annual cycle that is dominated by the spring flood of the Mississippi and Atchafalaya Rivers. During the winter, shelf freshwater content is low, with the highest content appearing as a discontinuous band along the inner shelf. In summer an isolated high-content region is present in the center of the shelf. This high-content region dissipates, and the pattern migrates toward the southeast in the late summer. By late fall, the winter distribution pattern is again present.

A fill time for the freshwater volume on the shelf was also estimated for each cruise. The freshwater volume appears, in most cases, to have originated near the time of the previous spring flood.

Two of the study years had river discharges well below the long-term mean, while the third year discharge approximated the long-term mean. These results, then, may not be applicable to large discharge years.

ACKNOWLEDGEMENT

This work was supported by the Louisiana Sea Grant University Program and by the Coastal Sciences Program, Office of Naval Research.

Mr. Scott P. Dinnel is a graduate student in the Marine Sciences Department of Louisiana State University. He received his B.S. degree from the University of South Carolina and his M.S. from LSU. His present research deals with transport processes on continental shelves.

Dr. William J. Wiseman, Jr., is a Professor in the Department of Marine Sciences and Coastal Studies Institute at LSU. He received the BSEE, M.S., M.A., and Ph.D. degrees from The Johns Hopkins University. His present research interests include shelf and estuarine dynamics and geophysical signal processing.

Circulation on the Louisiana/Texas Shelf

Mr. John D. Cochrane
and
Mr. Frank J. Kelly
Texas A&M University

We attempt to provide a coherent sketch of the low-frequency circulation on the Texas-Louisiana Continental Shelf (Figure 11.11) on the basis of scattered current measurements, sea-surface salinities, other hydrographic data, and wind observations. During most of the year along much of the coast, longshore wind stress appears to drive the coastal currents. The dominant feature we find in the prevailing shelf circulation is a cyclonic gyre elongated to cover much of the shelf.

Current and wind measurements made almost without interruption for more than six years off Freeport, Texas (1978-1984), and for nearly five years off Cameron, Louisiana (1981-1985), show that monthly mean alongshore stresses and currents have remarkably similar annual progressions. Figure 11.12 for Freeport shows that both longshore components are directed downcoast (to the southwest) in all months except June, July, and August. July shows small upcoast (northeastward) values. Variation at Cameron is similar, although the normally downcoast stress is zero rather than upcoast in July.

Because of the lack of similarly long current series for other coastal locations and the very close relationship between wind and current, we turn to wind data to broaden our picture. The monthly mean alongshore stresses for coastal locations (Figure 11.13) exhibit a convergence (change in direction) which migrates seasonally along the coast. From May to July, the stress off Freeport changes direction as the convergence passes going upcoast (east). It reaches Cameron (approximately) in July. In August it begins a rapid retreat downcast passing Port Isabel. In the fall or winter, convergence migrates more slowly upcoast, reaching Freeport in June. The close relationship of current to wind argues that there is convergence in alongshore current with a similar migration. Available current data are consonant with such a migration, but are not sufficiently extensive to follow it in detail.

The evidence we have examined indicates that stretch of downcast flow is the inshore limb of a cyclonic feature over the shelf. Evidence of flow seaward from the convergence is provided by a tongue of low-salinity surface water extending offshore from the Port Aransas, Texas, region in spring. Evidence for a shoreward flow off Louisiana is not as clear. However, computations based on coastal wind stress and bottom resistance (which is larger off Atchafalaya Bay because of the greater extent of shallow water) indicate a divergence in alongshore currents centered near 92°W.

To complete the picture of a cyclonic gyre dominating the shelf, we note evidence for an offshore limb over the shelf break, roughly in which flow runs counter to that of the coastal (inshore) limb, that is, to the north or east. The tongue of freshwater extending out from the convergence is found, where observations permit, to turn northward or eastward along the shelf break. Current measurements on or near the Flower Garden Banks in January, May, and June 1980 show a prevailing current direction toward east-southeast (Rezak et al., 1983). Current meters at about 12 m depth over Baker Bank (73 m depth) operated from March 1978 to March 1980 (personal communication from Cortis Cooper) show a resultant current approximately along the isobaths toward the east-northeast.

A more complete picture of the cyclonic feature over the shelf is provided by maps of sea-surface geopotential (dynamic height), relative to 70 decibars, based on the GUS III cruises of 1963, 1964, 1965 (Temple et al, 1977). Monthly mean values (Figure 11.14) show an elongated cyclonic gyre (low in geopotential) over the shelf in all months except July and August. The feature implies the significant features which we inferred above from other evidence. From February through July, a second low is present off the south Texas coast, a ridge separating it from the larger low. The ridge migrates seasonally in a manner very similar to that of the convergence indicated by monthly ocean wind stresses.

Our simple picture of the circulation on the shelf seems to fit the data now available very well. There are, however, obvious gaps in the data which, we hope, will be filled eventually. Our qualitative picture should be quantified, probably by mathematical modelling. Open Gulf circulation evidently influences the shelf, and this influence should be investigated.

This abstract is based on Cochrane and Kelly (1986).

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John Cochrane received an M.S. from the Scripps Institution of Oceanography of the University of California. In 1955 he worked with R.B. Montgomery at The Johns Hopkins University. In 1956 he joined the faculty of Texas A&M University, Department of Oceanography. His primary interests are the water characteristics of the worlds oceans and the descriptive oceanography of the intertropical zone of the oceans and of the Gulf of Mexico and Caribbean Sea, including the shelf regions.

Frank Kelly is an Assistant Research Scientist with the Environmental Engineering Division of the Civil Engineering Department at Texas A&M University. His interests are the circulation of the Gulf of Mexico, the effect and fate of Loop Current eddies in the western Gulf of Mexico, and the dynamics and circulation of the Texas-Louisiana Shelf. He received an A.B. in physics from the University of California, Berkeley, in 1972 and an M.S. in oceanography from Texas A&M University.

Drifting Buoy Studies in the Western Gulf of Mexico

Dr. George Z. Forristall
Shell Development Company

In July 1985, a large eddy broke off from the Loop Current (LC) in the Gulf of Mexico and was named Fast Eddy. Several cruises which will be reported on elsewhere gave detailed snapshots of its structure, but much of the information on its evolution was supplied by the numerous drifting buoys which were deployed in and around it. The buoys were manufactured by Polar Research Laboratories and Horizon Marine, and tracked by the Argos system. They were drogued at 50 or 100 meters depth. The information from the buoys was particularly valuable in tracking Fast Eddy, since the lack of thermal contrast in the surface waters of the Gulf in the summer makes infrared remote sensing nearly useless.

We have interpreted the motion of buoys embedded in eddies by modeling the buoy track as an elliptical orbit about a steadily translating center. Model parameters were computed by a least squares fit to the raw buoy position time series. Given about one orbit of the feature, the model produces a stable estimate of the eddy center position and its constant propagation velocity, the orbital period, and the principal radii of the ellipse and its orientation.

Figure 11.15 shows buoy tracks from Julian days 170-200 in 1985. Two of the buoys were embedded in a closed circulation in the center of a northwestward extension of the LC. If no other information was available, it would seem that they were, in fact, in a detached eddy. However, the other two buoy tracks plotted in Figure 11.15 show that the water at a greater radius from the center did not make a closed orbit, at least during the first part of the time period shown. There was a pronounced meander at the southeastern edge of what would become Fast Eddy, but the separation was not yet complete. It seems that much of the LC water entering the Gulf through the Yucatan Strait must have been taking a short circuit out the Straits of Florida, while only a small portion wrapped around the closed circulation.

Shortly before day 200, Fast Eddy detached completely and moved rapidly westward, as shown in Figure 11.16. Two of the buoys were clearly in the eddy at the start of this time period. The one which was deployed near the center of Fast Eddy rapidly moved to a larger radius. This change of radius of the buoy orbit cannot be interpreted as a divergence of the eddy, since the other buoy made a closed orbit at a larger diameter during the same time period.

After its one orbit of Fast Eddy, the buoy that was at the larger radius suddenly shot off to the southwest and began orbiting another anticyclonic feature. This warm eddy had not been detected previously, but must have been shed by the LC sometime between the loss of infrared data at the end of May and the birth of Fast Eddy in July.

The data shown demonstrate that in a basin the size of the Gulf of Mexico, a relatively small number of drifting buoys can give a reasonably clear view of the major features of the circulation. Compared to other sources of data, they are also quite economical.

Dr. Forristall studied mechanical engineering at Rice University, receiving a B.A. in 1966 and a Ph.D. in 1970. Following postdoctoral positions in the Mechanics and Geology Departments of the Federal Institute of Technology in Zurich, he joined Shell Development, where he is now a Staff Research Engineer. Most of his work at Shell has been on the specification of storm driven waves and currents.

Hurricane-Generated Currents on the Continental Slope

Mr. Cortis Cooper
Conoco R&D

The presentation can be broken into four parts: an overview of previous work on hurricane-driven currents, description of a model developed at Conoco over the past year, comparisons between the model and data from two Gulf hurricanes, and documentation of three types of low-frequency responses suggested by the model which have not been previously documented in the literature.

The ocean's response to a hurricane is a strong function of the local water depth, and can be categorized into three regimes: a deepwater region of order 1000 m or greater where topography is of little consequence, a shallow water regime of order 50 m or less where topography is important but stratification is not, and the transition region covering the outer shelf and slope. Previous modeling has focused on the deep and shallow water regimes where topography and stratification can be neglected, respectively. Only a few models have been developed for the slope and these have compared poorly to existing data.

Because of the lack of a good model of the outer shelf, Conoco has developed a model for this region. The model is an extension of the model of Price (1981, JPO). It uses four layers, the nonlinear primitive equations, and an explicit, finite different numerical algorithm. The model differs from Price's in that it includes free surface fluctuations and topography. Since the model requires that the number of layers at a given grid remain fixed in time, it was necessary to introduce three artificial steps of order 100 m in the modeled topography. The lower two steps are of little consequence since they lie on the shelf break where the topography is changing rapidly. However, the upper step does clearly introduce a transition region occupying a substantial portion of the shallow shelf. Model results from the outer portion of this region will be less accurate than other portions of the model.

The model was used to hindcast Hurricanes Eloise and Frederic. In both cases, the only forcing was due to winds. The wind fields were derived from post-synoptic hindcasts, and developed prior to the ocean modeling -- there was no joint tuning of the wind and ocean models. Initialization of the ocean model was based on historical temperature and salinity data, and no motion. A model grid of 0.2 degrees was used to cover the entire Gulf. Both straits were assumed closed.

Two data sets were available from Eloise: a thermistor string and velocity meter at environmental data buoy 10, and velocity meters on a platform off the South Pass of the Delta. Comparisons with the meter at buoy were within 20 cm/s for the periods when the meter was within the mixed layer. At the platform, the model reproduced 90% of the observed variance of the mixed layer velocities.

Current data during Frederic were taken from three moorings located near DeSoto Canyon. The moorings ranged in water depth from 100 to 465 m, and the storm passed at a mean distance of 100 km from the sites. Comparisons between the model and data were reasonable -- the model reproduced better than 80 percent of the observed variance at the upper and lower meters.

Three low-frequency responses were frequently observed in the model hindcasts: convergence zones, coastal jets, and shelf waves. The first two were characterized by velocity scales of 1 m/s, inertial periods, and e-folding scales of ten days. Convergence zones were initially generated by clockwise changes in the storm's path. A relatively strong shelf wave response was observed. These waves were baroclinic with a peak mixed layer velocity of order 50 cm/s and phase speed of 4 m/s.

Cortis Cooper received his B.Sc. and M.Sc. from the Parson's Hydrodynamic Lab at MIT in 1977. He has since worked as a private consultant (including an MMS circulation modeling study), and is presently employed as a metocean specialist at Conoco. In the recent past, he has participated in several joint industry studies of eddies in the Gulf of Mexico, including the use of drifting buoys, hydrographic surveys and current shear measurements.

Circulation Modeling Progress: (A) The Topographic Intersection Problem, and (B) Thermodynamics

Dr. Alan J. Wallcraft
JAYCOR, Inc.

INTRODUCTION

The Gulf of Mexico Circulation Modeling Study was started by MMS in

October 1983 as an "extremely modest effort building on existing/ongoing modeling efforts in the Gulf of Mexico." The initial requirement was for an existing circulation model with capabilities approaching those required and the ability to deliver an "early simulation run." At the end of the four year program, the requirement was for a circulation model of the entire Gulf with horizontal resolution approaching 10 km, and vertical resolution (initially less important) approaching

mixed layer	1-10 m
thermocline	10 m
deep layer	100 m

with realistic bottom topography, coastline and wind forcing, which must exhibit loop-current eddy shedding, and other known regional circulation features.

The Existing NORDA/JAYCOR Model (October 1983)

This was a two layer, non-linear, hydrodynamic, free surface, semi-implicit, primitive equation ocean circulation model on a beta plane, with realistic coastline, and full scale bottom topography confined to the lower layer. The horizontal grid resolution was 0.2 degrees (20 by 22 km), with a upper layer rest depth of 200 m. The model can be driven by inflow through the Yucatan Strait compensated by outflow through the Florida Strait, and/or by winds.

Problems with the Existing Model (1983)

1) Only 0.2 degree horizontal grid resolution - need 0.1 degree.
2) Model is hydrodynamic-thermohaline circulation particularly important during fall and winter, and over shelf areas.
3) Crude representation of the vertical density profile-need mixed-layer physics.
4) Model has full scale bottom topography (which is essential for a good simulation), but the layer interface(s) must not intersect the bottom. Shallowest topography in model is at 500 m.

MODEL DEVELOPMENT PLAN

Year 1

Use existing 2-layer 0.2 degree Gulf of Mexico model. Find "best" representation of coastline and bottom topography. Initially, use seasonal wind forcing and constant inflow; later simulations will use winds based on 12 hourly FNOC surface pressure analysis and time varying inflow.

Year 2

Use 2-layer model, but on a 0.1 degree grid, and with low eddy viscosity. Expect richer flow field, including wind induced flow instabilities. Some experiments will use 1-layer (reduced gravity) model, but all delivered simulations will have 2-layers.

Year 3

Develop 3-layer model with bulk thermodynamics. Densities in the upper two layers will be allowed to change locally with time, under control of the equation of state and temperature equation added to model. Initially 0.2 degree simulations, later 0.1 degree grid will be used.

Expect to see thermohaline circulation and improved representation of permanent thermocline. Three layers also better resolve "hydrodynamic" circulation, and thinner upper layer increases the accuracy of surface velocities.

In addition, modify the 2-layer hydrodynamic and 3-layer thermodynamic models to allow the layer interfaces to intersect the bottom topography. This will allow the minimum bottom depth to be raised from 500 m to about 20 m. Layer intersection is not generally found in layered ocean models, and so its successful implementation is less certain than other phases of the program. However, if successful, it will significantly improve the realism of the simulations over the continental shelf.

Year 4

Complete 0.1 degree 3-layer simulations. Then, couple circulation model results to a mixed layer model (TOPS). TOPS is the Navy's operational mixed layer forecast model. Simplest version of TOPS is one dimensional, with 15+ fixed vertical levels covering upper 500 m. TOPS can accept geostrophic currents from any suitable source; the 3-layer model is suitable but the 2-layer (hydrodynamic) is not.

This final coupled model will give detailed vertical density profiles, and greatly improve the simulation accuracy in shelf regions.

PROGRESS

Years 1 and 2

All tasks in years one and two are complete, and final reports have been accepted by MMS.

Year 3

A major thrust of the 3rd year program, in progress, is the development of a version of the layered ocean model that will allow layer interfaces to effectively intersect the bottom topography, thus removing what is probably the most serious deficiency of the present model, namely, that the topography is confined to the lowest layer, i.e., its minimum depth is about 500 m. When intersection occurs in a conventional layer model, the layer thickness becomes negative which is clearly unphysical. This leads to unrealistic results and, if the situation persists, catastrophic failure of the run due to undamped instabilities. The obvious solution of setting a minimum layer thickness at or about zero does not work because (a) it leads to loss of mass, and (b) clamping the layer thickness induces dispersive ripples in interface at the intersection point (i.e., we have an unresolved boundary layer). One promising approach to the layer intersection problem is to insure positive layer thicknesses via 'Flux Corrected Transport', a technique that was originally developed for fluid problems with shocks (Book et al, 1981). In this method, the continuity equation is solved for layer thickness using two different sets of transports, one obtained via a low order (highly dispersive) scheme guaranteed to give monotonic results and the other via a standard (ripple prone) high order scheme. The low order scheme used alone would prevent layer intersection, but it very rapidly damps out circulation features and, therefore, would not produce realistic simulations. Instead, the final layer thickness at each point is a linear combination of the two solutions, chosen to be as close as possible to the high order solution. Away from areas of layer intersection, the high order scheme will be used alone, and the solution will be identical to that without FCT, but near intersections just sufficient contribution from the low order scheme will be used to ensure a positive layer thickness. In other words, bottom topography is still confined to the lowest layer; that layer can get very thin so there is effectively no contribution from the deep layer over the shelf and no limit on how shallow the bottom topography can be. This method has already been used with some success in a similar layered ocean model, both for interfaces that intersect the surface and, more recently, for layers that intersect the topography (Bleck et al, 1983). The major problem with the model is that FCT is an inherently explicit scheme, in contrast to the existing ocean model which treats gravity waves implicitly (to allow much larger timesteps).

Two dimensional (x-z) versions of a two-layer hydrodynamic model that uses FCT to allow layers to intersect the bottom have been tested on sections across the Gulf of Mexico on a 0.2 degree grid. Initial tests in three dimensions are in progress for the Gulf of Mexico on a 0.4 degree grid. A fully explicit model's timestep would be controlled by the external gravity wave speed (about 150 m/s), but here the depth averaged flow is treated implicitly so the timestep depends on the internal gravity wave speed (about 3 m/s). The existing ocean model, with topography confined to the lowest layer, treats both external and internal gravity waves implicitly and can use a timestep 3 to 5 times longer than the FCT code.

Figure 11.17 shows the region used for the two dimensional experiments: it is a section across the Gulf of Mexico at 26N on a 20 km grid. The position of each model grid point is indicated by a vertical line below the topography contour; in all the plots, data is only available at grid points, and straight lines are used to connect data values. The upper layer rest depth is 300 m over deep water, but is less near 98W and 82W where the continental shelf is shallower than 300 m deep. The lower layer is set to be at least 10 cm thick across the entire region, so there is a lower layer over the continental shelf although it is too thin to be seen in the plot. Figure 11.17 is for 2 days into an experiment to test the ocean model with no applied forcing. The layers are in exactly the same position as at the initial time, and the velocities are zero everywhere. This demonstrates that the model does not deviate from an initial rest state without applied forcing.

Figures 11.18 and 11.19 show only the upper 450 m of the water column for a gravity wave sloshing experiment where there is no applied forcing, but the layer interface is initialized with a single period cosine profile across the region. Figure 11.18a shows the initial state with about 100 m variation in the depth of the interface from east to west; note that the lower layer is again 10 cm thick where the topography is shallower than the expected interface depth. Figure 11.18b is for day 3 of the simulation: the layer interface is now almost level. Figure 11.19a is for day 6: the layer interface has moved up or down about 100 m at each end to reverse the profile. It is no longer exactly sinusoidal, however, because gravity waves travel more slowly in shallow water than they do in deep water. The interface is level again between day 9 and day 10. Figure 11.19b is for day 12; the interface is again shallower to the west as it was on day 0, but the wave is almost square and the model blows up at day 15 as the wave 'breaks'. The conversion of the original wave into a breaking wave is to be expected given that gravity waves travel more slowly in shallow water.

The second major element of the 3rd year is the addition of bulk layer thermodynamics to the model. The existing model is 'hydrodynamic,' i.e., the density in each layer is constant and fixed for all time, with the fixed densities and the density difference between layers set to realistic mean values for the Gulf of

Mexico. The addition of thermodynamics allows the density to vary in space and evolve with time under the control of an equation of state and a temperature equation, forced by heat fluxes and the density of inflow water. Mixing of denser fluid from the layer below into each layer is also allowed and this can prevent the layer interface surfacing due to upwelling; that is, the layer gets denser rather than getting thinner. In hydrodynamic models there is no exchange of fluid between layers.

Initial thermodynamic experiments use the simple, one-active, layer-reduced gravity version of the model, which defines the lower layer to be infinitely deep and at rest. This model does not allow topographic steering, but is a useful test bed for more realistic Gulf simulations. Instead of forcing the model with heat flux data, which is still being prepared, the model is required to relax back to a monthly density climatology based on sea surface temperature maps from historical ship observations. The relaxation period is about 360 days in the center of a Loop Current (LC) eddy, but is only 90 days over the continental shelf where rapid winter cooling is important.

Figure 11.20 shows the sea surface and corresponding density fields for January. The density ranges from 25.8 sigma-t over the shelf to 24.0 sigma-t in the Yucatan Straits. The model sets the density of the LC inflow through the straits to agree with the density climatology there month by month. Figure 11.21 shows contour maps of sea surface height and of density for an experiment without wind forcing and with a constant inflow transport of 20 Sv. It is for a day in December, and so the shelf areas are cool. Note the strong density front between the large anti-cyclonic and the smaller cyclonic eddies in the northwest Gulf. In this case, a new eddy is in the process of developing on the LC as it extends into the Gulf. Figure 11.22 is for 180 days later, in the summer. The Anti-cyclonic eddy has detached from the LC and is in the central Gulf. It is already cooler than the LC. The shelf areas are significantly less dense than they were during the winter.

Bleck, R., C. Rooth, D.B. Boudra 1983: "Wind-Driven Spinup in Eddy-Resolving Ocean Models Formulated in Isopycnic and Isobaric Coordinates", Rosenstiel School of Marine and Atmos. Sc., U. of Miami, Florida.

Book, D.L., J.P. Boris, S.T. Zalesak 1981: "Flux-Corrected Transport" in D.L. Book (ed), Finite Difference Techniques for Vectorized Fluid Dynamics Calculations, Springer-Verlag.

Dr. Alan J. Wallcraft has been the principal investigator for JAYCOR's ocean modeling effort since 1981, overseeing and participating in projects in the areas of model development, model comparison, diagnostic software, data preparation, and the numerical ocean modeling of semi-enclosed seas. His early Gulf of Mexico experiments were probably the first mesoscale eddy resolving simulations of any semi-enclosed sea to include a realistic coastline and full scale bottom topography. Dr. Wallcraft received his BSc in mathematics and computer science from Essex University and his PhD in numerical analysis from Imperial College, London.

Plans for Future Work in the North Central Gulf of Mexico

Dr. Evans Waddell
Science Applications
International Corp.

In September 1986, MMS signed a contract with Science Applications International Corporation to conduct a two-year physical oceanographic field measurement program in the north central Gulf of Mexico. The general program objective is to develop an appropriate data base to be used in isolating and describing the circulation patterns and processes in the study region. An additional program concern involves documenting aspects of the optical properties of the shelf waters and relating these to circulatory patterns.

Measurements and observations to be made or used during this study include

- o Subsurface current/temperature
- o Transmissivity (shelf only)
- o Hydrography and water quality
- o Satellite thermal imagery
- o Satellite tracked drifting buoys
- o Ship-of-opportunity program (SOOP)

In addition, several optional aerial Expendable Bathythermograph (XBT) surveys have been proposed.

Primary measurements will be made on a transect approximately as shown in Figure 11.23. There will be four shelf moorings between approximate 15 m and 150 m (the shelf break) water depths containing 8 current meters and 6 transmissonmeters. Three shelf moorings in 1000, 1500, and 3000 m of water will contain 11 current meters. In addition, two inverted echo sounders (IES) will be deployed in deep water near and beyond the end of the mooring transect. Gulf-wide and study area specific satellite imagery will be used during cruise planning and data synthesis. Five to six drifting buoys will be released in various features such as Loop Current (LC) eddies and possibly the LC proper to document further dynamic and kinematic characteristics of these oceanographically important features.

Focus for the various members of the scientific team is on processes and environments rather than on types of observations. As such, each PI or group of PI's will be working with the full range of appropriate and relevant data. Key focus will be on

- o Shelf Dynamics and Water Quality (Dr. W. Wiseman and Dr. N. Hojersiev)
- o Slope Circulation
  - Eddy related: (Dr. David Brooks and Mr. Frank Kelly)
  - Non-Eddy induced circulation patterns: (Dr. Peter Hamilton)
- o Sea-Surface Temperature Patterns
  - Gulfwide: (Dr. Fred Vukovich)
  - North-Central Gulf: (Dr. Peter Hamilton)
- o Loop Current Eddies
  - Lagrangian Perspective: (Dr. Jim Lewis)

At present, the plans call for a 12-month measurement program beginning in early Spring 1987. Total program length is expected to be approximately two years. As with all prior programs, MMS and SAIC are anxious, where possible, to integrate plans and activities with others working in the Gulf of Mexico. Such coordinated efforts invariably enhance all programs and produce improved understandings of physical oceanographic conditions throughout the Gulf.

Dr. Evans Waddell is Division Manager for Marine Science and Engineering with Science Applications International Corporation (SAIC). At present, he is also Program Manager for the MMS-funded Physical Oceanography Program in the Gulf of Mexico. He received his Ph.D. in marine science (physical oceanography) from Louisiana State University in 1972. His recent research involvement emphasizes shelf and shallow-water physical oceanographic processes.

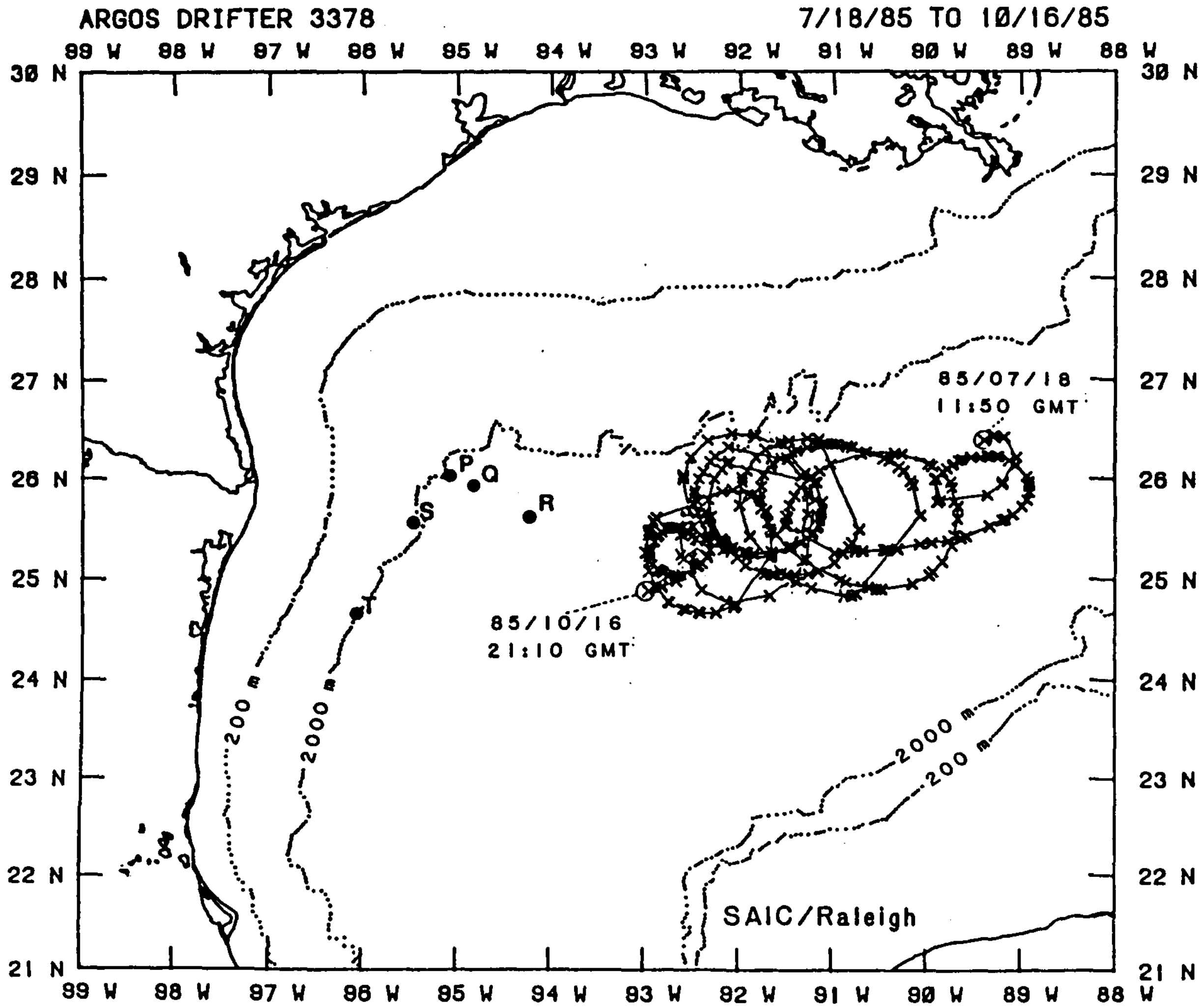


Figure 11.1.--Partial trajectory for buoy 3378. Current meter moorings (P, Q, R, S, T) are also shown.

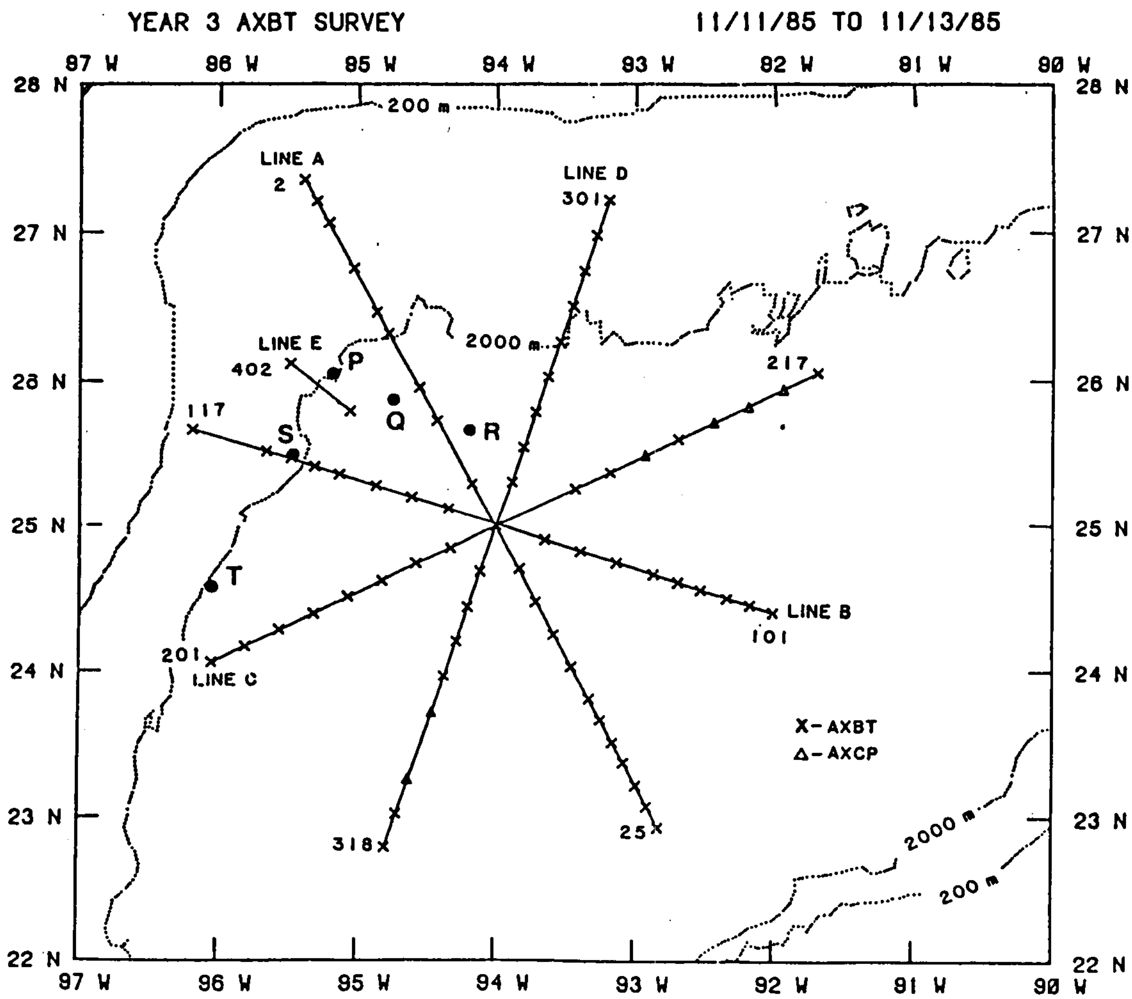


Figure 11.2a.--Aerial XBT survey prior to ring interacting with adjacent slope.

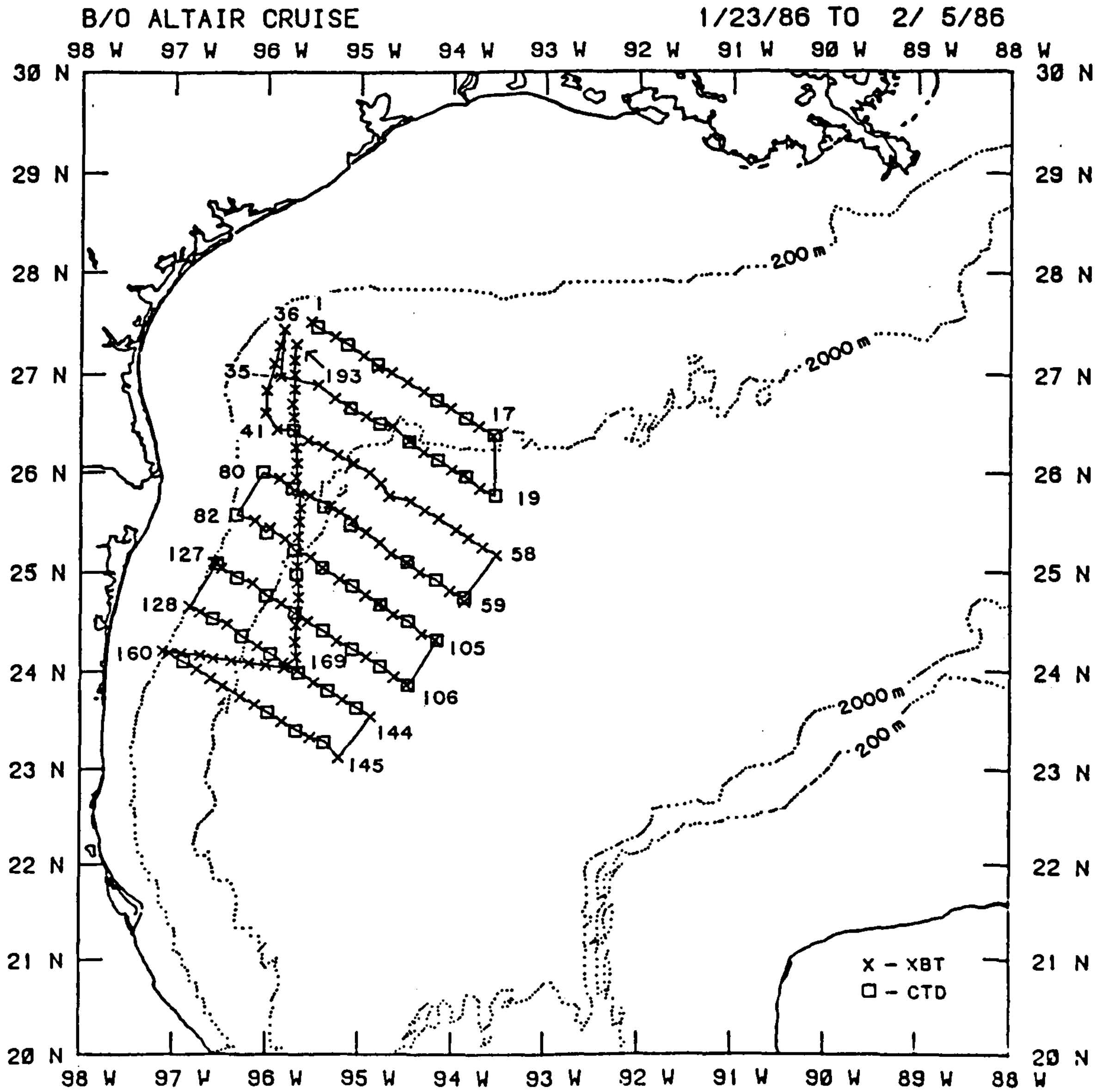


Figure 11.2b.--Hydrographic survey of eddy after interaction with slope began.

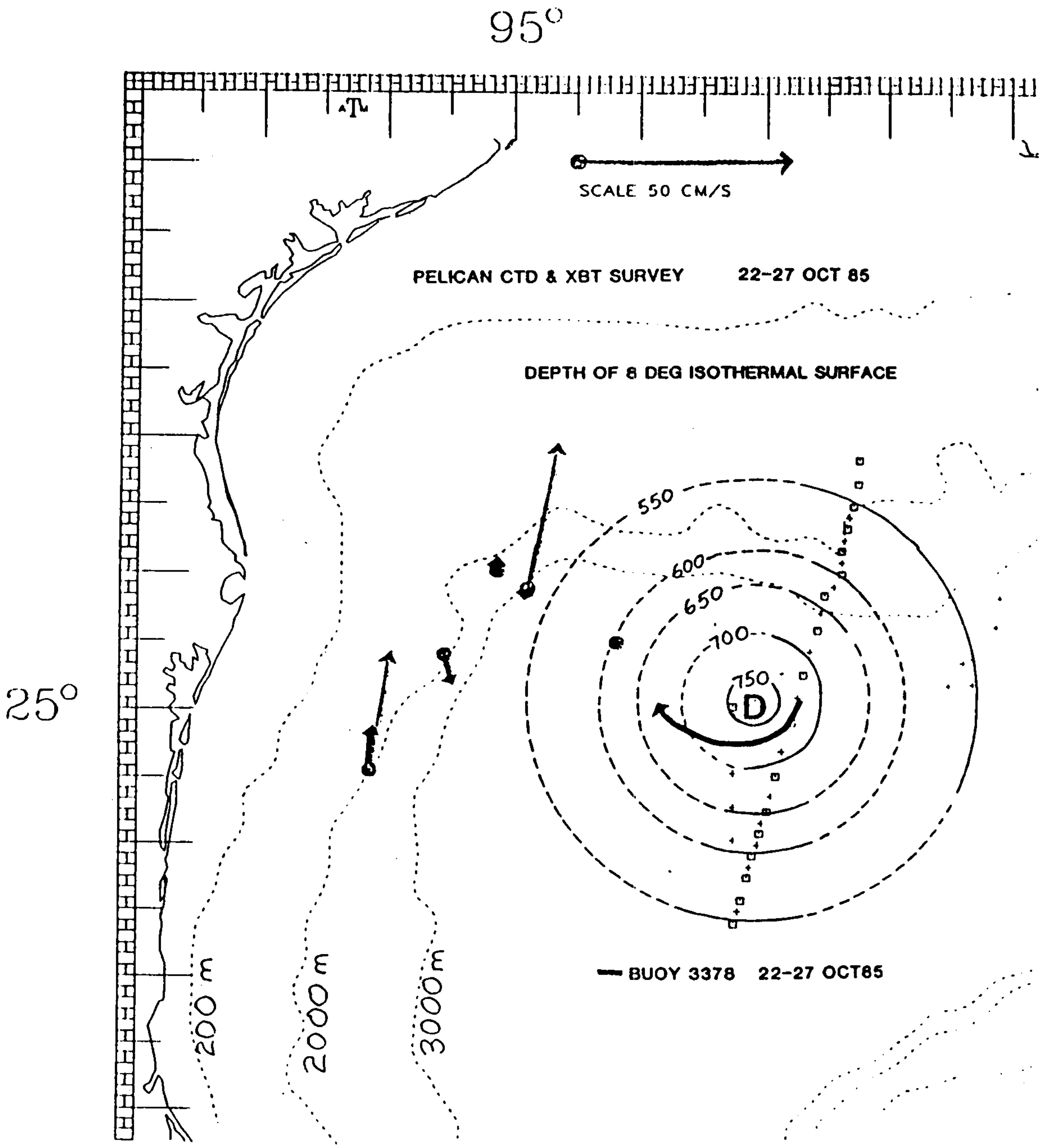


Figure 11.3.--Partial hydrographic survey of the eddy, showing idealized isothermal depth contours; also shown are the drifter track and 3-day averaged current vectors.

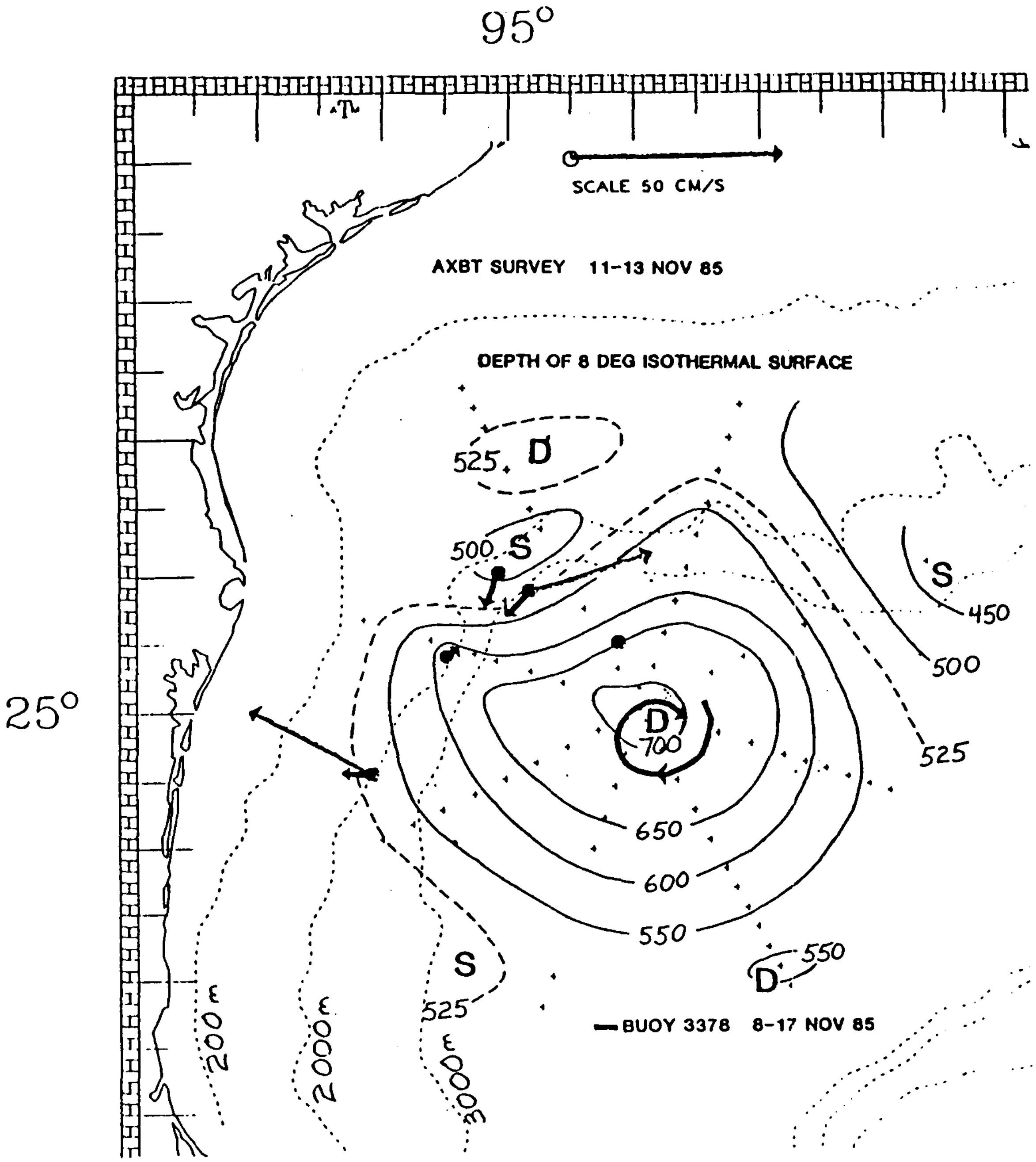


Figure 11.4.--Complete hydrographic survey (AXBT); data shown are similar to Figure 11.3.

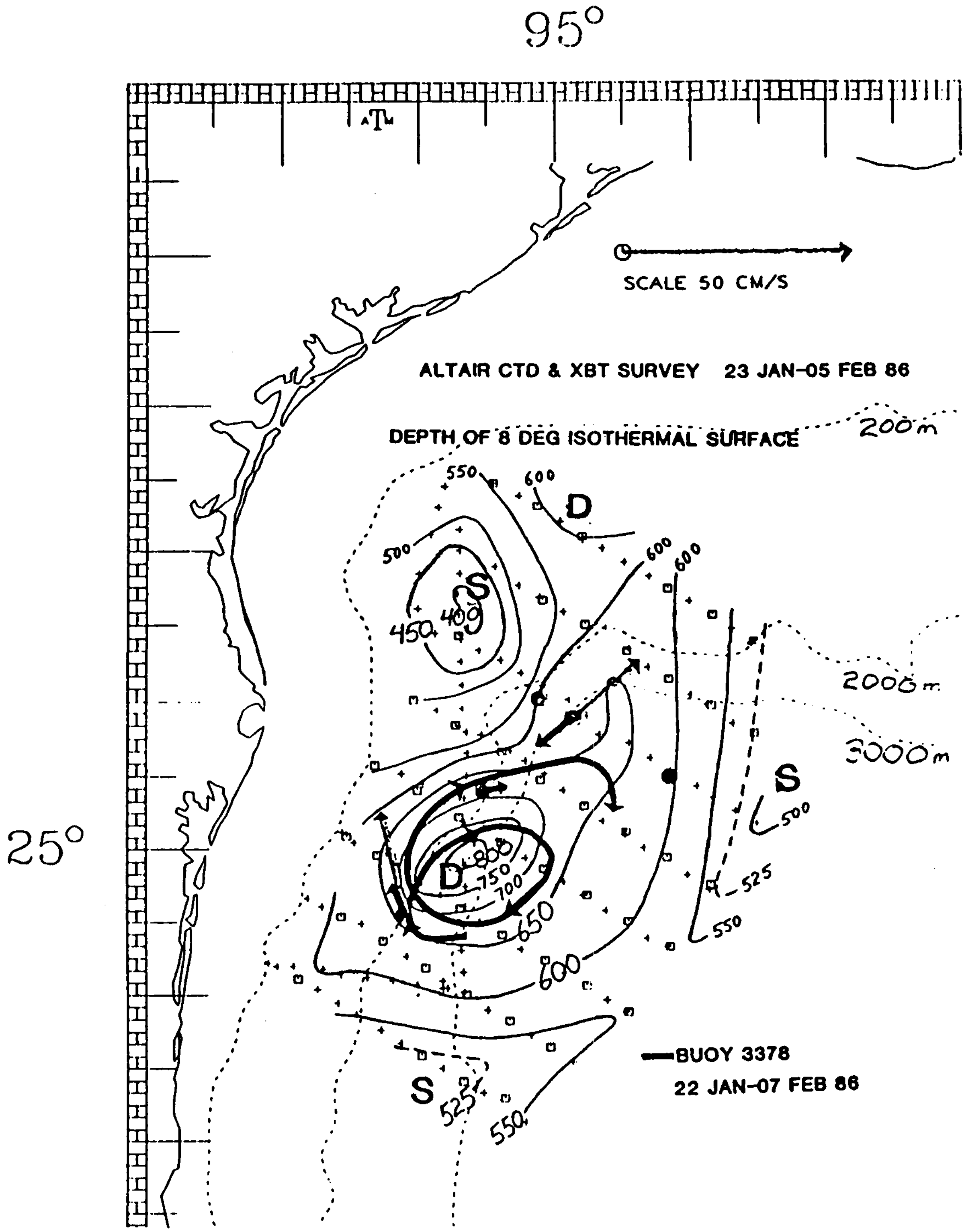


Figure 11.5.--Complete hydrographic survey (CTD/XBT); data shown are similar to Figure 11.3.

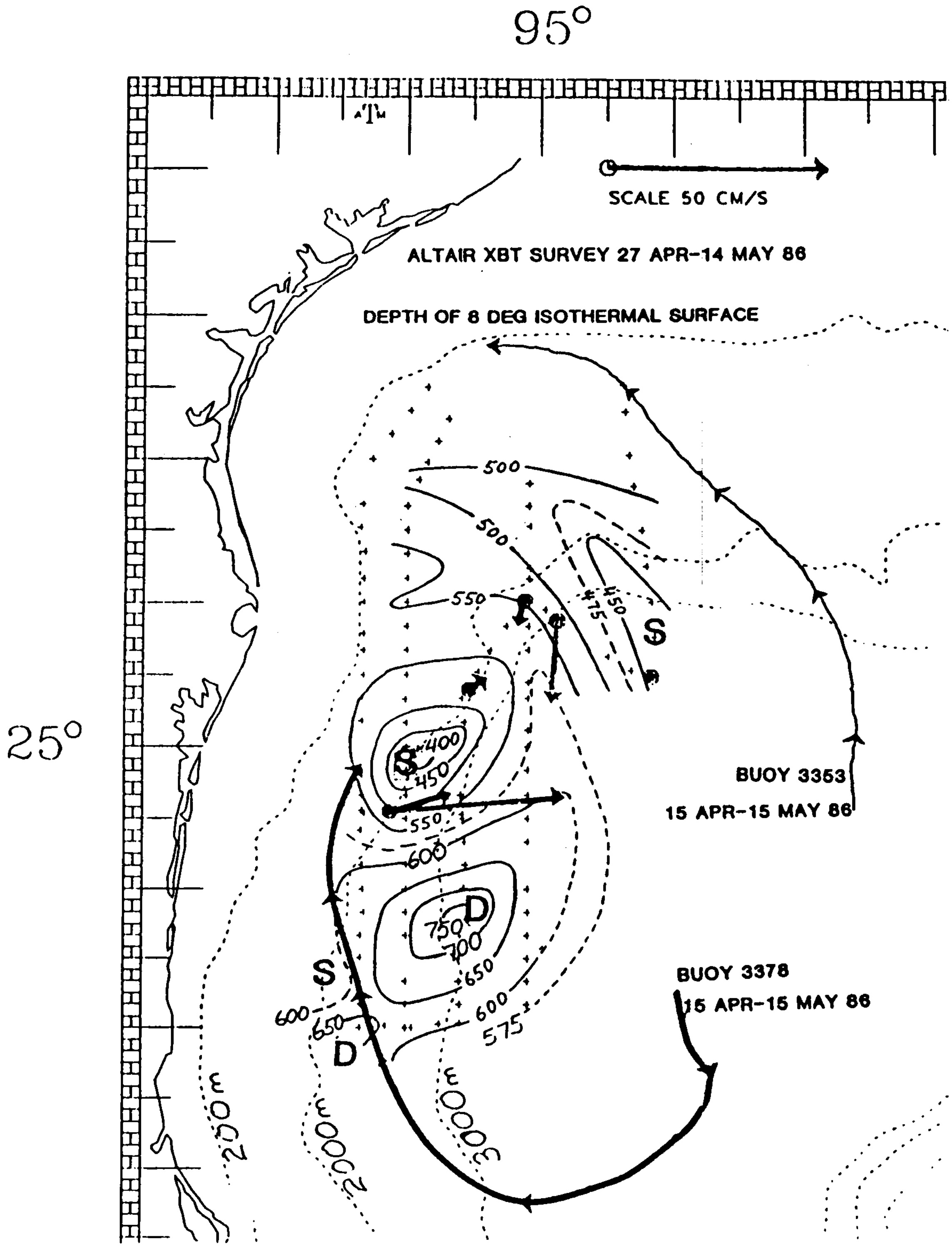


Figure 11.6.--Complete hydrographic survey (CTD/XBT); data shown are similar to Figure 11.3.

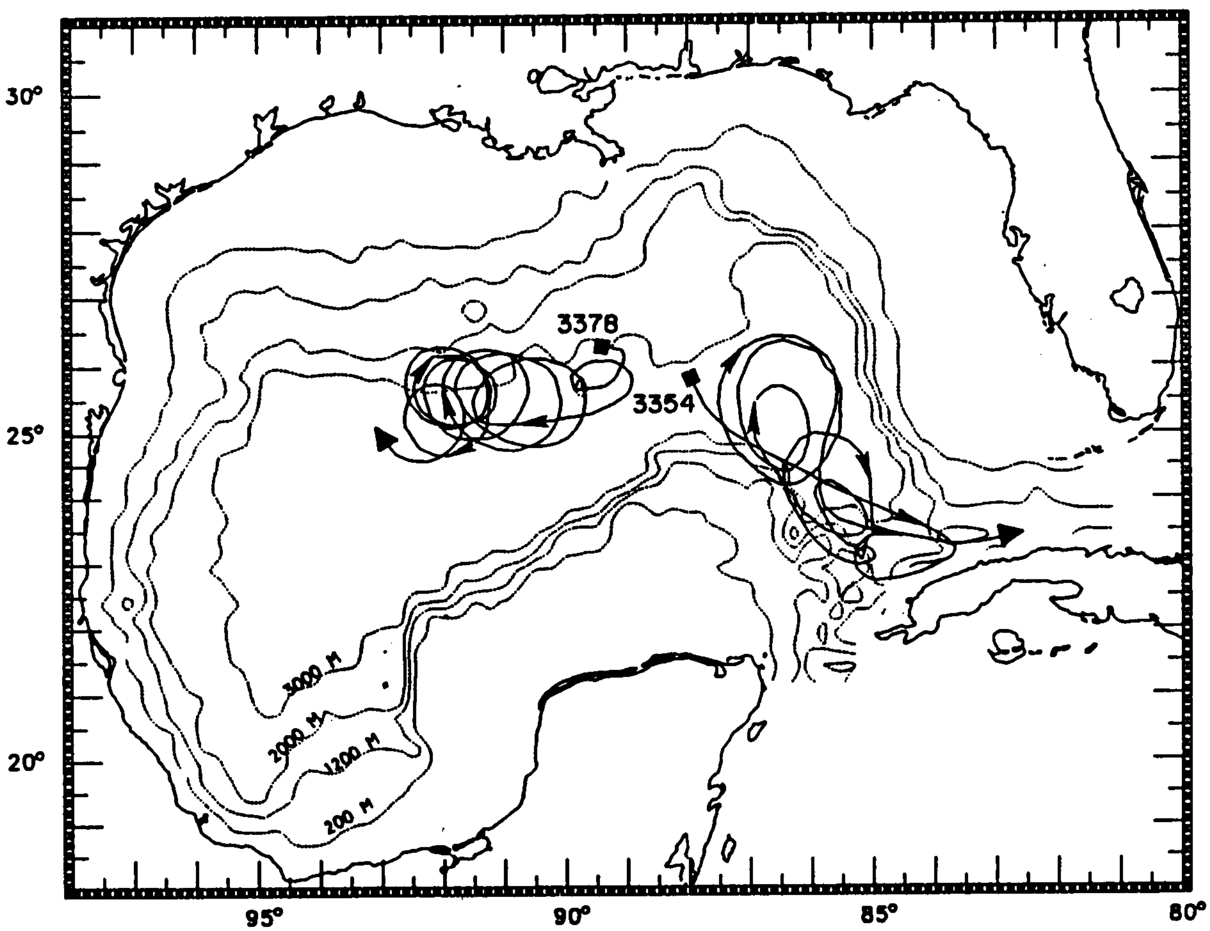


Figure 11.7.--Trajectories of buoys 3354 and 3378 seeded 18 June 1985 and 18 July 1985, respectively (■ locations on trajectories).

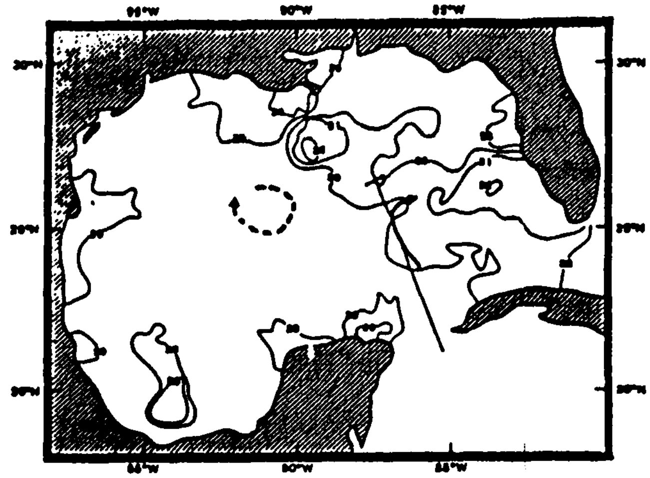


Figure 11.8.--Trajectories of drifters 3354 (solid line) and 3378 (dashed line) during 13-19 August 1985 plotted on the corresponding weekly GOM SST chart.

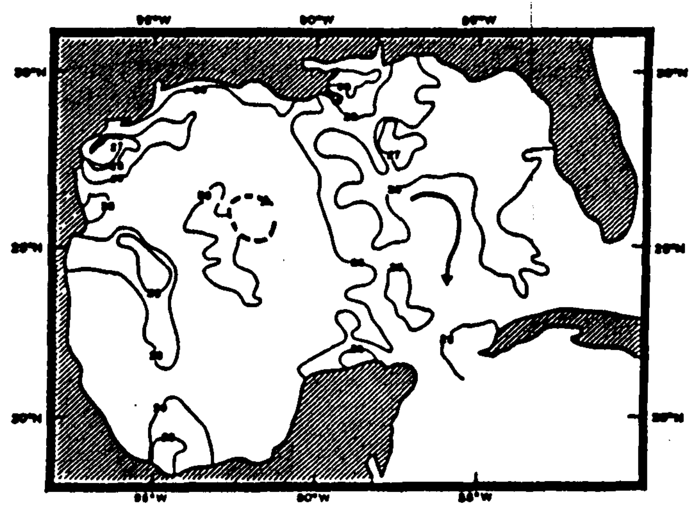


Figure 11.9.--Trajectories of drifters 3354 (solid line) and 3378 (dashed line) during 10-16 September 1985 plotted on the corresponding weekly GOM SST chart.

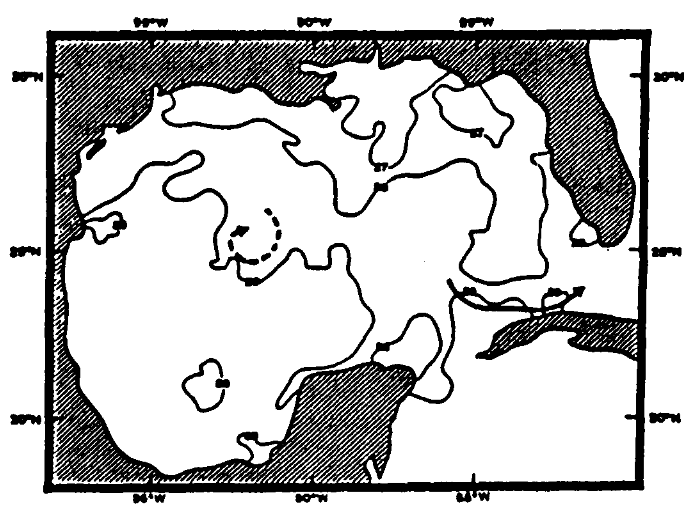


Figure 11.10.--Trajectories of drifters 3354 (solid line) and 3378 (dashed line) during 17-23 September 1985 plotted on the corresponding weekly GOM SST chart.

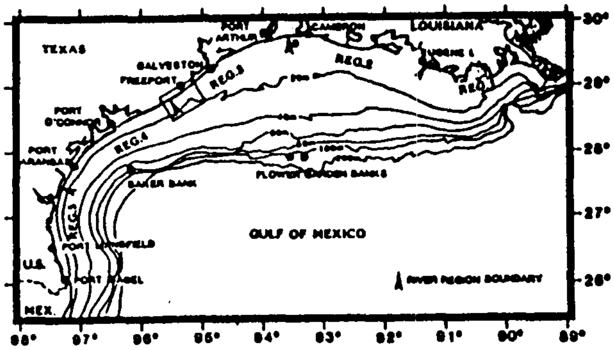


Figure 11.11.--Map of the Texas-Louisiana Continental Shelf showing locations discussed in text.

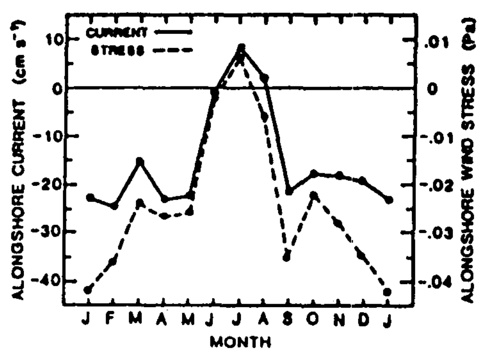


Figure 11.12.--Monthly mean alongshore components of wind stress at NDBC Station 42008 together with monthly mean alongshore components of surface current (3.7 m below sea surface) at moorings A, B or C off Freeport, Texas. (See text in regard to moorings used in computing means.) The positive alongshore direction is 55° clockwise from the north.

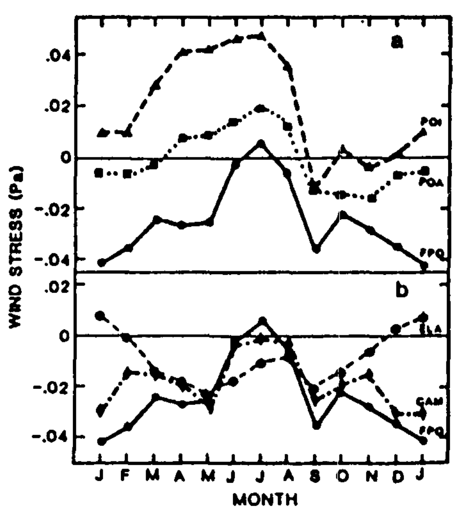


Figure 11.13.--Monthly mean alongshore components of wind stress for the waters (a) off Port Isabel, Texas (POI), Port Aransas, Texas (POA), and Freeport, Texas (FPO); and (b) off the latter (FPO), Cameron, Louisiana (CAM), and the Louisiana coast between 92°W and the Mississippi Delta (ELA).

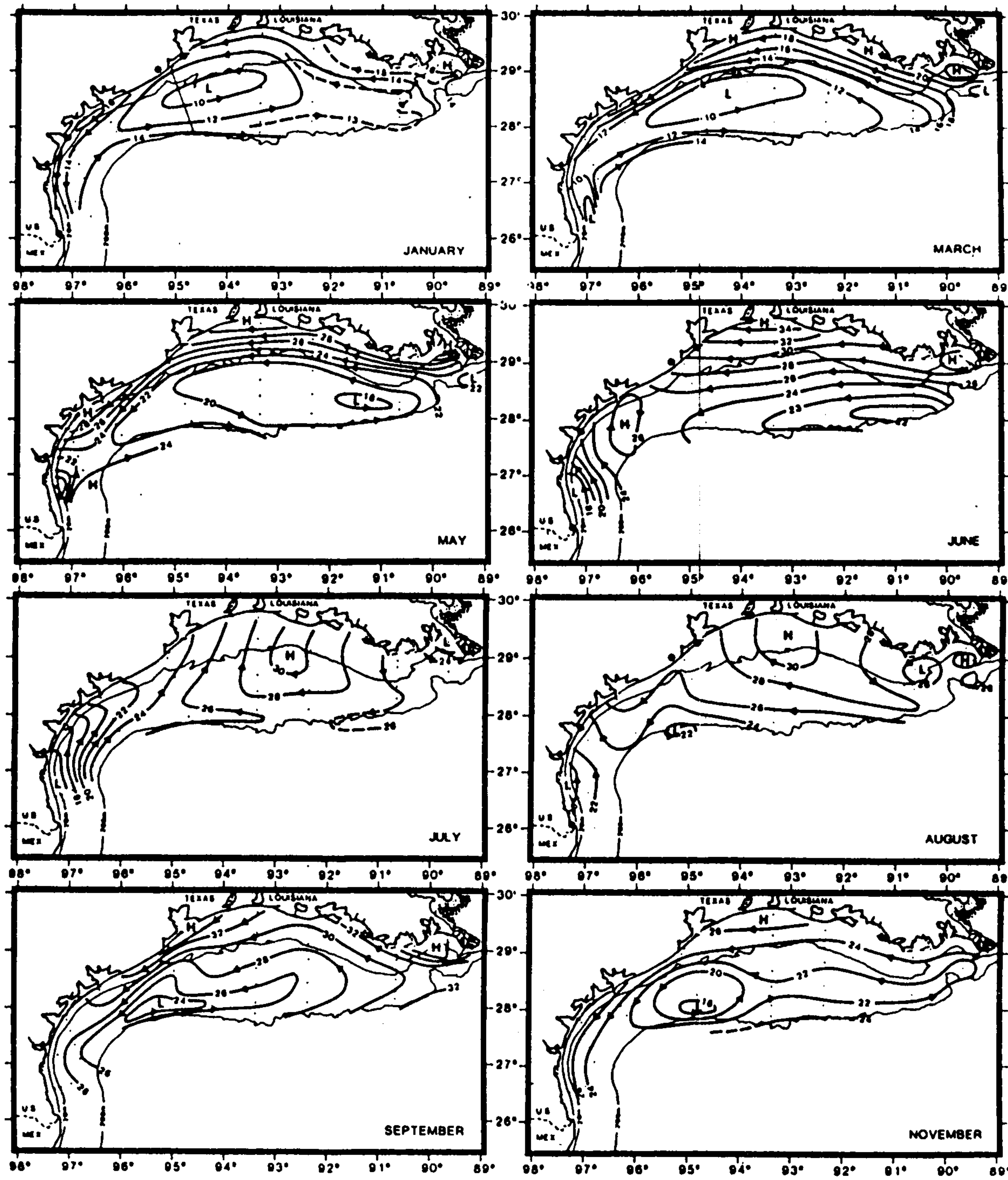


Figure 11.14.--Monthly mean geopotential anomaly (dyn cm or 10^{-1} J kg^{-1}) of the sea surface relative to 70 dB or 0.70 MPa for representative months based on data taken aboard M/V GUS II in 1963, 1964 and 1965.

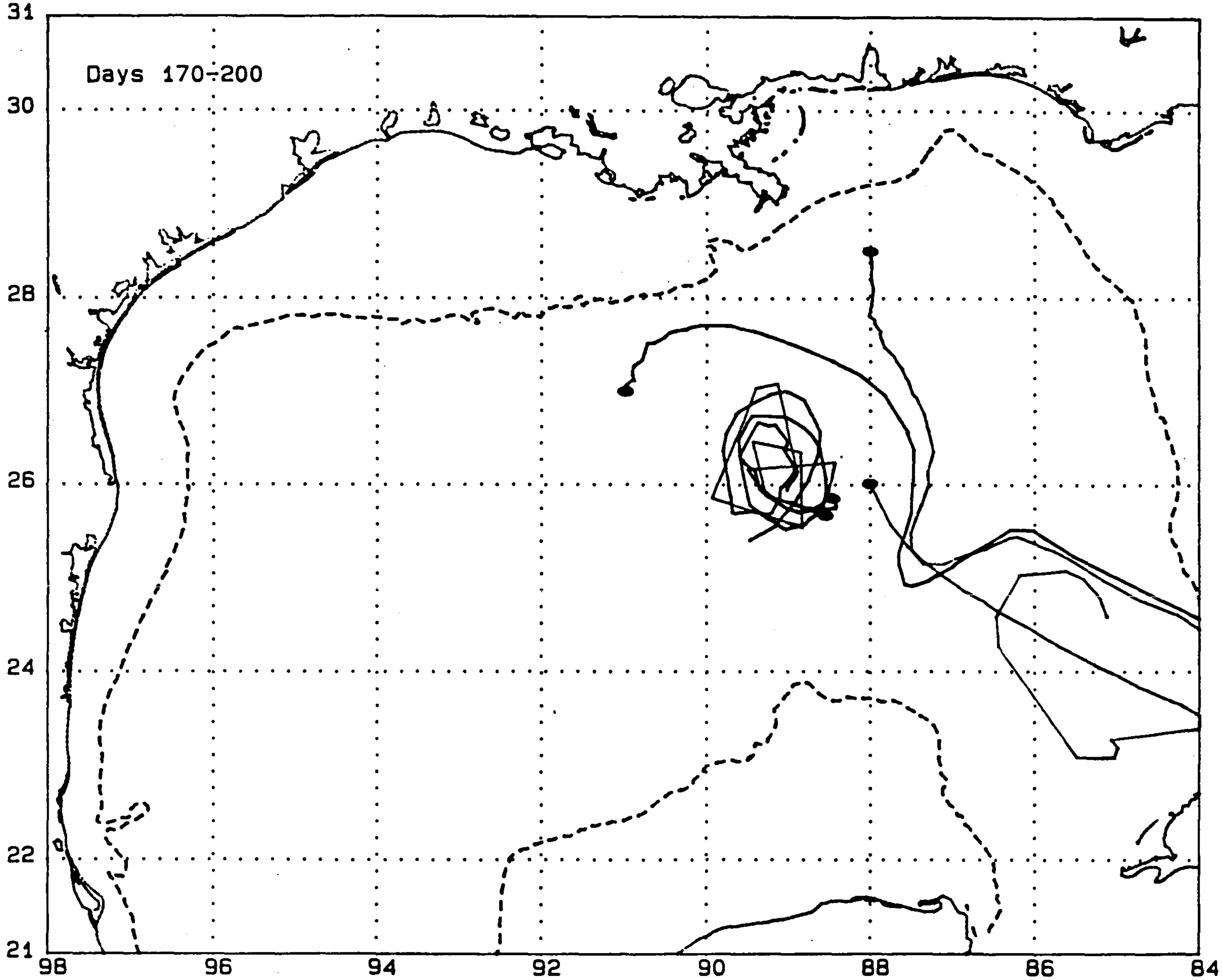


Figure 11.15.--Buoy tracks from Julian days 170-200 in 1985.

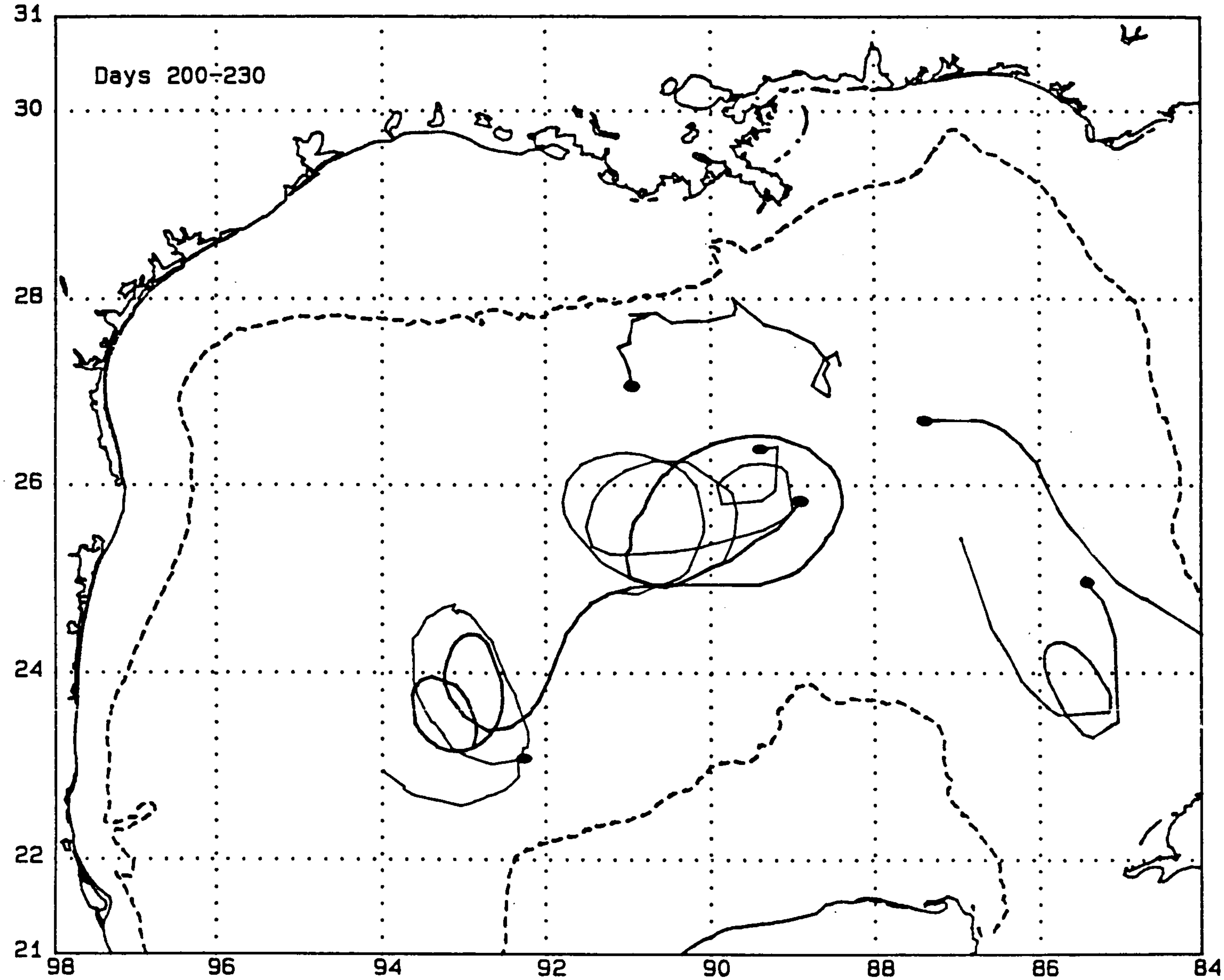


Figure 11.16.--Buoy tracks after Julian day 200 in 1985.

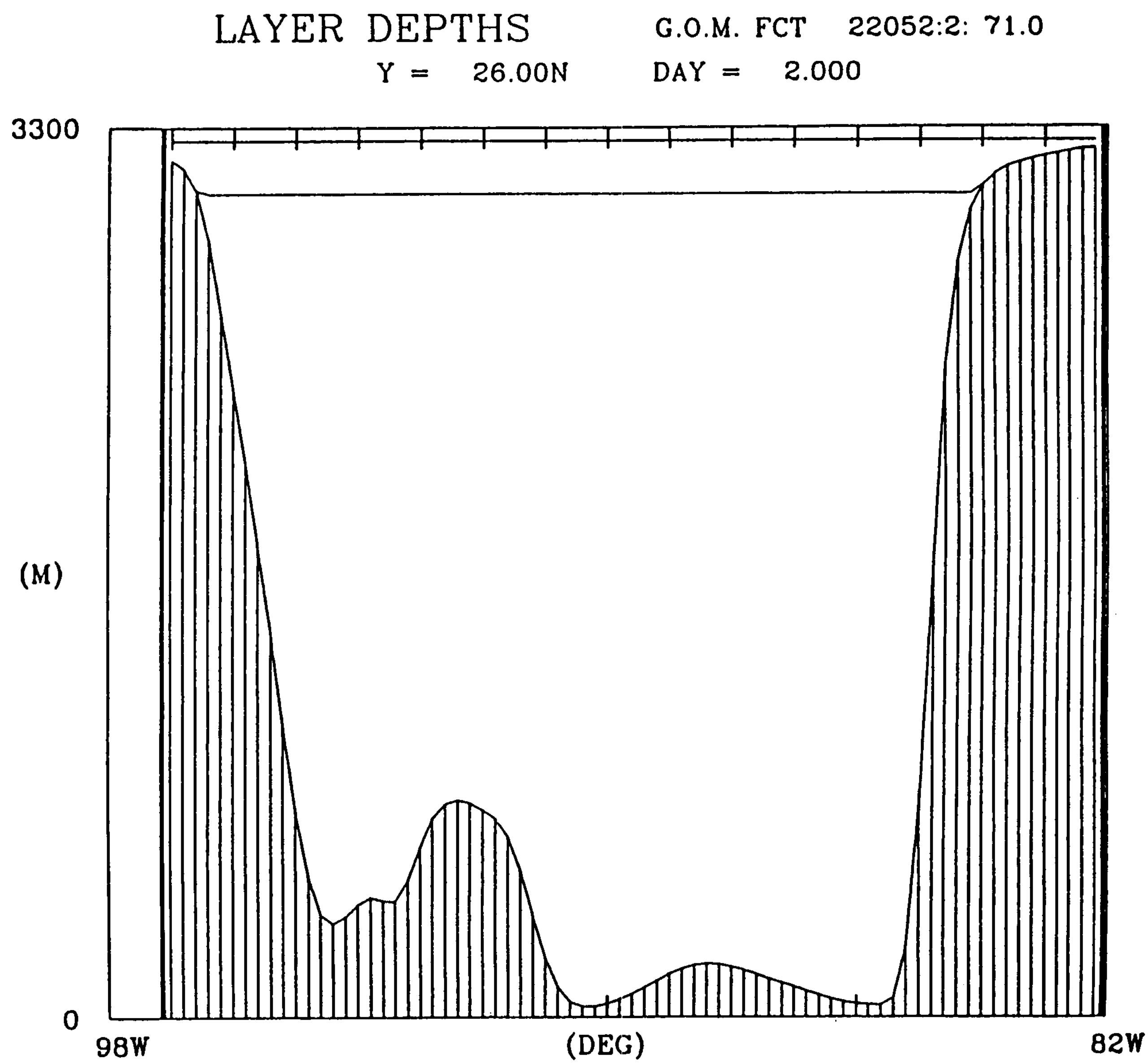
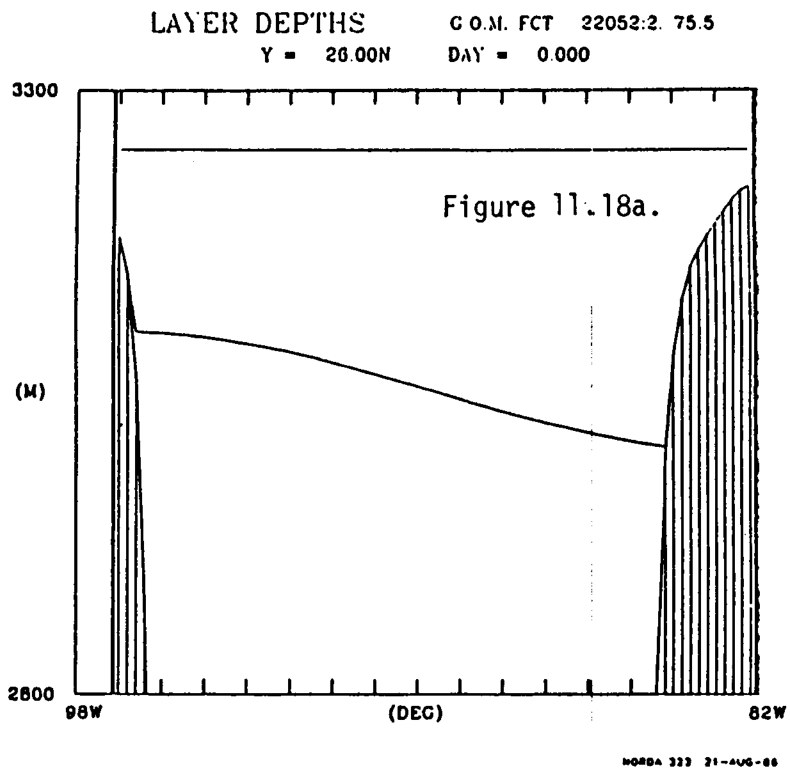


Figure 11.17.--Layer depths for a two dimensional, two layer, hydrodynamic model with full scale bottom topography that uses Flux Corrected Transport to allow the layer interface to 'intersect' the topography. The figure is for day 2 of an experiment testing the stability of the rest configuration in the absence of external forcing. There has been no change over the 2 days. The lower layer is 10 cm thick at all points where the topography appears to intrude into the upper layer.



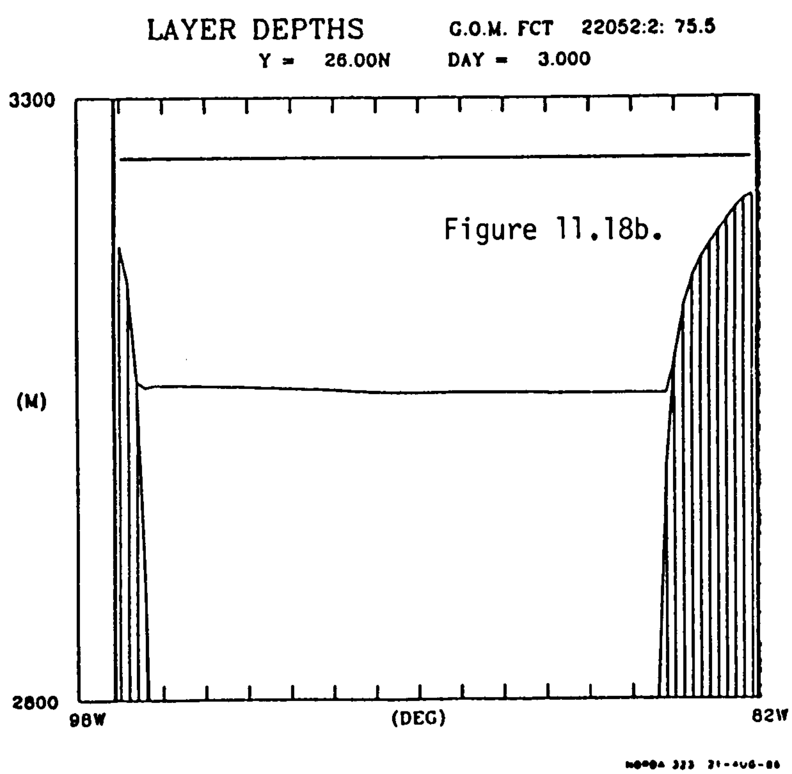
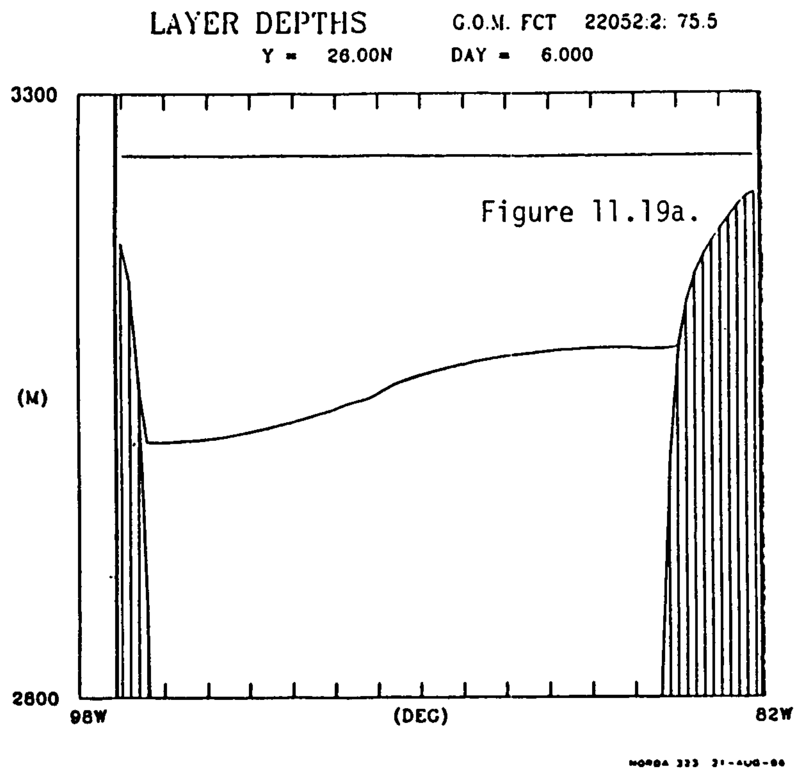


Figure 11.18.--Layer depths for a two dimensional, two layer, hydrodynamic model that uses Flux Corrected Transport to allow the layer interface to 'intersect' the topography. Only the upper 450m of the water column is shown. Figure 11.18a shows day 0 and Figure 11.18b shows day 3.



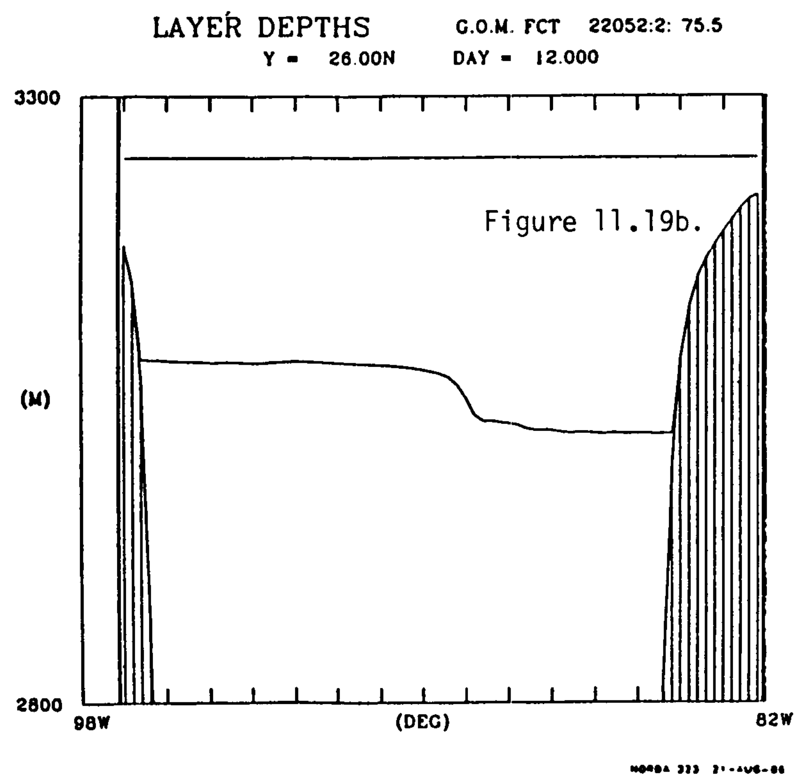
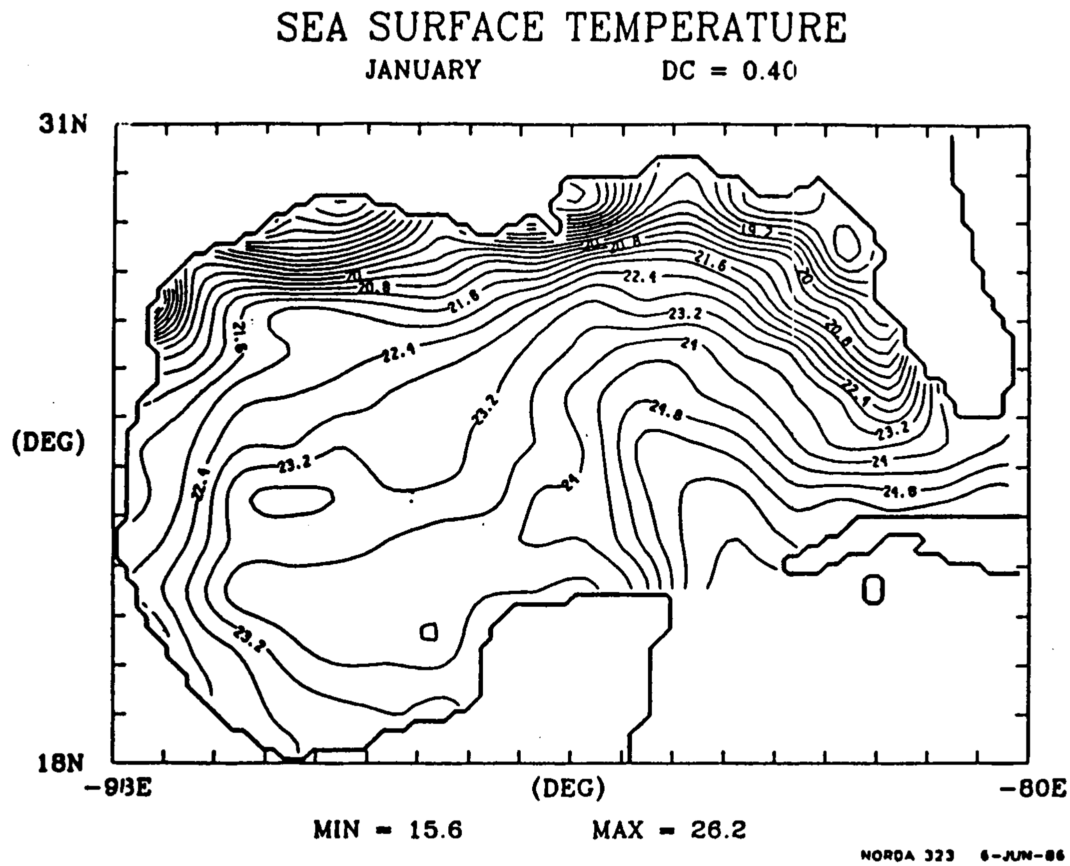


Figure 11.19.--Layer depths for a two dimensional, two layer, hydrodynamic model that uses Flux Corrected Transport to allow the layer interface to 'intersect' the topography. Only the upper 450m of the water column is shown. Figure 11.19a shows day 6 and Figure 11.19b shows day 12. The simulation halted at about day 15 because the interface wave 'breaks'.



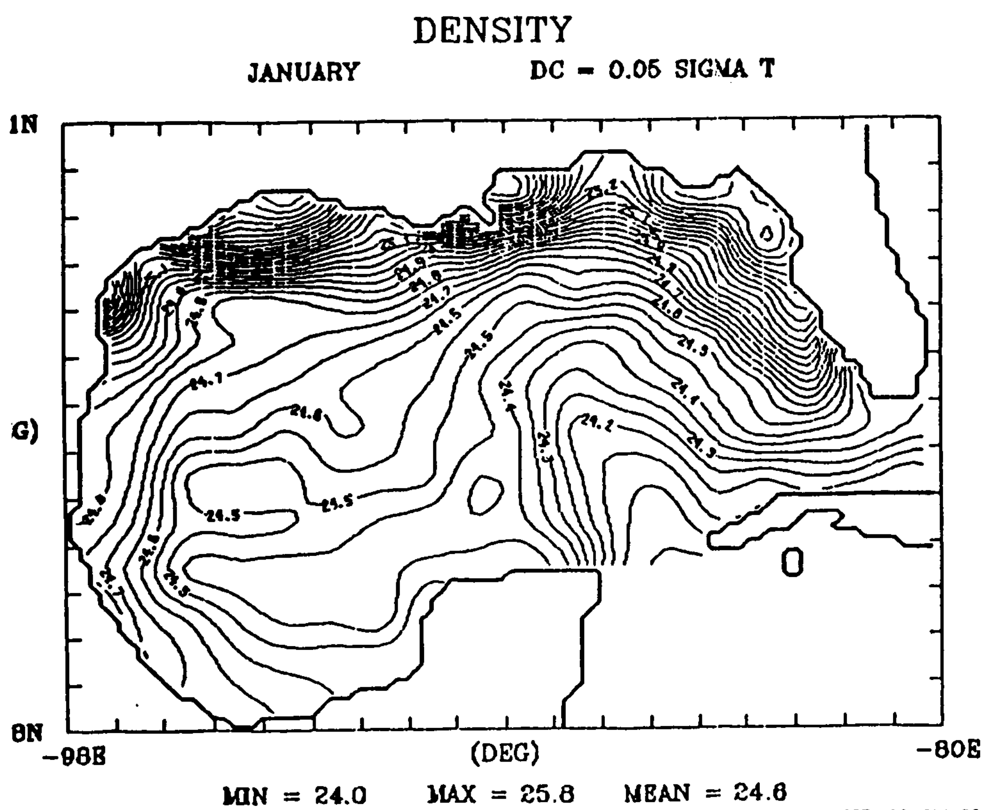
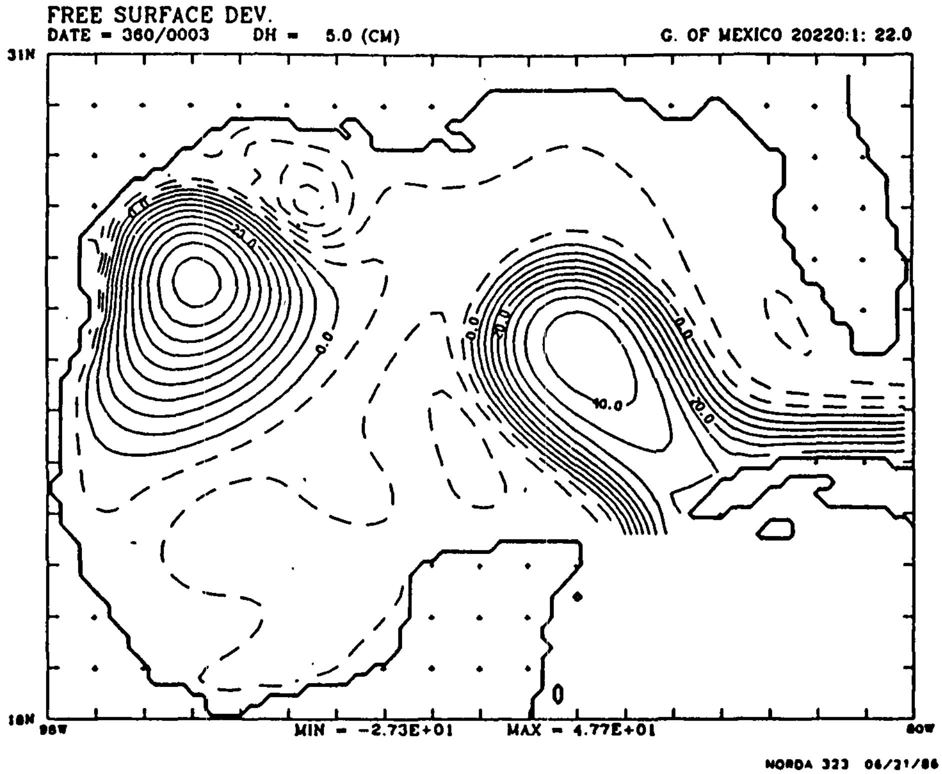


Figure 11.20.--Sea surface temperature and the corresponding calculated upper layer density for January, from a monthly climatology based on historical ship observation data.



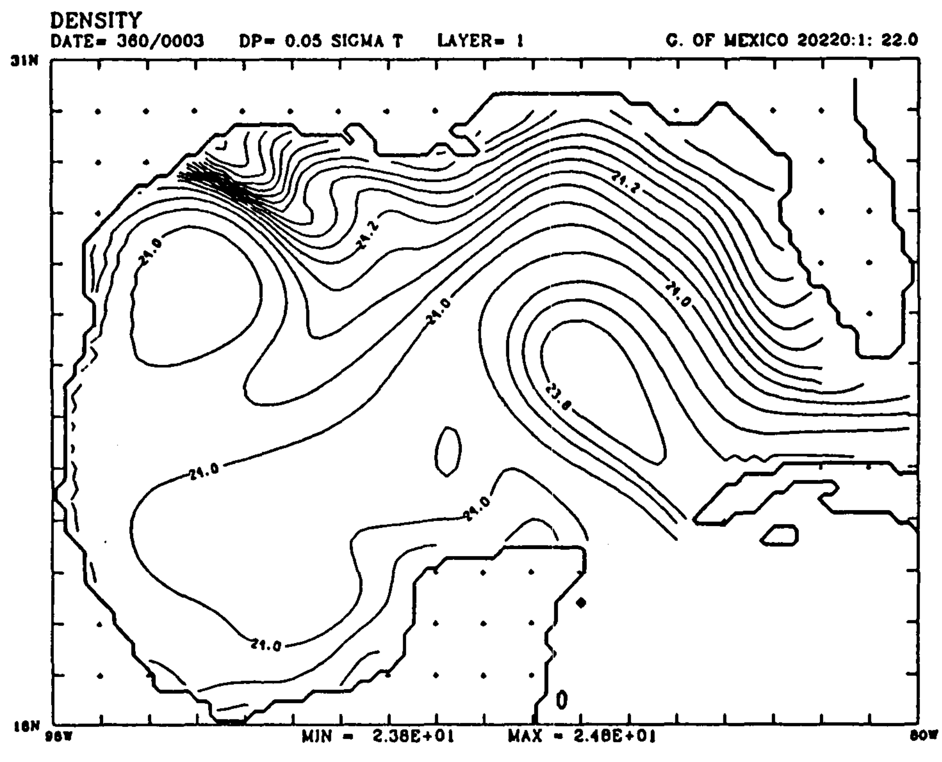


Figure 11.21.--Instantaneous (a) free surface deviation, and (b) upper layer density, from a thermodynamic reduced gravity model of the Gulf with no wind forcing. Snapshots are for December 26 after 4 years of spinup from rest.

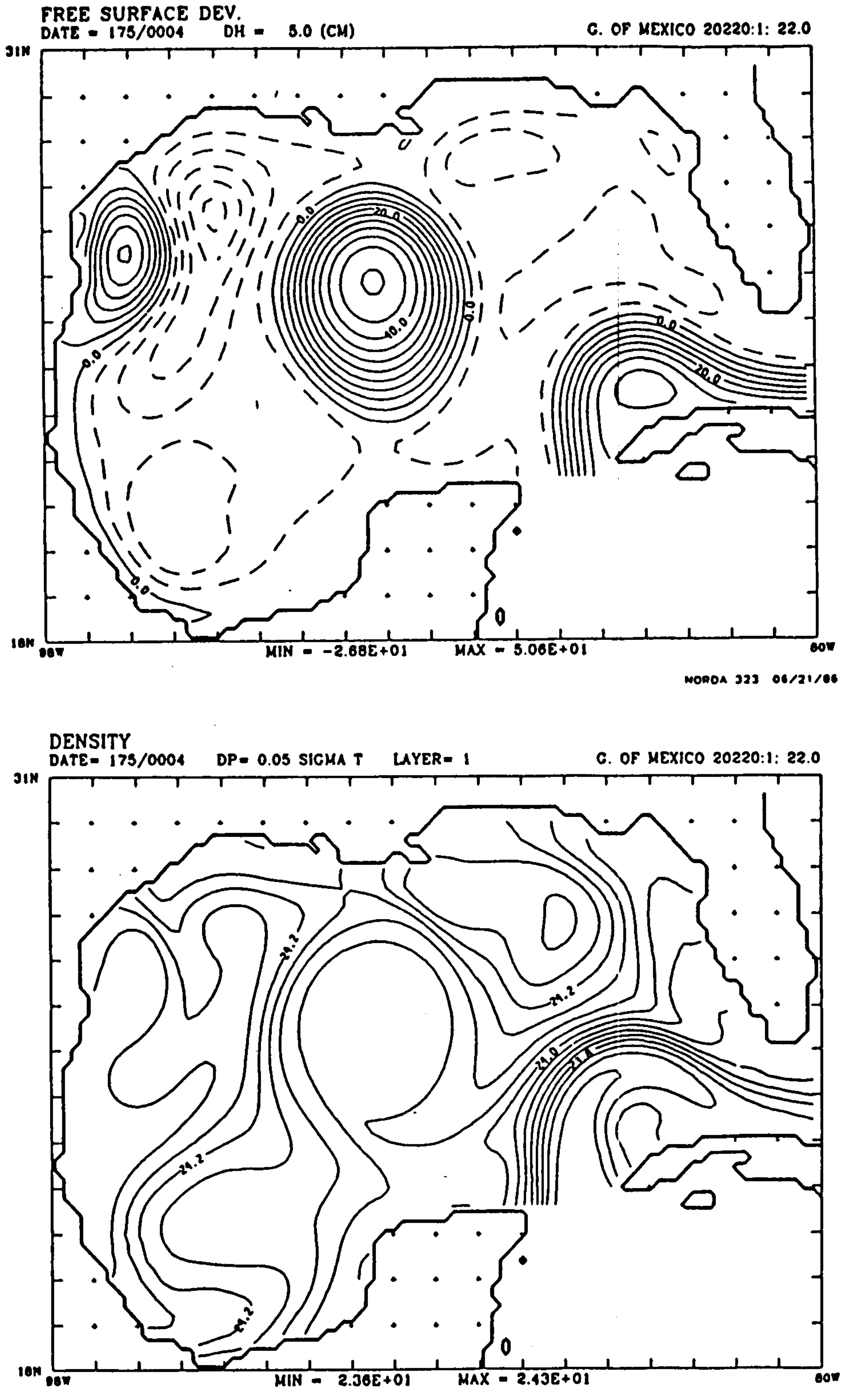


Figure 11.22.--Instantaneous (a) free surface deviation, and (b) upper layer density, from the same simulation as Figure 11.21. Snapshots are for 180 days later than Figure 11.21, i.e., for a day in the summer.

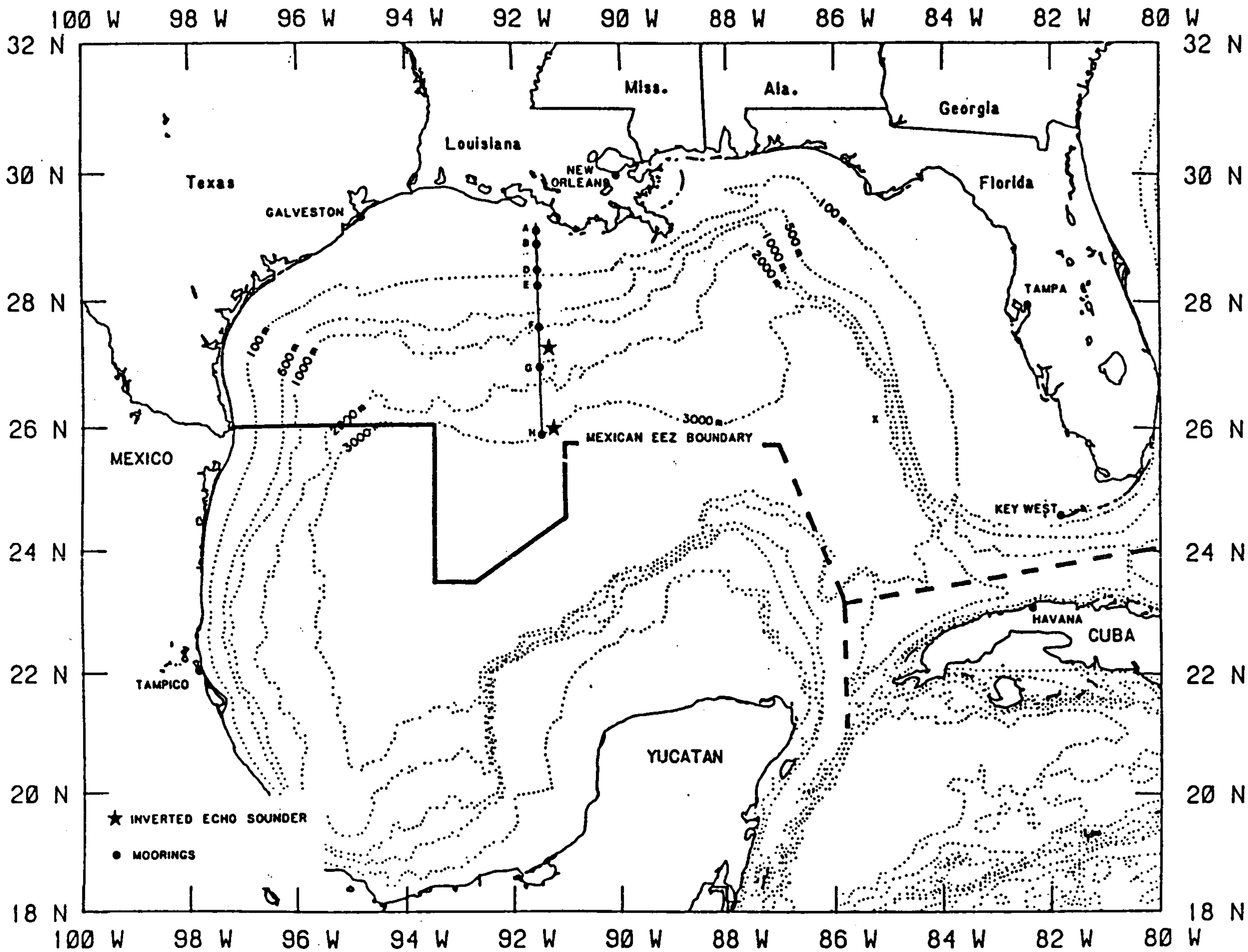


Figure 11.23.--Approximate mooring transect to be occupied during the North-Central Gulf Study.

MARINE ECOLOGICAL STUDIES

Session:	MARINE ECOLOGICAL STUDIES
Chair:	Dr. Robert M. Rogers
Date:	November 6, 1986

Presentation Title	Speaker/Affiliation
Marine Ecological Studies: Session Overview	Dr. Robert M. Rogers Minerals Management Service Gulf of Mexico OCS Region
Effects of Burmah Agate and Alvenus Oil Spills and Natural Events on the Beach Fauna, Galveston, Texas	Dr. Donald E. Harper, Jr. Texas A&M University Marine Laboratory
Establishment of Dune Grasses in Sands Contaminated by Alvenus Oil	Dr. James W. Webb Texas A&M University at Galveston Department of Marine Biology
Recovery of Marsh Vegetation Following Oiling and Cleanup After the Alvenus Oil Spill	Dr. Steve K. Alexander Texas A&M University at Galveston Department of Marine Biology
Oxygen Depleted Waters on the Louisiana Continental Shelf	Dr. Nancy N. Rabalais Louisiana Universities Marine Consortium
The Demersal Fish and Penaeid Shrimp Fauna of the U.S. Gulf of Mexico Continental Shelf: An Ecological Overview	Dr. Rezneat M. Darnell Texas A&M University Department of Oceanography

Marine Ecological Studies: Session Overview

Dr. Robert M. Rogers
Minerals Management Service

In the interest of transferring information between researchers involved with issues relevant to petroleum development and the MMS, this session was established to offer a forum for such an interchange. The need to be informed on the various research efforts in the Gulf of Mexico is vital for formulating the MMS environmental studies program. Although numerous research projects could have been included in this session, a large number of them have been included in other sessions as addressing special problems.

The first three speakers in this session were involved in various problems associated with oil spills, including the determination of effects of oiling vs. clean-up methods on beach fauna, ability of dune plants to recolonize in oiled sands, and effectiveness of clean-up efforts on oiled wetland plants in an enclosed bay.

Hypoxia has long been recognized as a problem of unknown origin in coastal estuaries and on the shallow OCS. The next speaker addresses recent progress toward determining spatial and temporal extent, intensity, and potential causes of oxygen depletion on the continental shelf.

The final speaker has been working under MMS sponsorship to analyze spatial and temporal variations in benthic species, using available databases. An atlas of distribution patterns with ecological considerations in the northwestern Gulf was completed in 1983. A similar bio-atlas in the eastern Gulf is nearing completion and should be printed in the near future.

Dr. Donald Harper of the Texas A&M Marine Laboratory (Galveston) led off a series of three papers on the effects of tanker oil spills on coastal flora and fauna. His presentation concerned effects of Burmah Agate and Alvenus oil spills on the beach fauna of Galveston, Texas. The Burmah Agate oil spill stranded on November 6, 1979 and Alvenus oil spill on August 9, 1984. A major hurricane, Hurricane Allen, passed in August 1980 and also affected beach faunal distributions.

Of three beach sampling sites studied during the three events, only the Spanish Grant beach site remained unaffected by development activities during the course of the study. The Burmah Agate event lightly oiled the study site and continued to receive some oil following clean-up activities. Only the haustoriid amphipods showed any evidence of responding negatively to the oil. However, the contraction in their distribution width may have been due to natural population variation.

Following Hurricane Allen in which no extensive sand was removed from the study site, no apparent effects were noted on population densities, except that centers of distribution of three major groups moved about 10 m landward.

One month after the Alvenus oil spill, there were virtually no organisms on Spanish Grant beach. This may have been attributable to either oil toxicity or the fact that heavy machinery, used to remove contaminated sand, may have also removed the organisms. A later storm removed all trace of oil, along with a considerable amount sand. By October, populations of the polychaete Scololepis began to increase, but no haustoriid amphipods or the bivalve Donax were collected. Haustoriids were still not present two years later.

Dr. James Webb of the Department of Marine Biology of Texas A&M University (Galveston) discussed the establishment of dune grasses in sands contaminated by an oil spill. Approximately 2 million gallons of oil that spilled from the British oil tanker M/T Alvenus washed ashore on Galveston beaches. In beach clean-up operations, approximately 90,000 cubic yards of oil-contaminated sand were picked up and transported to temporary storage areas or used in construction of parking lots behind the dune system.

Experiments, involving planting of dune plants in oiled vs. uncontaminated sands, indicated that the plants survived well in oil-contaminated sands. Survival of dune transplants actually resulted in better survival of plants in the oil-contaminated dune than in the oil-free dune. The amount of oil in the dune sands varied from 3 to 13 mg hydrocarbons/g dry sediment.

Comparison of survival of plants in plastic flower pots showed no significant difference between oiled and non-oiled sands. No seeds germinated and grew in either treatment. Although most of the oil-contaminated sands at the temporary storage site were transported elsewhere, oil-contaminated sands were still present two years after transplant. Two of the original transplant species had spread and created communities dominant in these plants. Many others colonized and grew well despite the amount of oil in the soil (generally over 49 mg hydrocarbons/g dry sediment).

Dr. Steve Alexander, also of the Department of Marine Biology, Texas A&M University (Galveston), discussed the recovery of marsh vegetation following oiling and clean-up after the Alvenus oil spill. Some 2,000 gallons of oil released from the British tanker were carried by high tides into a shallow open-water area behind west Galveston Island. The oil coated some 500 m of fringing marsh.

The shoreline was cleaned by cutting vegetation with a "weed-eater," followed by scraping oil off the sediment surface with a shovel and rake. A survey of the oiled shoreline was made prior to clean-up, 1 month, 3 months, and 11 months after clean-up. All plant species exhibited new growth from remaining roots within one month of clean-up, except *Spartina alterniflora* that had been completely covered with oil. Except for this case, which failed to regrow, vegetative cover along the entire shoreline was similar to that which had occurred prior to oiling. The clean-up of the marsh was effective under these conditions where the marsh was accessible and able to support the weight of the workmen. Two other considerations were the viscous nature of this particular oil and the fact that the plant root systems were largely left intact.

Dr. Nancy Rabalais of the Louisiana Universities Marine Consortium (LUMCON) spoke on oxygen-depleted waters on the Louisiana continental shelf. It has been noted for some time that during the summer there is an extensive and severe hypoxia in bottom waters of the inner continental shelf. The causes of this phenomenon and degree of human activity aggravation of the situation are important in understanding its impacts on this extremely productive area.

Under a program begun by LUMCON in 1985, significant progress has been made toward determining the spatial and temporal extent, intensity, and potential causes of oxygen depletion on the Louisiana continental shelf. The first, shelf-wide survey was conducted at the probable peak of the extent and intensity of hypoxia (15-20 July 1985). Low oxygen bottom waters occurred over 8,000 km^2 of the shelf from 5 to 60 km offshore. The areas of low oxygen extended from 2 to 20 m above the bottom. The low oxygen zone was most intense and extensive in the Mississippi River Delta Bight and westward to Marsh Island. The band narrowed to the Texas border and was confined to 9 to 12 m depth.

The salinity regime in July 1985, illustrated the typical presence of a coastal boundary layer which contained the low salinity runoff of the Mississippi and Atchafalaya Rivers as well as smaller rivers, bayous, and the extensive coastal marsh system. Data suggested complex 3-dimensional circulation patterns associated with the nearshore frontal zones as the processes involved in driving hypoxia rather than strictly vertical flux of organic matter and stratification which inhibits vertical exchange.

In 1986, near-bottom waters, depleted of dissolved oxygen, were found on the Louisiana continental shelf from mid-April through at least mid-October. During a shelf-wide July cruise, dissolved oxygen levels were hypoxic over large areas, about 9,500 km^2 of bottom from 5 to 50 km offshore in depths of 5 to 50 m. The configuration of the area of hypoxia differed from that in 1985 with a larger area being found off southwestern Louisiana, and the area of southeastern Louisiana being smaller. Although the data on water column structure, satellite imagery, chlorophyll levels, and nutrient concentrations indicate that algal blooms on the shelf are the sources of organic matter which upon degradation consume oxygen in bottom waters, the relationship between surface chlorophyll levels and bottom hypoxia is not straightforward. Data suggest that benthic oxygen consumption was fueled by surface production of plankton, but that this production may have emanated from the highly productive, nutrient-rich coastal boundary layer inshore or the Mississippi River plume to the east. Several of the bottom water nutrient concentrations, in particular, silicates and phosphates, were closely related to the bottom water dissolved oxygen levels.

Dr. Rezneat Darnell of the Texas A&M University Department of Oceanography gave an ecological overview of the demersal fish and penaeid shrimp fauna of the Gulf of Mexico continental shelf. In 1980, he began a multidisciplinary synthesis of biological and ecological information concerning Gulf of mexico benthic communities. The first product of this study was an atlas of the Northwestern Gulf of Mexico, published in 1983. The second and final product to be published in the near future is an atlas of the Eastern Gulf. Together, these two volumes characterize the seasonal distribution patterns and ecology of demersal fish and penaeid shrimp species of the U.S. Gulf of Mexico continental shelf from the Rio Grande to the Florida Keys.

The basic data for this study were major bottom-trawling surveys. One survey covered the northwestern Gulf shelf (Rio Grande to the Mississippi River Delta), but 12 data sets were required to cover the eastern Gulf shelf (Mississippi River Delta to the Florida Keys). Once the field-collecting data were obtained, the taxonomy was updated and all catch data were standardized for trawl size, towing speed, and towing time. The resulting catch-per-unit effort information was plotted on standard maps to show the density distribution patterns. For abundant species, seasonal maps were prepared.

For the northwestern Gulf shelf, the dominant shrimp of the genus Penaeus are the brown (*P. aztecus*) and white shrimp (*P. setiferus*). Total fish catch densities tend to be higher nearshore than offshore and higher toward Louisiana than toward the Rio Grande. In terms of depth distribution, individual species fall into four basic groupings: nearshore, outer shelf, mid-shelf and trans-shelf groups. Individual species are affiliated with fine or coarse bottoms, and some show aggregations off tidal passes or the mouths of larger rivers.

For the eastern Gulf shelf, the dominant shrimp of the genus *Penaeus* is the pink shrimp (*P. duorarum*). The density distribution pattern of the total fish catch tends toward a patchy distribution with high densities associated with particular habitats. Individual species do show depth distribution groupings, but not as clearly as in the northwest. A few individual species are associated with fine or coarse bottoms. In the eastern Gulf many of the shelf species appear to exist as semi-isolated populations, each characterized by its own distinct depth distribution and seasonal patterns.

The demersal ichthyofauna of the eastern Gulf shelf is far richer than that of the northwest and is represented by more than twice as many species and over eight times as many unique species. The high species diversity of the eastern Gulf shelf reflects (a) habitat diversity, (b) availability of highly productive "live bottom" communities, (c) the dynamic nature of the benthic environment, and (d) West Indies colonization. From a zoogeographic standpoint, the U.S. Gulf continental shelf fish fauna includes three recognizable faunas: the northwestern Gulf fauna (Rio Grande to Mississippi River Delta), Mississippi Bight fauna (Mississippi River Delta to near the DeSoto Canyon), and the peninsular Florida fauna (DeSoto Canyon to the lower Keys).

RECOMMENDATIONS

From the series of presentations of oil spill impacts and clean-up, a number of conclusions and recommendations were made. Beach sands that are contaminated by spilled oils can be used in existing dune systems. Common dune plants can colonize or be transplanted into crude oil-contaminated sands successfully. The crude oil actually helps prevent dunes created by bulldozers from being leveled by wind because sand particles adhere to each other and do not move easily with strong winds. The undesirable aesthetic quality of black colored dunes will be ameliorated as new sand blows into the dunes and colonizing plants cover the soil surface. A drawback to placement of oiled sand into dunes is that if hurricane- or other storm-pushed tides reach the dunes, wave action may carry oil-contaminated sand from the dune, back to the beach or across the island in overwash fans. The chance of significant amounts of oil reappearing on the beach is probably minor because of the infrequency of hurricanes and the relatively low ratio of oiled to nonoiled-sands.

Dr. Darnell made a number of recommendations relevant to the maintenance of ecological integrity in the face of mineral resource development. For both the northwestern and eastern Gulf shelves, the following recommendations were put forth: need for maintenance of coastal wetlands and special shelf habitats (species spawning grounds, reefs, areas off tidal passes and river mouths, and habitat of rare species); need for care in dumping dredged materials and in undertaking across-shelf channelization; and need for special research studies (effects of commercial pollutants, cumulative and long-term effects of petroleum-related activities, and functional dynamics of shelf ecosystems). Additionally, for the Eastern Gulf shelf it was recommended that the seagrass beds be afforded special protection and that studies should be carried out to obtain better understanding of the current patterns and the life histories of key species of each major habitat type.

Dr. Robert M. Rogers is an oceanographer on the Environmental Studies Staff of the MMS Gulf of Mexico Region OCS. He has served as Contracting Officer's Technical Representative (COTR) on numerous marine ecosystem studies. Recently this has included a study of seagrass distributions off the Florida Big Bend and a synthesis of environmental information on the Mississippi/Alabama OCS. Dr. Rogers received his B.S. and M.S. degrees in zoology from Louisiana State University and his Ph.D. in marine biology from Texas A&M University.

Effects of Burmah Agate and Alvenus Oil Spills and Natural Events on the Beach Fauna, Galveston, Texas

Dr. Donald E. Harper, Jr.
Texas A&M University

The beach fauna of Galveston, Texas has been sampled periodically to determine the response of resident species to the impacts of oil spills and habitat removal caused by major climatic events. Three taxa, haustoriid amphipods, Scololepis squamata polychaetes and Donax spp. bivalves numerically dominate the fauna. These three taxa inhabit distinct, but overlapping areas of the mid and lower intertidal zones with haustoriids occurring highest in the intertidal and Donax lowest. Other organisms which occur in large enough numbers to be considered include the mole crab Emerita sp. and the polychaete Lumbrineris sp.

The responses of these organisms to three events are presented: the Burmah Agate oil spill which stranded on 6 November 1979, Hurricane Allen which passed over the lower Gulf of Mexico in August 1980, and the Alvenus oil spill which stranded on 4 August 1984.

Three beaches on Galveston Island were sampled following the Burmah Agate spill. All three beaches were oiled and the organismal response was virtually identical at the three beaches. Only the Spanish Grant site was sampled periodically after the Burmah Agate spill and is used here as the representative beach. The other two beaches were so radically altered by development activities that it is impossible to locate benchmarks. Samples were collected at weekly intervals, beginning on 6 November 1979, for four weeks, then monthly until December 1980. Hurricane Allen removed much of the beach in August 1980.

The Spanish Grant site and two beaches on Bolivar Peninsula, Rollover Pass, and High Island, were sampled following the Alvenus spill. High Island beach received no oil. Rollover Pass was lightly oiled, and Spanish Grant was heavily oiled. Samples were collected at monthly intervals for three months following the spill.

Sample collection and analysis for monitoring purposes began again at Spanish Grant in June 1986. These data have provided follow-up information on the effects of the Alvenus spill.

BURMAH AGATE OIL SPILL

The Spanish Grant site was lightly oiled on 6 November 1979, and apparently continued to receive some oil after the initial clean-up because bands of oil were found 2-3 cm below the surface during subsequent investigations one to two months after the spill. The effects of this spill appeared to be negligible; only the haustoriid amphipods showed any evidence of responding negatively to the oil. This response was a contraction in the width of the zone they occupied and was only evident two weeks after the spill. The contraction may be real because the haustoriids occupy the upper portion of the intertidal where oil is most likely to stick to the sand. It is entirely possible, however, that the apparent contraction was within the range of natural population variation.

HURRICANE ALLEN

Spanish Grant beach was sampled before and after the passage of Hurricane Allen across the southern Gulf of Mexico. Analyses of beach profiles showed that about 30 m of back beach, including a 2.3 m high dune, were removed and that about 1.6 m of sand was removed from the mid intertidal region of the beach. The event, however, had no apparent effect on the population densities of beach organisms. The only difference in pre- and post-storm data was that the centers of distribution of the three major groups of organisms had moved about 10 m landward.

ALVENUS OIL SPILL

Alvenus oil first stranded on 4 August 1984. Some of the oil sank and was trapped between the offshore bars, and oil kept stranding after the surface slick was gone. Pre-spill data indicated that High Island had normal abundances of haustoriids and Scololepis, but there were no Donax. Both haustoriids and Donax were absent from Rollover Pass beach, which had much coarser sand than the other two beaches. Pre-spill data were not collected at Spanish Grant but qualitative samples collected on 8 August 1984 indicated that the three major taxa were present in their respective positions on the beach. One month after the spill, there were virtually no organisms on Spanish Grant beach, whereas populations were unchanged on Rollover Pass and High Island beaches. The absence of Spanish Grant beach fauna may be attributable to either toxicity of the oil, or to the fact that road graders and front end loaders were used to remove contaminated sand from the beach and may have also removed the organisms. All traces of Alvenus oil were removed from the beaches, along with a considerable amount of sand, by a gale force on 20-21 September 1984.

Collections in September and October 1984 revealed that populations of haustoriids and Scololepis had decreased somewhat at High Island and Rollover Pass. At Spanish Grant, populations of Scololepis began to increase, but no haustoriids or Donax were collected. Haustoriids were still not present at Spanish Grant on 16 August 1986, and relatively few Donax were collected.

The absence of haustoriids may be explained by the fact that amphipod larvae are not planktonic. Eggs are carried and hatch in marsupia, and dispersion is accomplished by "rafting", lateral current transport or swimming of the adult. Thus, repopulation of a depopulated beach could be quite slow. Scololepis has a planktonic larval stage and repopulation can occur more quickly. Donax also has a planktonic larval stage and the reason for low numbers two years after the spill may pertain more to natural population fluctuations than to perturbations on the beach.

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

Establishment of Dune Grasses in Sands Contaminated by Alvenus Oil

Dr. James W. Webb
Texas A&M University at Galveston

On 30 July 1984, an estimated 10,157 metric tons (MT) of Venezuelan crude oil were spilled from the British oil tanker M/T Alvenus into the Gulf of Mexico 16.1 km south of Cameron, Louisiana. The oil slick drifted southwesterly for 160 km to Galveston Island, Texas where 2,700 MT of oil drifted onto beaches. Initial landfall was August 4, 1984. Although all oil was categorized as a heavy viscous crude, two types of crude oil, Merey and Pilon, were in the holds of M/T Alvenus. Both types had relatively high specific gravities (0.958-0.978). Approximately 70% of the fresh crude oil was composed of insoluble high molecular weight asphaltenes. The oils also contained a large fraction of aromatic hydrocarbons. However, oil collected from the beaches and seawall rocks in August contained no low molecular weight aromatics, apparently because of weathering that had occurred.

Approximately 2 million gallons of oil washed ashore. Since Galveston beaches are highly used by tourists and residents of Galveston and nearby cities such as Houston, beaches with oil were not considered suitable for use by residents or visitors. It was necessary to scrape up sand to remove the oil because much of the oil penetrated the sand. Approximately 90,000 cubic yards of oil-contaminated sand were picked up. Some consideration was given to placement of the oil-contaminated sand in the dune system, but there was uncertainty as to the ability of plants to grow in the sand. The sand was transported to temporary storage areas or used in construction of parking lots behind the dune system.

Research was initiated in September 1984 to determine whether dune plants could grow in dunes created from oil contaminated sands. Since there were no actual oil contaminated dunes, one phase of the study was conducted on a sand storage site at Scholes Airport. One side of the storage pile had a 60% slope that was comparable to typical dunes. Four replications of 15 transplants of three species of dune plants, Panicum amarum, Spartina patens, and Sporobolus virginicus, plus seeds of S. patens were placed into the material on 11 September 1984. P. amarum consisted only of 1-2 foot tops of plants while the other two species had roots and stems. The plants were checked for survival and emerging seedlings on October 5 and 16 and November 7, 1984. In October 1986, the communities created were observed, and biomass measured. The total amount of hydrocarbons in the sediment was determined.

During a second phase of the study, transplants and seeds of S. patens and Sporobolus virginicus, cuttings of P. amarum, and a hybrid variety of P. amarum seeds were placed outdoors in plastic flower pots with Alvenus oil-contaminated sand or oil-free sand. The plants were watered twice a week for two and one-half months. Data on survival and seed germination were made October 25 and November 7, 1984.

On 11 September 1986, four replications of 25 transplants of S.

patens and 25 cuttings of P. amarum were placed in a dune. The dune was created by pushing Alvenus oil-contaminated sand from a parking lot into the line of dunes. A non-contaminated area was planted in a similar manner. Survival was monitored and amount of hydrocarbons in the sediment was determined.

SIGNIFICANT FINDINGS

Dune plants survived well in oil-contaminated sands in all experiments. All three species, including seeds of S. patens, transplanted in oil contaminated sands at Scholes field had some survival. By November 7, survival was 40% for S. patens, 33% for Sporobolus virginicus, 28% for seeds of S. patens, and 13% for P. amarum.

Comparison of survival of plants in plastic flower pots showed no significant difference between oiled and non-oiled sands. No seeds germinated and grew in either treatment. By November 7, 1984, S. patens had 50% survival in oiled sands and 37.5% in non-oiled sands. P. amarum had 31.3% survival in both treatments.

Survival of dune transplants in 1986 actually resulted in better survival of both species in the oil-contaminated dune than the oil-free dune. On October 28 there was 81% survival in oiled sands and 61.6% survival in non-oiled sands for S. patens. For P. amarum there was 28% survival in oiled sands and only 0.8% survival in non-oiled sands. The difference was statistically significant ($P<0.05$) for P. amarum but it was not significant for S. patens. The amount of oil in the dune sands varied from 3 to 13 mg hydrocarbons/g dry sediment.

Although most of the oil-contaminated sands at Scholes field were transported elsewhere, oil-contaminated sands were still present in 1986 at the site of the 1984 transplants. Two of the original transplant species, P. amarum and S. patens, had spread and created communities dominated by those species. Over 1,000 g/m of plants occurred in each of three transplant areas. Other plant species, such as, Cynodon dactylon, Cyperus ordoratus, Stenotaphrum secundatum, Sesbania drummondii, and Heterotheca subaxillaris colonized and grew well despite the amount of oil in the soil. These sands generally contained over 49 mg hydrocarbons/g dry sediment.

CONCLUSIONS AND RECOMMENDATIONS

Beach sands that are contaminated by spilled oils can be used in existing dune systems. Common dune plants can colonize or be transplanted into crude, oil-contaminated sands successfully. The crude oil actually helps prevent dunes created by bulldozers from being leveled by wind because sand particles adhere to each other and do not move easily with strong winds. The undesirable aesthetic quality of black colored dunes will be ameliorated as new sand blows into the dunes and colonizing plants cover the soil surface. A major drawback to placement of oiled sand into dunes is that if hurricane or other storm-pushed tides reach the dunes, wave action may carry oil-contaminated sand from the dune back to the beach or across the island in overwash fans. The chance of significant amounts of oil reappearing on the beach is probably minor because of the infrequency of hurricanes and the relatively low amounts of oiled-sands compared to nonoiled-sands that would be distributed to the beach and off-shore bars. In conclusion, oil-contaminated sands resulting from crude oil spills should be placed into the dune system and be transplanted. This would help to preserve the sand that is already in short supply. S. patens appears well suited for transplanting into oil-contaminated dune systems.

Dr. James W. Webb is an Assistant Professor in the Marine Biology Department of Texas A&M University at Galveston. The study of dune plant growth in oil-contaminated sands is closely related to on-going research on effects of oil spills on salt marsh plants. Dr. Webb's primary research interest deals with plant ecology, particularly interactions of plants with wildlife and human induced perturbations. Dr. Webb received his Ph.D. in range science from Texas A&M University, M.S. degree in wildlife biology from the University of Georgia, and B.S. in biology from the University of South Carolina.

Recovery of Marsh Vegetation Following Oiling and Cleanup After the Alvenus Oil Spill

Dr. Steve K. Alexander
Texas A&M University at Galveston

The British tanker Alvenus ran aground 10 miles south of Cameron, Louisiana, on July 30, 1984. Grounding caused a rupture in the No. 2 tanks, which released 3 million gallons of Venezuelan crude oil into the Gulf of Mexico. The oil traveled westward along the coast for four days, prior to landfall on the western tip of Bolivar Peninsula and west Galveston Island, Texas. The largest concentration of oil, 1.8 million gallons, made landfall on the beaches of west Galveston Island on the morning of August 4, 1984.

Before beachfront cleanup could be completed on west Galveston Island, an estimated 2,000 gallons of oil was carried by high tides into a shallow open water area behind the beach. The oil coated 500 m of fringing marsh, dominated by Distichlis spicata, Eleocharis sp., Paspalum vaginatum, Phragmites australis, Scirpus americanus, Spartina alterniflora, and Spartina patens.

Removal of oil from the marsh shoreline was initiated by cleanup crews within two days. The shoreline was cleaned by cutting vegetation with a "weed-eater" followed by scraping oil off the sediment surface with a shovel and rake. This method appeared successful in removing oiled vegetation and the majority of oil, with minimal disturbance of plant roots. Cleanup of the entire shoreline was completed within 8 days.

A survey of the oiled shoreline was made prior to cleanup and 1, 3, and 11 months after cleanup. For each survey, a visual determination was made of plant species and relative abundance at each 10 m interval; a photograph was taken at each 20 m interval. During the survey prior to cleanup, the shoreline edge was marked with a wooden stake at each 20 m interval. Shoreline position relative to each stake was noted during each subsequent survey.

All plant species exhibited new growth from remaining roots within 1 month of cleanup, except S. alterniflora that had been completely covered with oil. The latter failed to exhibit new growth throughout the monitoring period, while S. alterniflora, only partially covered with oil exhibited excellent regrowth. By 11 months, vegetative cover along the entire shoreline was similar to that which had occurred prior to cleanup. Little or no change in shoreline position relative to wooden stakes was noted throughout the monitoring period.

The success of cleanup was likely due to several factors, including the accessibility of the marsh and its ability to support the weight of workmen (sandy bottom). Also, removal of oil from the sediment surface was aided by the viscous nature of the oil, which prevented penetration into the substrate. Lastly, plant root systems, left largely intact by cleanup, were able to recolonize the shoreline rapidly.

These results indicate that cleanup of marshes can be effective in certain situations. Therefore, cleanup should be considered a response alternative to mitigate oil impact in marsh areas.

Dr. Steve K. Alexander is an Assistant Professor of Marine Biology at Texas A&M University at Galveston. He received his M.S. and Ph.D. in marine sciences from Louisiana State University. His research has concentrated on fate and effects of oil in estuarine environments. He has been especially instrumental in developing guidelines for effective oil spill response in marshlands.

Oxygen Depleted Waters on the Louisiana Continental Shelf

Dr. Nancy N. Rabalais
Louisiana Universities
Marine Consortium

INTRODUCTION

Until the program sponsored in 1985 by NOAA's Ocean Assessments Division and Sea Grant Program, the Louisiana Universities Marine Consortium, and Louisiana State University, little focused study had been conducted on the annual phenomenon of oxygen-depleted bottom waters on the continental shelf off Louisiana. The potentially enormous consequences of oxygen depletion to living resources are of regional and national concern. The continental shelf and estuarine waters of the northern Gulf of Mexico yield over one-fourth of the fisheries biomass landed in the U.S., yet the inner continental shelf is the site of extensive and severe hypoxia in bottom waters during the summer. It is clear that the catch rates of penaeid shrimp and demersal fishes are reduced or virtually zero when bottom waters are hypoxic (<2 mg/l) (Pavela et al., 1983; Renaud, 1986). The degree to which human activities may be involved in the development or aggravation of oxygen depletion is unknown, but comparable conditions have been documented in several regions of the world's coastal environments.

SIGNIFICANT FINDINGS

We have made significant progress toward determining the spatial and temporal extent, intensity, and potential causes of oxygen depletion on the Louisiana continental shelf (Rabalais et al., 1986 a,b). Sampling began in mid-June 1985 and has continued to the present. Hypoxic and anoxic bottom waters were present in the Mississippi River Bight through the summer of 1985. Hypoxia occurred in water depths of 6 to 30 m, from 2 to 45 km offshore, and up to 12 m above the bottom. Hypoxic conditions continued off southeastern Louisiana through mid-August with some variability in the shoreward encroachment, extent above the bottom, and dissolved oxygen concentration (Figure 12.1).

Our first shelf-wide survey was conducted probably at the peak of the extent and intensity of hypoxia (15-20 July 1985). We plotted the occurrence of low oxygen bottom waters over 8,000 km^2 of the shelf from 5 to 60 km offshore in depths of 5 to 60 m (Figure 12.2). The areas of low oxygen extended from 2 to 20 m above the bottom. The low oxygen zone was most intense and extensive in the Mississippi River Delta Bight and westward to Marsh Island. The band narrowed to the Texas border and was confined to 9 to 12 m depth.

The salinity regime in July 1985 illustrated the typical presence of a coastal boundary layer which contained the low salinity runoff of the Mississippi and Atchafalaya Rivers as well as smaller rivers, bayous, and the extensive marsh system of coastal Louisiana. The bottom salinity field was dominated by the intersection of the bottom with the front separating the low salinity coastal waters from the mid-shelf waters. The maximum surface-to-bottom density differences were seaward of this bottom salinity front. It appeared that the core of minimum oxygen concentrations was offshore of the frontal boundary of bottom salinities and bottom densities and was less associated with the core of surface-to-bottom density differences. These data suggest complex 3-dimensional circulation patterns associated with the nearshore frontal zones as the processes involved in driving hypoxia, rather than the strictly vertical flux of organic matter and stratification which inhibits vertical exchange.

In 1986, near-bottom waters depleted of dissolved oxygen were found on the Louisiana continental shelf from mid-April through at least mid-October. In late March, oxygen concentrations fell below 2.5 mg/l in 10 m water depth. By mid-April, oxygen concentrations below 2 mg/l, and some below 1 mg/l, were present at the seabed in 10 to 19 m depth. Through most of the summer, hypoxia was present at 10 to 25 m water depths.

During a shelf-wide cruise in 1986 (7-17 July), dissolved oxygen levels were hypoxic over large areas, about 9,500 km^2 of bottom from 5 to 50 km offshore in depths of 5 to 50 m (Figure 12.2). The configuration of the area of hypoxia differed form that in 1985 with a larger area being found off southwestern Louisiana and the area off southeastern Louisiana being smaller.

Water column structure and chlorophyll levels and nutrient concentrations differed in 1986 from conditions found in 1985. Surface waters lower in salinity, higher in chlorophyll, and higher in nitrate were present across the shelf in 1986, whereas in the summer of 1985 these conditions were usually limited to the nearshore areas. Also, chlorophyll levels were generally greater in surface waters than in bottom waters, as opposed to 1985 when chlorophyll levels were normally higher near the bottom. Unusually and consistently high phaeopigment concentrations were not found in the bottom waters of hypoxic areas in the 1986 season as they were in summer 1985. A highly stratified water column persisted through September 1986 and continued to be moderately stratified through mid-October. In 1985, stratification broke down and bottom waters were oxygenated by mid-August as a result of the passage of Hurricane Danny and a low pressure system.

Data presented in Leming and Stuntz (1984) based on satellite imagery suggested that algal blooms on the shelf were the sources of organic matter which upon degradation consumed oxygen in bottom waters. Our results from 1985 and 1986 showed that the relationship between surface chlorophyll levels and bottom hypoxia is not straightforward. Highest surface chlorophyll concentrations (>5 ug/l) were found inshore, of or along the inner margin of, the oxygen-depleted zone. Pigment concentrations were also higher toward the Mississippi River Delta. Under conditions of severe hypoxia, bottom pigment concentrations were generally higher than those at the surface. Also, a greater proportion of the total plant pigments was composed of phaeopigments (i.e., degradation products) in the bottom waters, compared to the surface waters. The data suggest that consumption of oxygen in bottom waters was fueled by surface production of plankton, but that this production may have emanated from the highly productive, nutrient-rich coastal boundary layer inshore or the Mississippi River plume to the east.

Several of the bottom water nutrient concentrations, in particular, silicates and phosphates, were closely related to the bottom water dissolved oxygen levels. Bottom silicates increased as bottom dissolved oxygen levels decreased, and they were extremely high (>30 ug at/l) where bottom dissolved oxygen fell below 0.5 ug/l. This indicates diatoms as a source of planktonic material decomposition on the bottom. Phosphate in bottom waters increased as the dissolved oxygen decreased. Above 0.5 mg O_2/l, phosphate is a degradation product of organic material, primarily phytoplankton, in this case. Below 0.5 mg O_2/l, the high phosphate levels were related to anaerobic conditions and the nitrogen chemistry in these conditions, which is not clear at this point.

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Dr. Nancy N. Rabalais is an Assistant Research Scientist at Louisiana Universities Marine Consortium in Cocodrie, Louisiana. Dr. Rabalais received her B.S. and M.S. in biology from Texas A&M University and her Ph.D. in zoology from The University of Texas at Austin. She has participated in several NOAA-funded research programs concerning oxygen depletion and eutrophication in the Gulf of Mexico. The project described above is cooperative between the Louisiana Universities Marine Consortium and Louisiana State University and benefits from the combined efforts of R.E. Turner, Wm. J. Wiseman, Jr., and D.F. Boesch.

The Demersal Fish and Penaeid Shrimp Fauna of the U.S. Gulf of Mexico Continental Shelf: An Ecological Overview

Dr. Rezneat M. Darnell
Texas A&M University

In 1980, under sponsorship of MMS (then BLM) I began working on a multidisciplinary synthesis of biological and ecological information concerning bottom communities of the U.S. Gulf of Mexico continental shelf. It was originally conceived that I would survey the published literature, but it early became evident that an analysis of existing but unpublished databases would be considerably more informative. These databases have now been obtained and analyzed. The first product of the study, Northwestern Gulf Shelf Bio-Atlas, was published in 1983. The second and final product, Eastern Gulf Shelf Bio-Atlas, has also been completed and should be available for distribution in early 1987. Together, these two volumes characterize the seasonal distribution patterns and ecology of the demersal fish and penaeid shrimp species of the U.S. Gulf of Mexico continental shelf from the Rio Grande to the Florida Keys.

The basic data for this study were major bottom trawling surveys. One survey covered the northwestern Gulf Shelf (Rio Grande to the Mississippi River Delta), but twelve data sets were required to cover the eastern Gulf shelf (Mississippi River Delta to the Florida Keys). The combined databases represent more than two and a half million specimens. Once the field collecting data were obtained, the taxonomy was updated, and all catch data were standardized for trawl size, towing speed, and towing time. The resulting catch per unit effort information was plotted on standard maps to show the density distribution patterns. For abundant species, seasonal maps were prepared. The density distribution patterns have permitted analysis of individual species as well as multi-species assemblages. Management implications have also been addressed. The following discussion briefly summarizes some of the results of this study.

For the northwestern Gulf shelf the dominant shrimp of the genus Penaeus are the brown (P. aztecus) and white shrimp (P. setiferus). The density distribution of the total fish catch (all species combined) shows a double gradient (Figure 12.3). Densities tend to be higher nearshore than offshore and higher toward Louisiana than toward the Rio Grande. In terms of depth distribution, individual species fall into four basic groupings: nearshore, outer shelf, mid-shelf, and trans-shelf groups. Individual species are affiliated with fine or coarse bottoms, and some show aggregations off passes or the mouths of larger rivers.

For the eastern Gulf shelf the dominant shrimp of the genus Penaeus is the pink shrimp (P. duorarum). The density distribution pattern of the total fish catch (Figure 12.4) does not exhibit major gradients, but tends toward a patchy distribution with high densities associated with particular habitat types (east Mississippi Delta area, Florida Big Bend seagrass beds, nearshore area off the Everglades, southwest Florida mid/outer shelf, and DeSoto Canyon area). Individual species do show the nearshore, outer- shelf, mid-shelf, and trans-shelf groupings, but the distinctions are not as clear-cut as in the northwest. A few individual species are associated with fine or coarse bottoms. In the eastern Gulf many of the shelf species appear to exist as semi-isolated populations, each characterized by its own distinct depth distribution and seasonal patterns.

The demersal ichthyofauna of the eastern Gulf shelf is far richer than that of the northwest and is represented by more than twice as many total species (347:164) and over eight times as many unique species (208:25). The high species diversity of the eastern Gulf shelf reflects a) habitat diversity, b) availability of highly productive "live bottom" communities, c) the dynamic nature of the benthic environment, and d) repeated invasions from the West Indies region. From a zoogeographic standpoint, the fish fauna of the U.S. Gulf continental shelf includes three recognizable faunas: the northwestern Gulf fauna (Rio Grande to the Mississippi River Delta), Mississippi Bight fauna (Mississippi River Delta to near the DeSoto Canyon), and the peninsular Florida fauna (DeSoto Canyon to the lower Keys).

Management implications relate to the maintenance of biological and ecological integrity of the natural systems while permitting development of the mineral resources. Management recommendations fall into three categories: habitat and species protection, caution in undertaking certain development activities, and conduct of further studies to develop needed knowledge. For both the northwestern and eastern Gulf shelves, the following recommendations were put forth: maintenance of coastal wetlands and special shelf habitats (species spawning grounds, reefs, areas off tidal passes and river mouths, and habitat of rare species), need for care in dumping dredged materials and in undertaking across-shelf channelization, and need for special research studies (effects of commercial trawling; sources, fates, and effects of major chemical pollutants; cumulative and long-term effects of petroleum-related activities; and functional dynamics of shelf ecosystems). Additionally, for the eastern Gulf shelf, it was recommended that the seagrass beds be afforded special protection and that studies should be carried out to obtain better understanding of the current patterns and of the life histories of key species of each major habitat type.

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

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

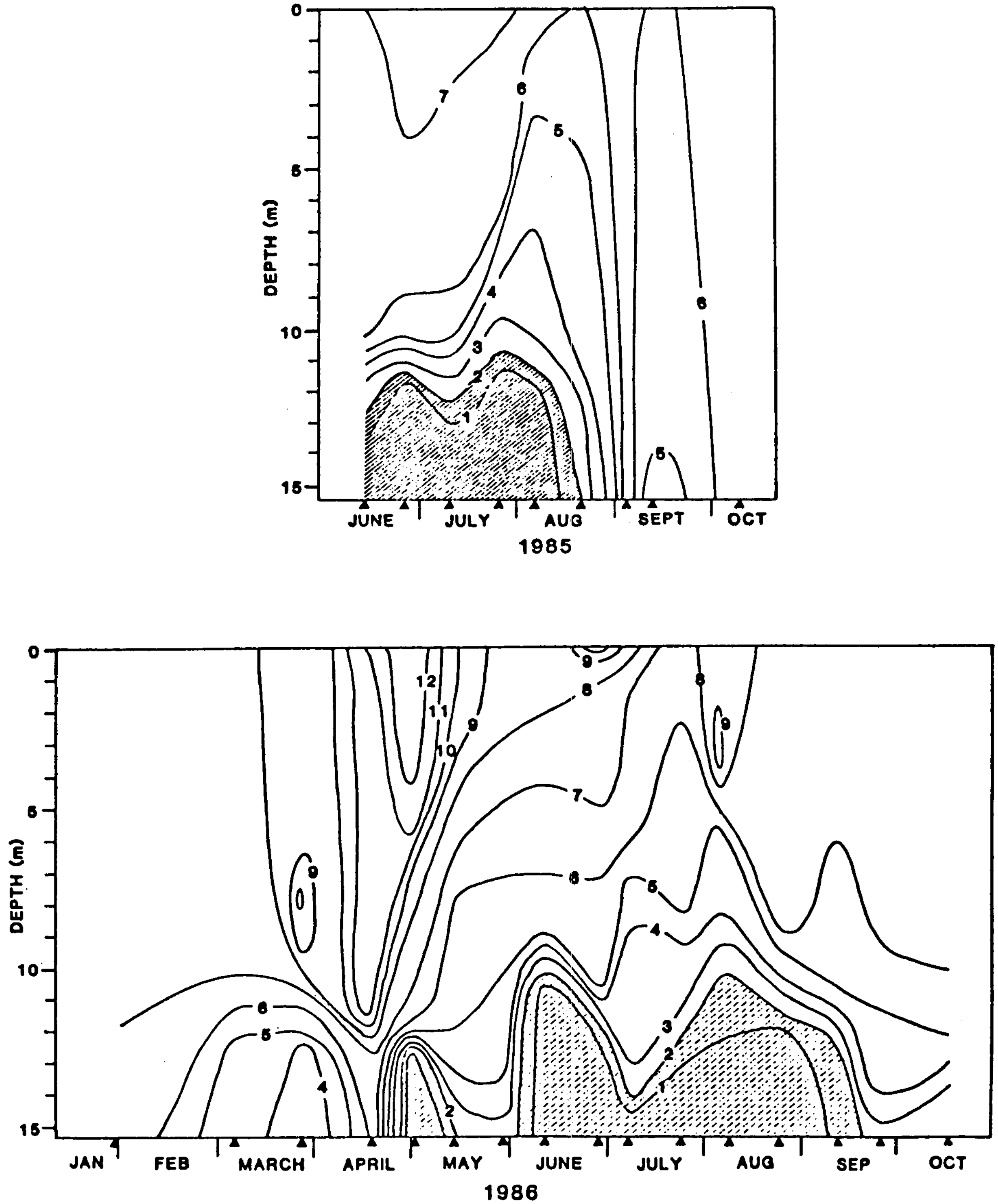

Figure 12.1.--Dissolved oxygen concentrations in mg/l for the water column at Station C5 off Terrebonne, Timbalier Bays (28°54.88'N, 90°29.35'W, 15.5 m) during 1985 and 1986. Sample dates indicated along bottom axis. Hypoxic water (<2 mg/l) indicated by shaded areas.

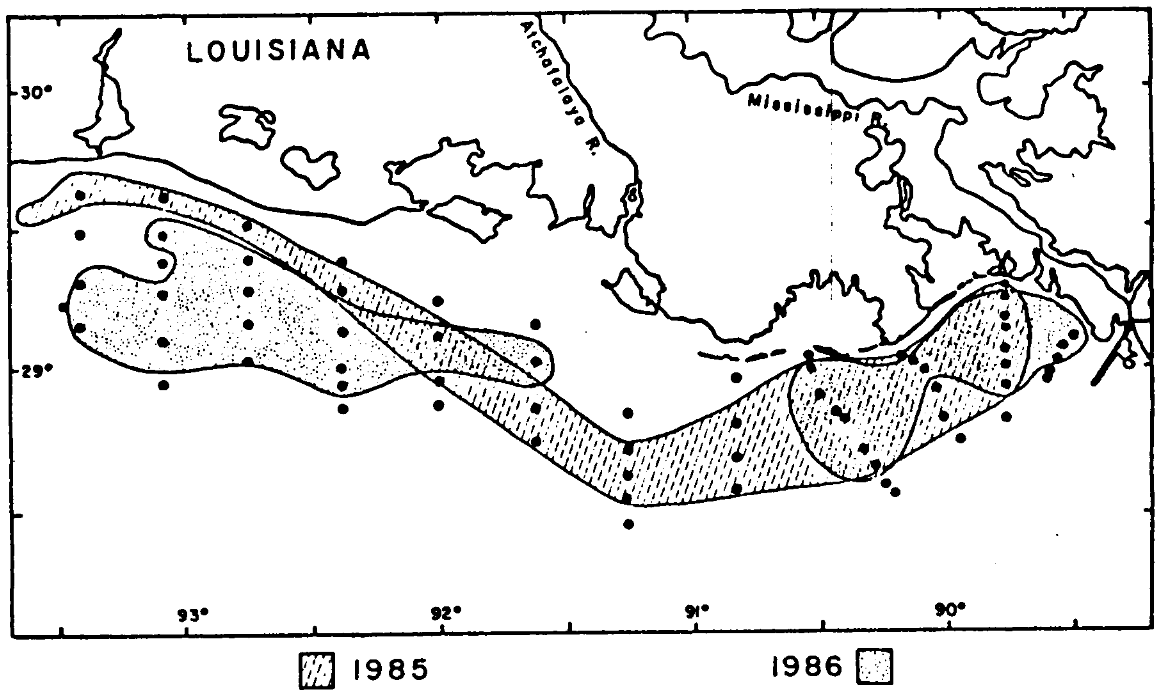

Figure 12.2.--Areas of Louisiana shelf where hypoxic bottom waters were found in 1985 and 1986. Station locations indicated by closed circles for 1986 stations only.

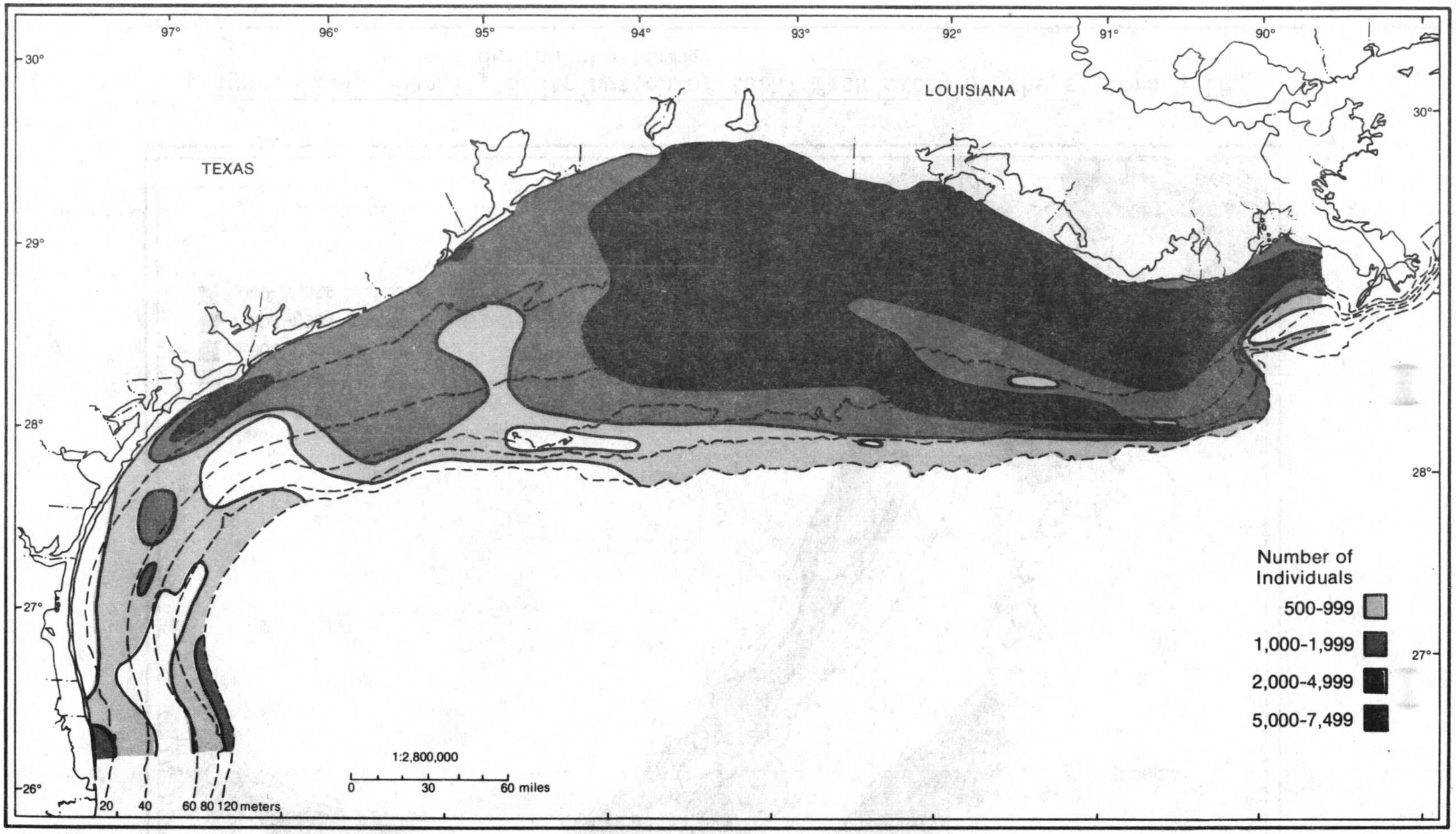

Figure 12.3.--Density distribution of total fish catch on the northwestern Gulf shelf during the summer.

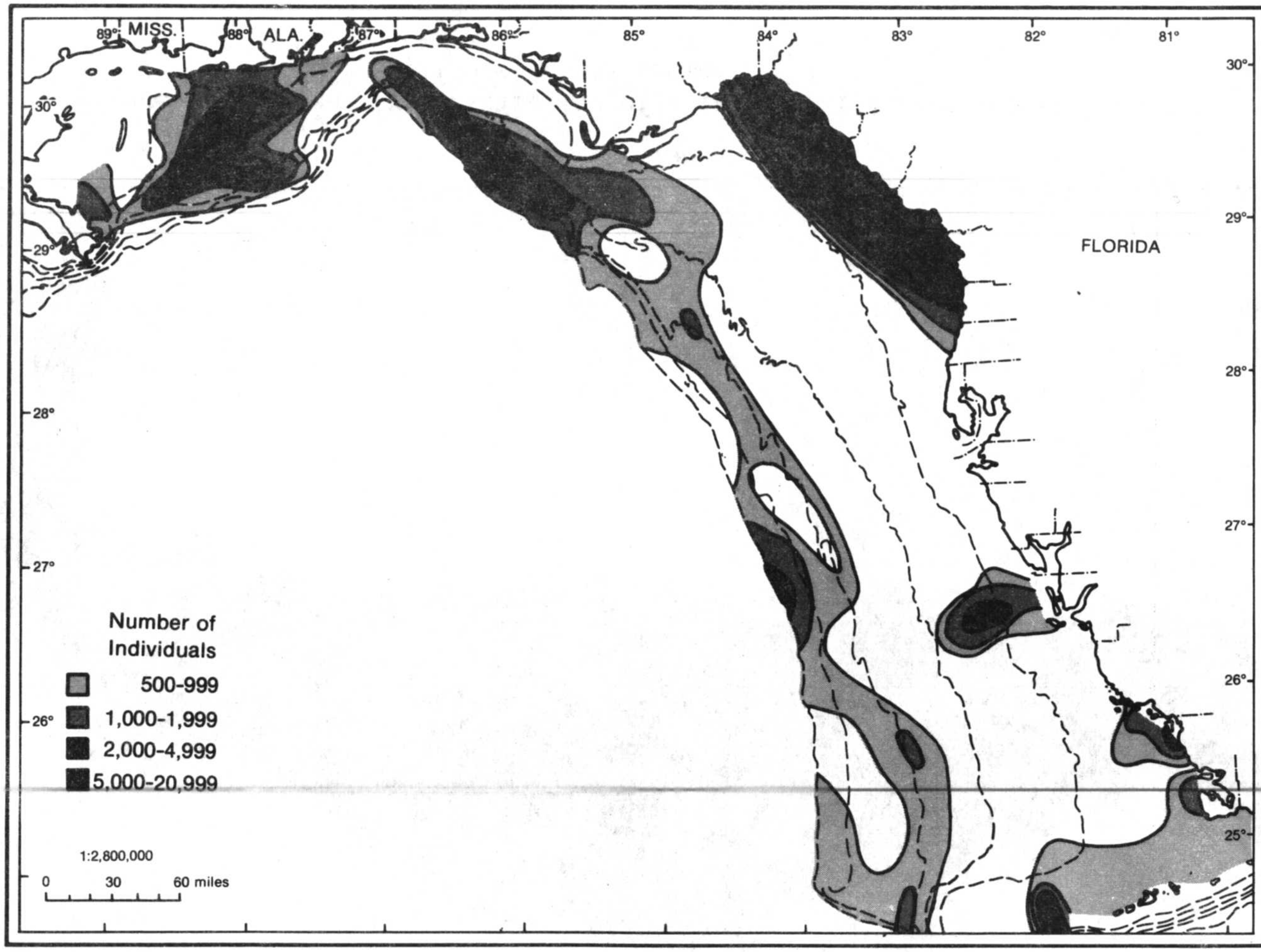

Figure 12.4.--Density distribution of total fish catch on the eastern Gulf shelf during the summer.

SEA AND SHORE: COASTAL RECREATION AND PETROLEUM DEVELOPMENT

Session.	SEA AND SHORE: COASTAL RECREATION AND PETROLEUM DEVELOPMENT
Chair:	Mr. Villere C. Reggio, Jr.
Date:	November 6, 1986

Presentation Title	Speaker/Affiliation
Sea and Shore: Coastal Recreation and Petroleum Development: Session Overview	Mr. Villere C. Reggio, Jr. Minerals Management Service Gulf of Mexico OCS Region and Ms. Susan B. Gaudry Minerals Management Service Gulf of Mexico OCS Region
Louisiana's Artificial Reef Program	Ms. Virginia Van Sickle Louisiana Artificial Reef Initiative
Rigs-to-Reefs Selection Criteria: What Attracts Louisiana Offshore Recreational Fishermen to Petroleum Structures	Mr. William R. Gordon, Jr. Southwest Texas State University Department of Geography and Planning
Rigs, Reefs, and Resource Management	Mr. Joseph M. McGurrin Artificial Reef Development Center
Inventory and Measurement of Coastal Recreation Benefits	Mr. John Titre Waterways Experiment Station
The Shipshape Debate on Mitigating Marine Litter	Mr. Robert Blumberg, Deputy Director U.S. State Department Office of Oceans and Polar Affairs
"Stashing Trash without a Splash"	Mr. Wayne Kewley Offshore Operators Committee

Sea and Shore: Coastal Recreation and Petroleum Development: Session Overview

Mr. Villere C. Reggio, Jr.
and
Ms. Susan B. Gaudry
Minerals Management Service

Over the past 30 years, approximately 25,000,000 acres have been leased offshore in the Gulf of Mexico. The development of oil and gas resources in the marine environment has had a visible and lasting affect on recreational endeavors in the coastal and offshore areas of Louisiana and Texas. We have had the unique opportunity in the Central and Western Planning areas to study and share information on how recreating people respond to extensive offshore petroleum operations. By-and-large, we have learned that recreational activity and the recreational industry can co-exist and prosper in conjunction with exploration, production, and product transportation activities associated with oil and gas operations. The most persistent and pervasive effects are increased saltwater fishing as a result of production platforms being introduced into the marine environment, and the accumulation of debris associated with offshore operations washing up on Texas and Louisiana beaches.

Through the environmental review, coordination, and assessment process, we have sought to understand the obvious recreational effects directly associated with the operational aspects of offshore petroleum development. In the past, we have used the Information Transfer Meeting to document and define the scope and nature of these impacts. More recently, we have encouraged communication on how we can prolong the positive environmental effects of the OCS program and minimize the negative impacts through public and private efforts. In that light, representatives from Mississippi (Ron Lukens), Florida (Larry Wine), and Texas (Rick Ekstrom) briefly informed the session attendees of specific permit locations where oil and gas structures are being sought for artificial reef developments. Mr. Roger McManus, Executive Director of the Center for Environmental Education described his organization's key role in generating public and private support and cooperation for finding solutions to the marine debris problem in the Gulf.

Ms. Virginia Van Sickle and Dr. Charles Wilson, cochairmen of the Louisiana Artificial Reef Initiative, were the first scheduled presenters on the program. Ms. Van Sickle outlined the State's progress in seeking a permanent leadership role in converting rigs-to-reefs. Specifically, the State of Louisiana has recently enacted legislation creating the Louisiana Artificial Reef Program. The primary objective of the program is to maintain the fisheries habitat associated with oil and gas structures through the continued use of these structures in permitted artificial reef sites. The Louisiana Fishing Enhancement Act, which created the program, also established the Louisiana Artificial Reef Council which is responsible for administering the overall program. The Act also established an Artificial Reef Development Fund that will be used to operate the program. Louisiana State University, in cooperation with the Louisiana Department of Wildlife and Fisheries, is presently preparing the Louisiana Artificial Reef Plan which will guide the development of the State's permanent offshore artificial reef system.

The second speaker was Bill Gordon, from Southwest Texas State University, who investigated activities of saltwater fishermen in southeast Louisiana as part of his doctoral research at Texas A&M. He verified the importance of oil and gas structures as a recreational fishing attraction and determined some interesting facts from the 200 boating fishermen he interviewed. Almost all were itinerant Louisianians willing to travel 220 miles per day by car and boat for the opportunity to fish around offshore oil and gas structures. The typical fisherman he interviewed trailered a 23-foot boat 80 miles to the launch site and traveled 60 miles by boat to fish between 6 or 7 production platforms. The offshore rig fisherman readily seeks out favorite platforms as far as 30 miles offshore with nothing more than experience, production platforms, or a compass as a navigation guide. Most often he ties directly to the production platform and repeats this recreational activity 22 times per year. Mr. Gordon's investigation corroborates research findings by the National Marine Fisheries Service and others on the importance of oil and gas structures to Louisiana marine fishermen and provides additional information useful to the Louisiana Artificial Reef Planning Program.

The third speaker was Mr. Joseph M. McGurrin, from the Artificial Reef Development Center (ARDC). The aim of the ARDC is to serve as a national interface for government, industry, and community interests in artificial reef development. Its goal is to incorporate artificial reefs into effective fishery management programs. Mr. McGurrin affirmed that converting obsolete oil and gas structures to artificial reefs can enhance fishing resources. Research has shown that certain OCS platforms can harbor 20 to 50 times more fish than nearby areas with sandy or muddy bottoms. When a platform is removed, the associated marine environment is destroyed and commercial and sport fishing opportunities are lost. Recycling post-production oil rigs as artificial reefs becomes an attractive option for both building fish habitat and preserving fishing opportunities. Additionally, since most of the removal costs are lost income to the oil companies, the development of alternatives for platform disposition offers the possibility for significant financial benefits for the offshore producers.

In 1983, the MMS adopted the first Rigs-to-Reef Policy to encourage the conversion of selected obsolete petroleum structures to artificial reefs on a case-by-case basis. However, the number of Rigs-to-Reefs projects actually undertaken has been very limited, due to a number of constraints. The newest constraint involves endangered species. Platforms that are cleared from their original sites (whether it be for shore based disposal or reef deployment) are generally removed by using explosives. These explosions may be linked to deaths of endangered sea turtles, and concerns have been raised about rig removal activities being in violation of the Endangered Species Act.

The fourth speaker was Mr. John Titre, from the U.S. Army, Corps of Engineers. He expressed concern that the Louisiana coastal marsh is being lost at a rate of 40 square miles per year. As a result, there is concern about the effects of marsh loss on recreation, wildlife, and aesthetic values, and the availability of the marsh for future generations. The New Orleans District and the Corps of Engineers Waterways Experiment Station have initiated a study to inventory recreation use of the Louisiana coastal marsh and to identify the benefits that users obtain. Maps are being prepared that identify where users concentrate for major opportunities of duck hunting, freshwater and saltwater fishing, recreational shrimping, and crabbing, in addition to nonconsumptive wildlife-oriented pursuits. User zones are being established to help planners and managers pinpoint critical areas, in conjunction with benefits derived, to better prioritize marsh creation actions.

The initiation of this study reflects the concern which the Corps of Engineers and the State of Louisiana have for maintaining quality recreation experiences provided by one of the nation's most important marsh environments now and in the future. Based on what researchers have learned so far, recreation studies should adopt a regional perspective whenever possible; coastal values, both ecological and sociological, need to be integrated during a study for better understanding of the full benefit that the marsh provides to society; and, finally, monitoring with the use of straightforward cost-effective inventory and assessment procedures for measuring the amount and quality of recreation experiences must be part of planners' and managers' tools to maintain a satisfied public.

The fifth speaker was Mr. Robert Blumberg, Deputy Director of the State Department, Office of Oceans and Polar Affairs. His discussion focused on problems caused by garbage, particularly plastic and other synthetic materials in the marine environment. He acknowledged that large numbers of marine mammals, sea turtles, fish and birds are being lost each year as a result of entanglement in, and ingestion of, plastic materials. In addition, several U.S. coastal states are experiencing severe problems due to beach litter attributed directly to the disposal of plastics and other marine debris from ships.

The State Department, in cooperation with the Coast Guard, is developing U.S. positions on international protocols designed to help alleviate this problem. The proposed Annex V, is similar in approach to that for ANNEXES I and II of MARPOL 73/78, the International Agreement to prevent pollution from ships. ANNEX V prohibits the disposal into the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets, and plastic garbage bags. It also establishes guidelines for other garbage disposal into the sea.

The last speaker was Mr. Wayne Kewley from the Offshore Operators Committee (OOC). The OOC is an organization formed 35 years ago to interact with government agencies in carrying out their regulatory functions. It consists of over 60 companies that conduct essentially all of the oil and gas exploration and production activities in the Gulf of Mexico and the Atlantic Ocean. The primary goal of the OOC has always been to promote protection of the marine environment.

Early last year, the National Park Service surveyed the beaches at Padre Island to determine possible sources of the litter. While the majority of the surveyed waste came from other users in the Gulf, the oil and gas industry was also represented in the refuse.

The OOC recently produced a short movie on beach litter entitled "All Washed Up," which was completed in May of 1986 and was shown at their annual meeting. All OOC member companies have been urged to purchase copies and show it to all their employees and contractors who work offshore. They are also being asked to use an environmental or regulatory professional to properly introduce the film and lead a discussion on the litter problem.

As a result of this film, the OOC was recently presented a "Take Pride in America" award by the National Park

Service. The "Take Pride Program" is a National public awareness campaign to encourage everyone to develop a feeling of stewardship of our public lands. The OOC shares the concern of public and private groups who are determined to make litter an unacceptable part of our society.

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

Ms. Susan B. Gaudry is an Environmental Protection Assistant in the MMS Gulf of Mexico's Environmental Assessment Section. Her responsibilities include preparation of environmental impact statement sections on pertinent regulations and on oil spills.

Louisiana's Artificial Reef Program

Ms. Virginia Van Sickle
Louisiana Artificial
Reef Initiative

Commercial and recreational fishermen of Louisiana and bordering states have long recognized the importance of oil and gas structures for offshore fishing. By late 1983 there were 4,056 such structures in state and federal waters in the Gulf of Mexico, and over 90% of these structures were located off the Louisiana coast. A recent survey completed by the National Marine Fisheries Service indicates that these structures are the ultimate destinations of over 65% of all offshore recreational fishing trips originating in Louisiana.

Since oil and gas platforms are so commonplace in coastal Louisiana, many citizens and management groups believed that these structures and associated habitats were "permanent" and would always be available for fishing. However, this is not the case. It has been estimated that 470 structures have already disappeared from Louisiana's coast and that by the year 2000, 40% (1,625) of the oil and gas structures in the Gulf of Mexico will have been removed.

Unfortunately, it is under the popular fishing platforms within twenty miles of shore where the oil and gas fields are being rapidly depleted and have the shortest remaining life expectancies. Fifteen hundred of the 1,625 structures scheduled for removal will be from water depths less than 100 feet.

Recognizing this potential loss of marine fisheries habitat, the State of Louisiana has recently enacted legislation creating the Louisiana Artificial Reef Program. The primary objective of this program is to maintain the fisheries habitat associated with oil and gas structures through the continued use of these structures in permitted artificial reef sites. The Louisiana Fishing Enhancement Act which created the program also established the Louisiana Artificial Reef Council which is responsible for administering the overall program. The Act also established an Artificial Reef Development Fund that will be used to operate the program. Louisiana State University, in cooperation with the Louisiana Department of Wildlife and Fisheries, is presently preparing the Louisiana Artificial Reef Plan that will be submitted to the Joint House and Senate Natural Resources Committee of the Louisiana Legislature for approval in the Spring of 1987. This plan will be based upon the criteria established in the National Fishing

Enhancement Act and upon user needs which have been identified through LSU research efforts. The plan will include the locations of the first artificial reef sites which will be permitted on behalf of the State. It is anticipated that the first artificial reefs will be established under the program during the Fall of 1987.

Virginia Van Sickle is Assistant Director of the Louisiana Geological Survey. Formerly she served as Deputy Secretary of the Louisiana Department of Wildlife and Fisheries. Since 1973, Virginia has been associated with Louisiana State University and State Government focusing on research, development, management, and administration of the coastal marine environment of Louisiana. She has worked as a liaison with the Federal OCS program for several years, and as cochairman of the Louisiana Artificial Reef Initiative (LARI) played a lead role in drafting a legislative initiative which established a feasible framework for a major artificial reef program for Louisiana.

Rigs-to-Reefs Selection Criteria: What Attracts Louisiana Offshore Recreational Fishermen to Petroleum Structures

Mr. William R. Gordon, Jr.
Southwest Texas State University

INTRODUCTION

During the past couple of years, there has been an increased use of traditional planning concepts in the siting and deployment of artificial reefs. With a recent federal mandate for artificial reef planning (the National Fishing Enhancement Act of 1984), some coastal states are presently faced with the drafting and implementation of artificial reef programs. Although many states have had such programs for three decades, or more, the planning represented by many of these efforts has been oriented more to biocentric concerns as opposed to meeting recreational or commercial user-needs.

An essential consideration in the planning process addresses the characteristics of candidate sites for reef deployment. In selecting appropriate sites, a paramount question often dealt with is, "What is an effective and safe travel distance from shore to the proposed reef site for recreational fishermen?" Travel ranges of twenty or thirty miles have been the most common distances recommended.

The Sport Fishing Institute, in recent planning applications has employed similar travel distance values (20 miles) as concentric arcs radiating from coastal access points. Within these arcs, constraint mapping (as devised by Ian Mcharg) has been used to identify positive and negative factors influencing the siting of artificial reefs. It is presently argued that the use of concentric arcs or zones is only an initial step in the site selection process.

If artificial reef programs, intended to meet user needs, are to be judged successful in terms of use, then the need exists to <u>refine</u> the site selection process based upon typical user behavior. The research findings discussed in this presentation, are based upon observations of user behavior in the Delta Region of the Central Gulf of Mexico. Understanding the selection and location process, as well as the travel patterns of recreational boaters within the vast assemblage of petroleum platforms or <u>de facto</u> reef structures located offshore the Louisiana Delta Region, will hopefully aid in generic reef planing efforts; and in the site selection process involved in a "Rigs-to-Reefs" program for the state of Louisiana.

METHODS

In an exploratory study during the summer of 1985, two hundred marine recreational fishermen were intercepted and interviewed at six different launch locations within the study area. Information was gathered addressing the nature of onshore travel to the launch site used on the day of the study, onshore recreational infrastructure needs, offshore site selection and travel characteristics, species of fish taken, preferred seasons for fishing and the intensity of offshore fishing undertaken in the study area.

Marine recreational fishermen were asked to identify which platforms that they had fished that day. This information was digitized and mapped to identify the offshore trip characteristics involved in traveling from the launch site to the first platform fished at. Other trip data included platform-to-platform trip distances, as well as the distances from the last platform fished to shore. Distance values were also analyzed for nearshore fishermen, offshore trollers fishing near platform locations and for bluewater fishermen fishing beyond the hundred fathom isobath.

RESULTS AND DISCUSSION

A profile of the typical marine recreational fisherman interviewed during the on-site study revealed that the fisherman is male and is from Louisiana (97%). In traveling from home to the launch site that was used, a majority of the respondents demonstrated a high mobility in pursuing their recreation. Eighty-four percent of these individuals trailered their recreational craft to marine launch sites within the study area.

The high mobility of the marine recreational fishermen within the study area is attributable to two factors. First, many fishermen have access to relatively inexpensive, lightweight boat trailers that are capable of being towed at highway speeds. Second, the very size of the craft they own make it possible for towing to various marine launch locations. An analysis of all craft used by marine recreational fishermen in the Delta Region revealed that the typical craft was about 23 feet in length.

While traveling an average distance of 81 miles from home to shore, over half of the recreational fishermen (52%) surveyed indicated that they travel from home to shore on a day-trip to go fishing. (This distance, from home to shore, would be nearly the distance that one would travel from New Orleans to fish in the Grand Isle/Fourchon region). The remainder specified that they either used hotels (11%), camps (18%), or self-contained mobile units (7%) on an over-night basis.

Criteria Used in Selecting and Locating Offshore Fishing Destinations

One of the major goals of the research was to investigate those criteria or standards used by marine recreational fishermen within the study area in selecting offshore petroleum platform destinations. In an open-ended format, fishermen were asked to note those factors that attract them to a particular platform. Nearly sixty percent indicated that their choice was based on their past fishing experience at that location. One-fourth of the respondents noted that the variety of fish species at a known platform, or species desired, was an important consideration in their selection of an offshore destination.

Lesser considerations included physical characteristics, such as the clarity of water at the platform site, the closeness of the platform to shore and the depth of water at its location. Personal motivations based upon fishing at a new location for its potential catch, and by recommendations of friends who had previously fished at the chosen platform were also factors in selecting an offshore destination.

When asked if water depth was a factor in selecting an offshore fishing destination, nearly fifty-five percent of the fishermen interviewed stated that depth was important. Twenty-five percent of the respondents said that depth was not a factor.

Locating Offshore Oil and Gas Platforms

In an open-ended format, fishermen were asked to indicate the primary means by which they locate the offshore platform or platforms that they plan to fish on a given day. A little over half of the respondents indicated that they used a compass in navigating offshore waters. Nearly twenty percent stated that they depended upon visual sightings of known reference points to aid them in reaching their offshore objective.

When looking for their offshore destination, as a means of assisting their offshore navigation, nearly fifty percent of the respondents indicated that the size and/or configuration of a platform (or a cluster of platforms) was useful in aiding them. Respondents were asked to verify whether or not a platform's known shape or appearance is useful in locating offshore platform destinations. Nearly sixty-six percent of the respondents indicated that they generally use the shape or configuration of a platform, or complex, as a means to locate their position while on the water. As noted by some of the respondents, this particular exercise may be confusing to the person navigating, especially if there has been a period of time between offshore visits. Changing reference points occur as new platforms are installed and old platforms are removed.

Marine Travel Characteristics

Upon returning to shore from their fishing trip, marine recreational fishermen were asked to recount the nature of their offshore trip and to indicate which platforms or lease blocks that they had fished. The locations of these platforms or blocks were digitized to calculate the following distance values: launch site-to first platform encountered, platform-to-platform, last platform-to launch site, and the travel distance for the entire trip.

The typical marine recreational fisherman within the study area reported an average travel distance of 21.1 miles from his launch site to the first platform fished. When traveling from platform to platform, a mean distance of 11.5 miles was traversed. A reported average travel distance of 17.7 miles, from the last platform encountered to the launch site, was slightly less than the values for the initial trip offshore. A reported total trip length of 60.8 miles was traveled by the typical offshore fisherman encountered.

Fishermen who did not fish at or near platforms, but fished nearshore or in the coastal bay systems reported an average value of 16.3 miles for their trip. When all inshore and offshore trip lengths were calculated, a mean distance of 54.5 miles were traveled. When asked if distance offshore was a factor in selecting platform destinations, almost three-quarters of the respondents (71%) noted that distance was a consideration. Nearly one-fourth of the remaining fishermen (24.5%) stated that distance was of no great concern to them.

With an open-ended question, fishermen were then asked what would be the furthest distance offshore that they would travel in their present craft. An average value of the responses indicated that these fishermen would be willing to travel nearly 31 miles offshore.

Fishing Destinations

Asked if they had fished at any platforms that day, sixty-three percent of the respondents indicated that they had fished near, or at a platform. Fifty-nine percent stated that they had actually tied to a platform so as to fish. The remaining thirty-seven percent specified that they had fished either bay or near-shore locations, as well as bluewater locations offshore.

Survey results revealed that the typical platform fisherman fished an average of 6.6 platforms on the day of the interview. When comparing the average number of trips (6.6) to the average distance of platform to platform trips, an average distance between platforms visited of 1.7 miles was derived. This tends to suggest that platform fishermen within the study area were traveling to those structures located easily within their visible horizon. It may be further suggested that a clustering effect of offshore destinations is in fact taking place.

Seasonality and Intensity of Platform Fishing

Marine recreational fishermen within the study area demonstrated a dedication to fishing offshore platforms. The typical platform fisherman noted that he fishes an average of 22 days per year at offshore platforms. Over ten percent of the respondents indicated that they fish at platforms more than 50 days a year.

SUMMARY

Petroleum platforms serve as important offshore fishing destinations in the Central Gulf of Mexico. Marine recreational fishermen within the study area demonstrate high mobility on land, as well as on water. Noting the exploratory nature of this study, survey results also indicate a high level of fishing activity at offshore platform locations by the fishermen surveyed.

In a further analysis of MMS research conducted two years ago, which identified recreational user patterns in the Central Gulf of Mexico Region, the data from this study will be used in calibrating a regression model. This model will hopefully give insight into marine recreational travel behavior and those factors involved in choosing offshore platform fishing destinations located within the Delta Study Region.

Mr. William R. Gordon, Jr. is an instructor at Southwest Texas State University. Mr. Gordon teaches environmental planning and law at both the graduate and undergraduate levels. Having a B.A. in geography from the University of Southern Maine, Bill also holds a M.A. degree in geography, and a M.M.A. in marine affairs from the University of Rhode Island. Mr. Gordon is presently completing his doctorate in urban and regional planning at Texas A&M University.

Rigs, Reefs, and Resource Management

Mr. Joseph M. McGurrin
Artificial Reef Development Center

I. REEFS AND RECYCLING

The conversion of obsolete oil and gas structures on the Outer Continental Shelf (OCS) to artificial reefs (Rigs-to-Reefs) has great potential to enhance fishery resources. Rigs-to-Reefs can provide benefits for both the public and the petroleum industry: the public enjoys increased fishing and diving opportunities and the industry may recycle obsolete oil and gas structures with the goal of reducing company costs. Created by the Sport Fishing Institute, the Artificial Reef Development Center (ARDC) believes that Rigs-to-Reefs offers a unique opportunity for energy, fishery, and conservation interests to work together for the betterment of the environment and the community.

A. Rigs as Reefs

Research has shown that certain OCS platforms can harbor 20 to 50 times more fish than nearby areas with sandy or muddy bottoms. When a platform is removed, the associated marine environment is destroyed and commercial and sport fishing opportunities are lost. Thus, the idea of recycling post-production oil rigs as artificial reefs becomes an attractive option for both building fish habitat and preserving fishing opportunities.

While some of the ecological benefits of the Rigs-to-Reefs option have been identified, the precise number of the 4,000 petroleum structures located in U.S. costal waters that could eventually be used as artificial reefs is unknown. Rigs-to-Reefs can be a viable option for the use of <u>some</u> offshore energy structures, but <u>not</u> all. It is not the complete solution to the larger issue of the retirement and disposition of obsolete oil and gas structures on the OCS. But even if only a fraction of all offshore energy structures is suitable as reef material, the potential benefits of Rigs-to-Reefs are still great.

B. The Business of Rig Disposition

The Rigs-to-Reefs idea has been driven by the economic implications of Minerals Management Service (MMS) regulations requiring complete removal of post-production platforms. The cost of removing an individual structure ranges from thousands to millions of dollars, depending on its size and location and the water depth. It is rarely feasible to reuse obsolete structures for oil and gas operations, and their scrap value barely pays for shore based dismantling and disposal costs. Since most of the removal costs are lost income to the oil companies, the development of alternatives for platform disposition offers the possibility for significant financial benefits for the offshore producers.

C. Constraints on Rigs-to-Reefs Development

In 1983, the MMS adopted the first Rigs-to-Reefs Policy to encourage the conversion of selected obsolete petroleum structures to artificial reefs on a case-by-case basis. Despite the acknowledgement of the potential benefits for the fishing industry and the possible cost savings to the offshore oil and gas industry, the number of Rigs-to-Reefs projects actually undertaken has been very limited. This is due to a number of constraints.

There is a range of possible difficulties in deploying oil and gas structures in the ocean. The safety of ships could be jeopardized by the presence of poorly sited submerged platforms. Commercial fishermen who use trawls and other similar gear also are concerned about the safety of their equipment. The Department of Defense has raised national security questions about the detection of submarines around artificial structures. In addition, some entity must take responsibility for a Rigs-to-Reefs structure once it is placed on the ocean floor.

The questions of financial and legal responsibility have been major obstacles to development. In the projects undertaken to date, state and county governments have held reef titles and taken financial responsibility for reef maintenance (mainly in the form of keeping a buoy on the reef). Petroleum companies have undertaken the construction, transportation, and deployment costs of building reefs which have been very significant and well above the costs of shore-based scrapping. Proposals have been made to relieve such financial constraints by offering tax credits for the extra costs involved with reef donations. Another problem may be liability. Although the liability issue is addressed in the National Fishing Enhancement Act of 1984 (Title II - Artificial Reefs), concerns about possible court cases remain as a constraint to future development. This is particularly important where structures may be left in place or toppled on their original site and declared as an artificial reef. In this situation, reef deployment becomes a much more financially attractive option for the offshore petroleum industry, but there must also be a mechanism to determine the continuing legal responsibilities for the structures.

The newest possible constraint to Rigs-to-Reefs development involves endangered species. Platforms that are cleared from their original sites (whether it be for shore-based disposal or reef deployment) are generally removed by using explosives. These explosions may be linked to deaths of endangered sea turtles, and concerns have been raised about rig removal activities being in violation of the Endangered Species Act.

All of the above difficulties need to be resolved. Otherwise, the Rigs-to-Reefs option may be too risky or too expensive for industry to consider, and opportunities to put platforms to beneficial use precluded. With the exception of the endangered species problem, most of the constraints involve the use of Rigs-to-Reefs as a disposition alternative for the oil companies, not as resource management device for the public. This is the source of a basic policy question about Rigs-to-Reefs. Wouldn't the Federal Government be subsidizing the oil and gas industry if it allowed for less costly disposition methods or eased the associated Rigs-to-Reefs constraints?

"It is not a question of subsidy," says Secretary of Interior Donald Hodel. "Our job is to foster development of domestic energy resources on the OCS by making those resources available to industry for responsible exploration and development. If complete removal of platforms and onshore disposal become too costly, then industry will be less willing and able to develop the energy this country needs. And if the public does not particularly benefit from complete platform removal--if in fact the public is better served by an alternative to complete removal--how can we insist on huge expenditures of private money?"

The underlying rationale behind the Secretary of Interior's argument is that actions should be undertaken in order to serve the overall public welfare. If the Rigs-to-Reefs alternative is to better serve the public, research efforts need to go beyond offshore oil economics and also include marine resource enhancement and the building of fishery habitat. This has been the focus of the work of the ARDC on the improvement of Rigs-to-Reefs fishery habitat through research on constraints on artificial reef development.

II. RIGS-TO-REEFS AS A RESOURCE MANAGEMENT TOOL

Interest in the use of oil and gas structures as artificial reefs has been made highly visible through several demonstration projects supported by the oil and gas industry. While these projects demonstrated the technical feasibility of deploying obsolete rigs as reefs and established some of the biological values of the structures, there was still a need for a comprehensive approach to Rigs-to-Reef fishery deployment and resource management. The ARDC has undertaken this task through work on reef planning and siting, constraints on project development, and evaluation of reef resource benefits. The research is briefly summarized below.

A. Planning and Siting Tools

- "Artificial Reef Development for Recreational Fishing: A Planning Guide" is a generic manual that gives an overview of the reef development process. It is intended to assist reef builders to be more effective in their planning and deployment efforts.
- "Resource Planning For Artificial Reef Site Selection To Maximize Recreational Fishing Benefits In The Gulf Of Mexico" is a systematic approach to effective reef siting. It is a regional study on the best locations to build reefs and provides reef planners with a broad overview of development opportunities in the Gulf of Mexico. The mapping procedures include charts and text that can be used to site Rigs-to-Reefs projects according to optimum reef-user benefits as well as the most cost effective rig disposition alternatives.

ARDC planning and siting procedures have been used as part of the basic framework for developing the Louisiana artificial reef program. This is the first state reef program focusing primarily on obsolete production platforms as reefs.

B. Practical Problems of Development

- The ARDC Technical Report Series includes nine reports on the constraints to reef development. By investigating solutions to practical problems of reef construction, the ARDC reports facilitate effective reef development for state fishery programs, corporations, and the local community.

Given the constraints to rig disposition, the ARDC Technical Reports on permitting, maintenance, liability, and transportation costs are particularly applicable to Rigs-to-Reefs issues. The Reports have been used as starting points for addressing some of the problems presently hindering Rigs-to-Reefs development.

C. Evaluation of Benefits

- A major problem in promoting Rigs-to-Reefs efforts (as well as all artificial reef projects) has been the lack of information on the benefits of artificial reefs to various users. ARDC studies address the problem of the valuation of artificial reefs and define methods of measuring the economic value of reefs.

- o Artificial Reef Economic Impacts Study--This ongoing project is studying economic impacts of artificial reefs. Beyond the direct value of artificial reefs to users, the activities of reef users create economic impacts in coastal communities. The purchase of fishing and diving equipment, boat sales and rentals, bait, food, gas, and lodging creates economic activity within a community, and brings additional revenue to local government treasuries through sales taxes.
- o Rigs-to-Reefs Evaluation Research--This work is presently being conducted on a Florida Rigs-to-Reefs site and is the first comprehensive study of the socio-economic aspects of a platform deployed as an artificial reef.

Since the costs of Rigs-to-Reefs are beyond the financial capability of the state and local entities that have traditionally sponsored reef projects, the petroleum industry and government have expressed an interest in assisting reef efforts. In order to fully consider Rig-to-Reef financial incentives such as tax credits or allowing structures to be toppled in place, it is helpful to go beyond petroleum company costs and document the benefits of Rigs-to-Reefs to the community. ARDC reef valuation research offers a basis for economic arguments for an alternative to the disposition of obsolete offshore structures as scrap metal, and provides information to evaluate issues such as tax incentives for Rigs-to-Reefs donations.

III. CONCLUSIONS AND FUTURE ACTIVITIES

The aim of the ARDC is to serve as a national interface for government, industry, and community interests in artificial reef development. Its goal is to incorporate artificial reefs into effective fishery management programs. Rigs-to-Reefs offers a unique opportunity for public/private partnerships that provide overall benefits for society. The ARDC Rigs-to-Reefs activities are directed to providing the necessary information to:

1. Improve the process of converting obsolete petroleum platforms into artificial reefs.
2. Document the value of reef contributions to tourist and recreation-based communities which result from the enhancement of the fishery resource.
3. Evaluate the donation of obsolete platforms as artificial reef material rather than dismantling the structures for scrap value.
4. Examine financial and legal incentives that will encourage the use of petroleum platforms as artificial reefs.

As part of the overall Rigs-to-Reefs effort, the ARDC will continue to focus on applied research for solving reef development problems. The results of ongoing government, conservation, and industry efforts can be the enhancement of fishery resources, increased fishing and diving opportunities for the public, and a more cost-effective method of rig disposition.

Joseph M. McGurrin is the Director of the Artificial Reef Development Center in Washington, D.C. He has a B.S. in biology and psychology from the College of William and Mary and an M.S. in fishery science from the

University of Maryland.

Inventory and Measurement of Coastal Recreation Benefits

Mr. John Titre
Waterways Experiment Station

The Louisiana coastal marsh is being lost at a rate of 40 square miles (16 sq. ha.) per year. As a result, there is concern about the effects marsh loss may have on recreation, wildlife, and aesthetic values, and about the sustained use of the marsh by future generations. The New Orleans District of the Corps of Engineers has requested the Waterways Experiment Station, the principal research facility for the Corps, to inventory recreation use of the Louisiana coastal marsh and to identify the benefits that users obtain.

The challenge for our research team is to determine the amount and the quality of recreation experiences provided by the marsh. This will serve as a baseline against which to gauge changes in marsh conditions. For example, "Are certain experiences in the marsh abundant, scarce, or unique?" "Can the coastal environment provide for a range of recreational opportunities, and what resource conditions are needed to produce those experiences?" And finally, from a long-range planning perspective, "What will it take to maintain Louisiana coastal recreation in the future?"

Scientists at the Waterways Experiment Station continue to refine freshwater and coastal marsh assessment procedures. Although the marsh has a recognized ecological importance, few studies have dealt directly with recreation benefits on such a large geographic scale. The study area encompasses approximately 6 million acres (2.4 million ha.) of fresh, brackish, and salt marsh located in the eastern three-fourths of coastal Louisiana. Figure 13.1 delineates the boundaries of the study area. Most of the acreage is owned by large land corporations that lease portions for recreation.

This study would not be possible without the support of local managers and commercial operators. For example, commercial boat-ramp operators have provided daily launch records. It is not uncommon for an operator to launch 100 boats on a typical weekend day. At 90 boat-access ramps, we are conducting interviews over a 12-month period to estimate recreation visitor hours and to measure qualitative changes in user experiences in response to marsh conditions. This information is needed along with other decision inputs to establish and assign priorities to marsh creation and protection plans.

Inventory procedures have long been established for the fields of forestry, wildlife, and range sciences. The recreation inventory procedures used in this study parallel those established in other resource management disciplines by attempting to sort out the complexity of large wetland areas for planning and management purposes. In recreation we have often examined single parks or similar areas, yet seldom have we analyzed regional systems of recreational opportunities.

In this study, maps are being prepared that identify where users concentrate for the major opportunities of duck hunting, freshwater and saltwater fishing, recreational shrimping and crabbing in addition to nonconsumptive wildlife-oriented pursuits. Assisted by a micro-computer, we are overlaying this information with marsh types to establish use zones. This will help planners and managers pinpoint critical areas in conjunction with benefits derived to better prioritize marsh creation actions. This also serves as a basis for determining objectives for the desired major opportunities.

The quality element of the experience is being integrated with productivity changes in the coastal environment. This will allow planners to document the types of opportunities that might be deteriorating as the marsh changes. The set of resource conditions necessary for recreation to occur is being refined and inventory procedures simplified. This will enable outdoor recreation planners to monitor use periodically to reflect new challenges facing coastal recreation.

Based on what the research team has learned, we offer three main recommendations: first, recreation studies should adopt a regional perspective whenever possible. This places opportunities in the context of a range of choices that a resource can produce. Second, the full range of coastal values, both ecological and sociological, need to be integrated during a study for better understanding of the full benefit that the marsh provides to society. Third, monitoring with the use of straightforward cost-effective inventory and assessment procedures for measuring the amount and quality of recreation experiences must be part of planners' and managers' tools to maintain a satisfied user public.

The initiation of this study reflects the concern the Corps of Engineers and the State of Louisiana have for maintaining quality recreation experiences provided by one of the nation's most important marsh environments now and in the future.

Mr. John Titre is a natural resource specialist with the Waterways Experiment Station at Vicksburg, Mississippi. He is serving as project leader of a study to measure the amount of use and benefits associated with recreation along the Louisiana Coast. His experiences include implementing inventory and monitoring procedures for large wetland areas in the western U.S. and Latin America.

Mr. Titre received his B.S. in forestry at Southern Illinois University and his M.S. in recreation research at Texas A&M University. He is pursuing postgraduate training in geography.

The Shipshape Debate on Mitigating Marine Litter

Mr. Robert Blumberg
Deputy Director
U.S. Department of State

In recent years, problems caused by garbage, particularly plastic and other synthetic materials (including fishing nets) in the marine environment have resulted in increasing public concern. Mounting information has emerged from governmental agencies, including the National Marine Fisheries Service, a branch of the National Oceanic and Atmospheric Administration (NOAA), and the Marine Mammal Commission. In addition, much information is available from non-governmental sources, including the 1984 Workshop on the Fate and Impact of Marine Debris held in Hawaii and from many private environmental organizations. A paper by the International Maritime Organization (IMO) Secretariat prepared for last month's meeting of the London Dumping Convention (LDC) also outlines the problems associated with marine disposal of persistent plastics and other persistent material.

This information demonstrates that large numbers of marine mammals, sea turtles, fish, and birds are being lost each year as a result of entanglement in, and ingestion of plastic materials. In addition, several U.S. coastal states are experiencing severe problems due to beach litter attributed directly to the disposal of plastics and other marine debris from ships.

It should be noted that the marine debris problem is attributable not only to ship-generated garbage. It also emanates from the dumping of municipal waste, the discharge of materials into inland waterways and outfalls from plants which manufacture plastic and plastic products. However, these land-based sources are most appropriately dealt with through domestic agreements whereas ship generated pollution, which emanates from foreign flag as well as U.S. vessels, requires international regulation, implemented and complemented by domestic laws.

What can be done about plastic pollution and other marine debris generated by ships? It is clear that existing U.S. domestic statutes are insufficient to address the problem. The Refuse Act of 1899 (33 USC 407) prohibits the disposal of any refuse matter, including garbage such as plastics, from any source into the navigable waters of the United States, including the territorial seas. However, this statute is limited in geographical application and is difficult to enforce and prosecute since a violation or contravention carries very small criminal fines.

Additionally, the Federal Water Pollution Control Act (FWPCA), as amended, includes garbage as a pollutant and a National Pollutant Discharge Elimination System (NPDES) permit issued by EPA is required to discharge garbage. However, although such permits are extremely restricted, the geographic application of the FWPCA with regard to the discharge of garbage from vessels again is limited to U.S. navigable waters (3 miles).

The Marine Protection, Research, and Sanctuaries Act (MPRSA)(33 USC 1401 et. seq.) which implements the 1972 Convention on the Prevention of Marine Pollution by dumping of wastes and other matter (LDC), prohibits unlawful dumping or transportation of materials, including plastics, for dumping. The convention, as implemented by the Act, prohibits the transportation of persistent plastics as well as other specified pollutants to sea from U.S. shores for the purpose of dumping. The Act also prohibits material transported from outside the U.S. from being dumped in our territorial sea or contiguous zone. However, the LDC excludes from the definition of dumping "the disposal at sea of wastes or other matter incidental to, or derived from the normal operations of vessels, aircraft, platforms . . ." The LDC has not been applied to ship-generated garbage because such garbage has been considered incidental to the vessels' normal operations. Thus, it is clear that none of the foregoing conventions or U.S. statutes adequately addresses the problem of at-sea disposal of ship-generated garbage.

Now let us consider the MARPOL Convention, which is the primary international mechanism aimed at preventing unnecessary and uncontrolled discharges of pollutants from ships into the oceans of the world. In my view, MARPOL offers the potential for establishing more stringent and enforceable discharge requirements for garbage, including plastics, than currently exist under U.S. or international law. In brief, Annex V of this convention prohibits the disposal into the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets, and plastic garbage bags. It provides that the disposal into the sea of other garbage be made as far as practicable from the nearest land but, in any case, is prohibited if the vessel's distance from the nearest land is less than

- o 25 nautical miles for dunnage, lining, and packing materials which will float, and
- o 12 nautical miles for food wastes and all other garbage including paper products, rags, glass, metal, bottles, crockery and similar refuse.

There are three exceptions to the discharge prohibitions:

1. Disposal necessary for the purpose of securing the safety of the ship and those on board or saving life at sea; or
2. Escape resulting from damage to a ship or its equipment, or
3. Accidental loss of synthetic fishing nets or synthetic material incidental to the repair of such nets.

With regard to the third exception, the U.S. delegation to the 21st Session (April 1985) of the International Maritime Organization's Marine Environment Protection Committee (MEPC) proposed an amendment that would clarify and strengthen Annex V. As amended by the U.S. proposal, Annex V would except only accidental loss of nets and would not permit the disposal of synthetic material used to repair fishing nets. The MEPC agreed to this amendment at its 23rd Session (July 7-11, 1986), and it will be circulated in accordance with Article 16 (TACIT Amendment Procedure) of MARPOL 73/78, after entry into force of Annex V. This approach would obviate the need to make amendments prior to entry into force, which is a concern of countries that have already ratified.

Assuming that implementing legislation for Annex V is similar in approach to that for Annexes I and II of MARPOL 73/78, the Act to Prevent Pollution from Ships (Public Law 96-478), Annex V would apply to U.S. vessels wherever they are located. Similarly, Annex V would apply to foreign flag vessels wherever located, and states bound by it would be required to enforce Annex V regulations against all ships, including those of non-party states, using their ports, as otherwise under their jurisdiction.

While such vessels are in U.S. navigable waters or ports, they may be boarded to determine whether there has been a violation of the Annex. Furthermore, any person may report violations to an appropriate authority for consideration and action by the pertinent flag state.

At the July 2, 1986, Public Meeting of the National Committee for the Prevention of Marine Pollution (NCPMP), held in preparation for the 23rd Session of the MEPC, members of the marine industry, interested government agencies, environmental organizations and other public interests were asked to comment on Annex V regulations and the desirability of U.S. ratification. Those attending the meeting were unanimous in their support for ratification although the marine industry qualified their support with the proviso that adequate reception facilities for garbage be provided in all ports as would be required under Annex V. Facilities for receiving garbage brought ashore from foreign ports are currently regulated and approved by the Department of Agriculture. Department of Agriculture officials believe that the necessary reception facilities will be built by private industry in the locations where they do not now exist, and they do not foresee any major difficulties.

In addition, the Departments of State and Transportation have received numerous letters from environmental organizations and private citizens expressing their strong support for U.S. ratification. Finally, marine debris with particular emphasis on plastic was the subject of an August 12, 1986 hearing before the House Merchant Marine and Fisheries Committee which elicited substantial support for U.S. ratification of Annex V. As I noted earlier, the documentation necessary for a final determination on whether to transit Annex V to the Senate for Advice and Consent is being prepared. I expect that the decision will be positive and that Annex V will be transmitted to Senate at the beginning of 100th Congress which begins in January 1987.

In order for Annex V to enter into force internationally, it must be ratified by 15 states representing 50% of the gross tonnage of the world's merchant shipping. Currently 26 countries representing 44.5% of the gross tonnage of the world's merchant shipping have ratified. Ratification by the United States would increase that tonnage to 49%. While U.S. ratification itself would not bring Annex V into force, it is likely that our efforts will prompt other countries to act quickly and that it would enter into force in the near future.

Plastic pollution and other marine debris present a real hazard to the marine environment as well as aesthetic degradation and potential health risks. Controlling this problem is a formidable challenge to the United States and the international community. Annex V can play an important part in meeting this challenge, but establishing legal authority is only the first hurdle and will not itself guarantee success. Enforcement of Annex V provisions, or any garbage disposal regulations for the marine environment, is very difficult. But it is a beginning, and it will serve to change the perception that we can continue "business as usual" by discharging tons of plastic debris into the world's oceans without negative consequences.

Several means to increase the effectiveness and enforcement of Annex V have been suggested:

First, continued efforts to provide public information and education programs on the problem are a critical initial step in eliminating marine debris. Public awareness of the serious nature of the problem encourages mitigation efforts.

Second, with regard to ship-generated garbage, economically attractive compaction and recycling technologies could be employed on vessels to encourage retention of plastics.

Third, the prevention of lost fishing gear could be facilitated by developing a system for identifying sites of repeated net hang-up and possibly limiting fishing in those areas.

Fourth, the adverse effects of fishing gear could be mitigated through a system of gear marking or through gear modifications, such as the development and required use of biodegradable fishing gear.

Fifth, the use of biodegradable packaging could also diminish adverse impacts of ship-generated garbage.

With regard to this point, I would note that a bill (S.2596) was filed by Senator Chafee and others in the 99th Congress that would require NOAA to study the adverse effects of dumping plastics into the marine environment and that would require the use of degradable materials used for packaging, transporting, carrying, and bottling if they are capable of becoming entangled with fish and wildlife. While no hearings were held on this bill during the last session of Congress, it is expected that it will be refiled and will be considered when Congress reconvenes in January. The important point is that there is growing Congressional concern and awareness about the problem of marine debris.

Sixth, retention and retrieval of plastics could be further encouraged by a system of financial rewards or penalties.

Seventh, an expanded observer network would strengthen enforcement efforts. Finally, efforts could be made to identify areas of ecological sensitivity because of their role in breeding, migration, feeding or other factors, where marine creatures are particularly vulnerable to entanglement.

The MEPC at the urging of the U.S. has agreed to convene a working group at its next session (MEPC 24 -- February 16-20, 1987) to discuss means for implementing Annex V in the most effective manner. The U.S. will be studying the suggestions mentioned above and others, and will be making recommendations to the MEPC working group which could result in future amendments to Annex V, after it enters into force.

The Department of State and the Coast Guard believe that the problem of plastic pollution and other marine debris is largely an international problem that requires an international solution. Annex V, if effectively implemented and enforced, can be a major part of this solution.

Mr. Robert Blumberg is Deputy Director of the State Department, Office of Oceans and Polar Affairs. For several years, he has been a member of the U.S. delegation to the Marine Environment Protection Committee of the International Maritime Organization which developed Annex V of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78).

Currently, Mr. Blumberg's office in the State Department, in coordination with the Coast Guard, is developing the documents necessary for a Presidential determination on whether to transmit Annex V of the MARPOL Convention to the United States Senate for Advice and Consent. Mr. Blumberg is pleased to be here to discuss Annex V and the role it can play in controlling pollution of the marine environment by ship-generated garbage with particular emphasis on plastic. Mr. Blumberg also discusses the current status of Annex V, the administration's position with respect to its ratification by the United States, and the outlook and timing for such ratification.

"Stashing Trash without a Splash"

Mr. Wayne Kewley
Offshore Operators Committee

The Offshore Operators Committee (OOC) is an organization of over 60 companies that conduct essentially all the oil and gas exploration and production activities in the Gulf of Mexico, its adjoining coastal area, and the Atlantic Ocean. The OOC was formed 35 years ago to interact with various governmental agencies in carrying out their regulatory functions.

One of the primary goals of the OOC has always been to promote protection of the marine environment. The offshore industry is proud of its record of coexistence with commercial fishermen in the Gulf of Mexico who bring in multi-million dollar catches of shrimp and finfish from the same areas where we explore for and produce oil and gas. And the value of our production platforms as "artificial reefs" in the Gulf is becoming increasingly well known to both commercial and recreational fishermen. Florida has been actively pursuing our obsolete platforms for use as artificial reefs for several years, and the State of Louisiana is currently implementing an artificial reef program to allow these structures to remain in the offshore waters of the state so they can continue to provide these exceptional fishing opportunities.

Oil and gas development in the Gulf of Mexico has also proven to be compatible with the navigation interests of all types of marine traffic, from small recreational boats to giant supertankers. The offshore industry strongly believes the marine environment can be shared by many interests, including those interested in enjoying the beaches which grace our coastline.

The quality of these beaches and, in particular, those that bring thousands each year to Padre Island National Seashore, is now threatened by something which is decreasing the quality of our lives across the country: litter. This beach litter comes primarily from offshore, and in certain areas, such as the national seashore, it is concentrated to an extent where enjoyment of the beach is severely lessened.

Early last year the National Park Service surveyed the beaches at Padre Island to determine possible sources of litter. While the majority of the surveyed waste came from other users of the Gulf, the oil and gas industry was also represented in the refuse. The Minerals Management Service (MMS), as the lead regulatory agency over the offshore industry, was pressed by the Park Service to take action to stop our contribution to the problem.

In deciding what course of action to take, the MMS knew that making more regulations wasn't the solution to this problem. Federal regulations already in place make it illegal to dispose of solid waste materials into the Gulf. This is analogous to the litter situation we face across the country -- we already have numerous laws on the books that make littering illegal, yet litter persists in our parks and in our neighborhoods. So while the vast majority of our solid wastes go to shore for proper disposal, a small fraction ends up in the water as a result of accidents and a few thoughtless workers.

The MMS also knew that increased enforcement of existing laws wasn't the solution to stopping our share of the litter. The agency simply does not have the manpower necessary to oversee our operations closely enough to find the minority of our offshore workers who thoughtlessly litter.

After several discussions, the MMS and representatives of the OOC agreed that there was only one way to eliminate or drastically reduce our share of the litter, and that was increasing our emphasis on educating our employees about the litter problem.

Most operators had already included proper waste disposal practices in some type of orientation program for employees. Many also conduct internal regulatory compliance seminars where waste disposal is covered. And several companies, on their own, had already issued bulletin board notices or posters on offshore litter. But as an industry, there was definitely room for improvement in our efforts to bring the litter problem to the attention of all elements of the offshore oil and gas industry. The OOC determined that an effective way to do this would be to fund production of an educational videotape. In the fall of 1985 a contract was signed with a professional production company to produce a short movie on beach litter.

Entitled All Washed Up, the movie concerns three fictional offshore workers who are deliberately or accidentally responsible for causing litter to enter Gulf waters. These employees later encountered the same type of litter on the beach during their days off. The film is based largely on the premise that some offshore workers may think their litter is out of sight and mind, just because they're far from land. We believe that once our workers realize that in actuality they're littering their own beaches, they will become more concerned with stopping deliberate littering and with seeking ways to prevent accidents that cause waste to enter our waters.

The movie was completed in May of this year and was shown at the annual OOC meeting that month. All 60-plus member companies have been sent a letter from the chairman of the committee urging members to purchase one or more copies of the movie and to show it to all their employees and contractors who work offshore. They are also being asked to use an environmental or regulatory professional to properly introduce the film and lead a discussion on the litter problem.

To enhance the value of the movie, one of OOC's member companies recently produced a hardhat decal with the slogan "Clean Rigs - Clean Water-Clean Beaches." Hardhat decals are a popular way to convey messages in the oilfield. The decal is now being offered to all OOC members. If each person who sees the beach litter movie wears a decal, offshore workers will constantly be reminded of their responsibility for keeping our waters and beaches clean.

In the five months since the movie has been available, 88 copies have been purchased by 32 OOC members. The National Park Service has purchased several copies and is using it at orientation sessions at the National Seashore.

Last month the OOC was also complimented on the movie and our anti-litter efforts, when the National Park Service presented us their Take Pride in America Award at the Regional MMS office in New Orleans. The Take Pride in America Award is a national public awareness campaign to encourage everyone to develop a feeling of stewardship of our public lands. In a letter to OOC's Chairman which accompanied the award, Secretary of Interior Donald Hodel stated "The film, 'All Washed Up', which was produced by the OOC, helps to develop an individual and collective sense of stewardship among your member employees for the waters and shores of the Gulf of Mexico. Through its concern, educational efforts and cooperative action, the Offshore Operators Committee has exemplified the Take Pride in America Spirit."

The OOC shares the concern of public and private groups who are determined to make litter an unacceptable part of our society. We plan to keep this issue in the forefront of committee activities and to urge all member companies to help solve this problem. However, we would caution those who are looking for quick improvement in the amount of litter seen on Gulf beaches. Few improvements will be seen until it is made illegal for all users of the Gulf to dispose of their trash offshore.

The OOC-sponsored movie All Washed Up was then shown.

Wayne Kewley is employed by Conoco Inc. as the New Orleans Division Coordinator for Environmental Affairs. He serves as Chairman of the Fisheries Advisory Subcommittee of the Offshore Operators Committee. He received a B.S. in zoology from the University of Illinois and has done graduate work in aquatic sciences at Colorado State University and in public affairs at the University of Houston. Before employment with Conoco, he worked for the National Marine Fisheries Service and the U.S. Fish and Wildlife Service.

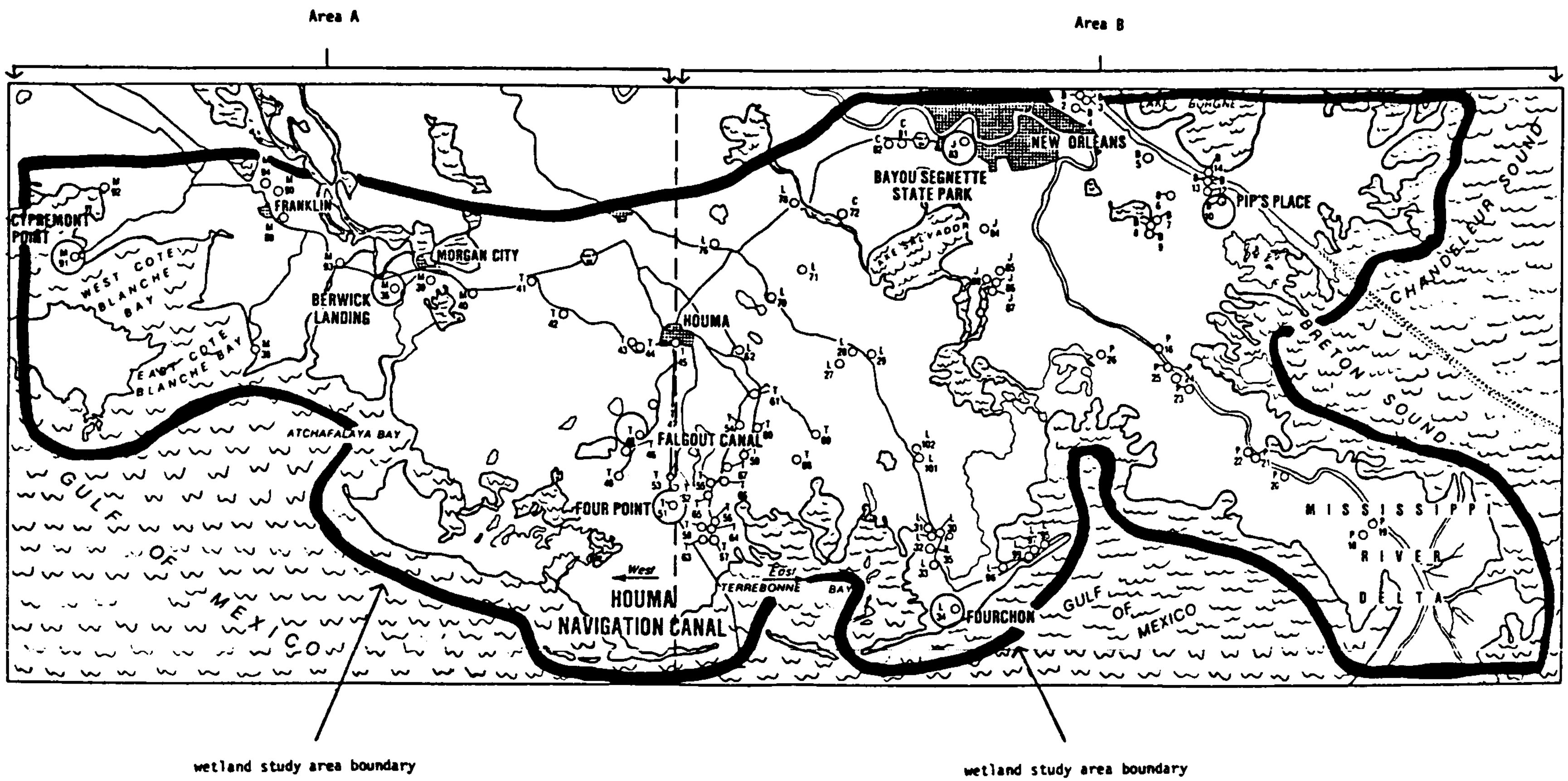

Figure 13.1.--The wetland study area.

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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