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March 2011
New Orleans, Louisiana

U.S. Department of the Interior
Bureau of Ocean Energy Management,
Gulf of Mexico OCS Region

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This meeting would not have been possible without the team effort of the chairpersons and co-chairpersons who are responsible for the agenda, specifically for the topic selections and invitation of speakers. We wish to thank the speakers for giving their time, effort, and expertise to this meeting. The University of New Orleans (UNO) Conference Services Office assisted with workshop logistics, and the staff at the Omni Royal Orleans excelled in their support and service. In particular, we thank Denise Michelet and Brian Bruhn of UNO for their efforts in the planning process. Audio-visual needs is one the most important aspects of this meeting and we owe a great deal of gratitude to Darren Morris and John Northcutt of New Orleans AVS for keeping the presentations flowing. We also thank Melanie McKay for her editorial skills and Judy Nides for her tireless efforts in the production of the final product. Finally, we thank all who attended and participated in the discussions for making this a true transfer of information meeting. This workshop was funded by the BOEM Environmental Studies Program.

INTRODUCTION

In meeting its mission to manage energy and minerals resources on the Outer Continental Shelf (OCS), the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE, previously the Minerals Management Service, now the Bureau of Ocean Energy Management) administers an Environmental Studies Program (ESP) to gather and synthesize environmental, social, and economic science information to support decision-making concerning the offshore energy program. The Outer Continental Shelf Lands Act established policy for the management of the OCS natural gas and oil leasing program and for the protection of marine and coastal environments. Section 20 of the Act authorizes the ESP and establishes three general goals for the program:

- to establish the information needed for assessment and management of environmental impacts on the human, marine, and coastal environments of the OCS and the potentially affected coastal areas;

- to predict marine biota impacts that may result from chronic, low-level pollution or large spills associated with OCS production, from drilling fluids and cuttings discharges, pipeline emplacement, or onshore facilities; and

- to monitor human, marine, and coastal environments to provide time series and data trend information for the identification of significant changes in the quality and productivity of these environments, and to identify the causes of these changes.

Toward this effort, BOEMRE sponsors the Information Transfer Meeting (ITM), bringing together researchers from throughout the United States and internationally to discuss research topics funded by the ESP and related areas of interest to BOEMRE. The ITM provides a forum for research and information exchange relative to the offshore energy industry.

The accomplishments of the ESP for the Gulf of Mexico and of other research programs or study projects were presented. The ITM is a place to foster an exchange of information of regional interest among scientists, staff members, and decision-makers from BOEMRE, other federal or state governmental agencies, regional industries, and academia.

Sessions for the 26th ITM included Physical Oceanography, Coastal Impacts, Sociology, Marine Archaeology, Deep-Sea Coral, Spill Response Technology, Protected Species Research, Natural Gas Hydrates, Offshore Ecology, Avian Research Design and Monitoring, Shallow Sediment Transport, and Physical Sciences.

Abstracts and Microsoft PowerPoint® presentations follow.

PLENARY SESSION

Chair: James Kendall, BOEMRE

Co-Chair: Alan Thornhill, BOEMRE

KEYNOTE ADDRESS

Michael R. Bromwich
BOEMRE Director

Good morning. I very much appreciate the opportunity to speak to you during this plenary session of our Information Transfer Meeting. We do not yet fully understand the implications and effects of last year's tragic oil spill—the full impacts may not be known for many years. But forums such as this give us the opportunity to share what we have learned and help to guide our future efforts. The information discussed here will contribute greatly to the knowledge about the spill itself and the effects of offshore energy production on our environment. This enhanced knowledge will help us to make better decisions for our environment and our economy.

One of the immediate lessons learned from the spill was that the standards for safety and environmental practices offshore must be raised. I am pleased to be able to speak to you about how we are doing that and about some of the challenges we face in an unsettled and unsettling environment.

Since I took over the agency in mid-June, we have been instituting lasting changes to the way we regulate offshore oil and gas drilling and development. These changes are long overdue. It's not unusual for serious reform to be triggered by a major catastrophe. In this case, it was the deepwater blowout of the Macondo well, the sinking of the *Deepwater Horizon* drilling rig, the tragic deaths of 11 workers, and a spill of nearly five million barrels of oil into the waters of the Gulf of Mexico.

The *Deepwater Horizon* tragedy immediately roused both government and industry out of a complacency that had developed over the past several decades. The result of that complacency was that the increased dangers of deepwater drilling were not accompanied by increased vigilance and concern for the safety of those operations. That is changing.

Our agency is upgrading its commitment to the responsible stewardship of our nation's offshore resources. These reforms are necessary—and reflect how seriously we take our responsibility to ensure that offshore drilling and its related activities, which are vital for the foreseeable future to our economy and security, are conducted safely.

When I was asked to take over responsibility for this agency, I received a broad, ambitious and urgent mandate from President Obama and Secretary Salazar—to reform offshore energy development and the agency responsible for overseeing it. Since that time, we have been working to make profound changes to restore the public's confidence that offshore oil and gas drilling and production can be—and will be—conducted safely and with appropriate protections for marine and coastal environments.

Following *Deepwater Horizon*, a broad consensus quickly emerged—in government and industry—that oil and gas safety rules and practices urgently need upgrading. But far more quickly than many people anticipated, that consensus began to fray as new rules were developed and new requirements were imposed on companies operating offshore. Some of the offshore operators and support companies clearly recognized that *Deepwater Horizon* was the symptom of a broader failure in both industry and government—a systemic failure to ensure that advances in drilling and workplace safety kept pace with increasingly risky operations and to ensure that the industry regulator had the tools and resources to do its job. These groups supported our efforts to strengthen regulation of offshore drilling and began to undertake their own efforts to raise standards for drilling and workplace safety, spill containment, and spill response.

But other operators with surprising and disturbing speed have seemed all-too-ready to shrug off *Deepwater Horizon* as a complete aberration, a perfect storm, one in a million. They point to the lack of a similar blowout in the decades before the explosion and spill and suggest that the steps taken in response were an unnecessary overreaction. In my judgment, that is as disappointing as it is short-sighted.

Our view is that this was a broad problem that needed to be addressed broadly and boldly. That view has been supported most recently by the report issued by the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. As the Commission describes in its report, regulatory and industry reform in the wake of a significant offshore disaster has happened before. The United Kingdom and Norway substantially changed their oversight of offshore drilling and production following the Piper Alpha and Alexander Keilland incidents. Australia is facing many oversight issues as a result of the Montara blowout, which occurred only eight months before *Deepwater Horizon*.

The challenges facing us, however, are unique in many significant respects. The scale of offshore oil and gas operations in U.S. waters, particularly in the Gulf of Mexico, is vastly greater than that of the North Sea. The economies of many of the Gulf Coast states are closely tied to offshore industry. The Gulf accounts for more than 25 percent of domestic oil production and approximately 12 percent of domestic gas production. In fact, for many months now, we have been hearing concerns expressed by business owners, public officials, and the public at large about the impact of the spill and its aftermath on the economies of Gulf Coast states. Those concerns are real and need to be taken seriously.

One of the inescapable problems that we are addressing is ensuring that government and industry make the fundamental reforms necessary to improve the safety and environmental protection in this massive industry, while at the same time allowing for the continuity of operations and production.

I. Scope of the Problem

As I mentioned a moment ago, there are some in the oil and gas industry that dismiss Macondo as an isolated event, not one that represents a systemic problem. But evidence developed by the President's Commission convincingly refutes the notion that *Deepwater Horizon* was a one-in-a-million event. The Commission identified 79 loss-of-well-control accidents in the Gulf between 1996 and 2009. That's a lot more than one in a million. Very recently, we saw a loss of well control in the Gulf involving a platform in shallow water. Thankfully, the consequences were not dire, but that event certainly undermines the claim that such events are exceedingly rare. It also undermines the claim, which we have heard repeatedly, that the risks in shallow water are trivial or non-existent.

The Commission also found that federal oversight was deeply compromised by combining separate and conflicting missions within one agency—namely, the responsibility for promoting the expansion of offshore leasing and drilling and the responsibility for ensuring safety and protecting the environment.

According to the Commission and others who have recently addressed these issues, regulators failed to keep pace with the dramatic transformation of the offshore drilling industry and the move to deepwater drilling. Neither inspectors on the front lines nor senior Minerals Management Service (MMS) officials had the tools or the training to fully oversee deepwater offshore drilling. Both industry and government were unprepared to contain a deepwater well blowout. And, very importantly, MMS did not receive predictable and adequate funding needed to oversee offshore drilling effectively. Over the past 20 years, the MMS budget for leasing, environmental protection, and regulatory oversight remained stagnant while deepwater drilling in the Gulf of Mexico expanded dramatically. Unfortunately, little has changed so far with respect to the funding issue—largely because of the Congress's inability to reach agreement on FY 2011 funding levels.

II. Reorganization

We at the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) are addressing the important structural issues the Commission identified in its report. Let me be specific about what we have already done and what we plan to do in the future. Together with Secretary Salazar, we have undertaken the most aggressive and comprehensive reform of offshore oil and gas regulation and oversight in U.S. history.

This reform includes the reorganization of the former MMS to establish mission clarity and to strengthen oversight; and it also includes the development and implementation of heightened standards for drilling practices, safety equipment, and environmental safeguards.

As we have previously announced, in the place of the former MMS—and in the place of BOEMRE, the direct and temporary successor to MMS—we are creating three strong, independent agencies with clearly defined roles and missions. MMS simply could not keep pace with the challenges of overseeing industry operating in U.S. waters in part because it had conflicting missions. It was expected to promote resource development, to enforce safety regulations, and to maximize revenues from offshore operations—and all of this with utterly inadequate resources.

The reorganization of the former MMS removes those conflicts by separating missions in three new agencies. The new agencies now have clear missions and structures that will support those missions. We are designing and implementing these organizational changes while we take into account the crucial need for information-sharing and the other links and connections among the functions of the former MMS. This is essential to ensure that the operating processes related to offshore leasing, plan approval, and permitting operate efficiently and effectively from the outset.

On October 1, 2010, the revenue collection arm of the former MMS became the Office of Natural Resources Revenue and now is located in a different part of the Interior Department, with a reporting structure and chain of command completely separate from the offshore regulator.

Over the coming months, the offshore resource management and enforcement programs will be established as separate, independent organizations. The next steps in the reorganization are more difficult but also extremely important: they involve separating the energy development functions and resource management functions from the safety and environmental enforcement missions of the nation's offshore regulator. Like the President's Commission, the Interior Department has concluded that the separation of these missions is essential to reforming the government's oversight of offshore energy development.

The creation of the two new independent agencies—the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE)—is more than just moving boxes around on an organization chart—it is about making fundamental, thoughtful changes in the way these agencies operate.

- BOEM will be responsible for managing development of the nation's offshore resources. This involves ensuring that the environment is protected and that the nation's offshore energy resources—including oil, gas, and renewable resources—are developed wisely, economically, and in the country's best interests.

- BSEE will independently and rigorously enforce safety and environmental regulations.

Since *Deepwater Horizon*¸ we have been rigorously analyzing the structural issues and conflict of interest problems that existed in the former MMS to lay the groundwork for the orderly commencement of the new bureaus.

An important step in our planning was to ensure that we can implement these changes while minimizing disruptions to the Bureau's daily operations. Given the national focus on energy development and production at a time of high gasoline prices, this is essential. We did it by discussing the reorganization with employees throughout BOEMRE over the course of many months. We received their input; collected and analyzed data relating to the Bureau's processes, systems, and regulatory metrics; and developed a number of alternatives for restructuring and reforming the Bureau. This work has been painstaking and time-consuming, but it has been essential to making informed decisions regarding the transformation of the Bureau.

Other significant changes we are making promote the principles of independence, development of rigorous and thorough science, and safety and environmental protection.

- We are separating resource management from safety oversight to allow permitting engineers and inspectors, who are central to overseeing safe operations, greater independence, more budgetary autonomy and clearer missions and leadership focus. Our goal is to create a tough-minded, but fair, regulator that can effectively keep pace with the risks of offshore drilling and will promote the development of safety cultures in offshore operators.

- We provide a structure that ensures that sound environmental reviews are conducted and that the potential environmental effects of proposed operations are given appropriate weight during decision-making related to resource management in BOEM. This is to ensure that leasing and plan approval activities are properly balanced. These processes must be both rigorous and efficient so that operations can go forward promptly with full understanding of their potential environmental effects and confidence that appropriate mitigation against those potential environmental effects are in place.

- We strengthen the role of environmental review and analysis in both organizations through various structural and organizational mechanisms. Those include:

  – The creation of a first-ever Chief Environmental Officer in BOEM. This person will be responsible for ensuring that environmental concerns are appropriately balanced in leasing and planning decisions and for helping set the scientific agenda relative to our oceans. This is a new, high-profile, and extremely important position, which we hope and expect will attract top-flight talent;

  – The separation of the environmental review and leasing programs in BOEM's regional offices;

  – The creation of new plan approval processes in BOEM;

  – The development, for the first time, of an environmental compliance and enforcement function, which will reside in BSEE; and

  – The establishment of the review and enforcement of Oil Spill Response Plans, which will be conducted in BSEE and will be addressed as a national-level priority.

III. Scientific Integrity in Decision-Making

One of the guiding principles of our reform agenda is a fundamental change in the approach to decision making, which includes a renewed commitment to develop thorough, credible, and unfiltered scientific data.

Over the past few decades, oil and gas development moved farther and farther offshore as industry sought new productive discoveries, sought to increase domestic oil and gas supplies, and provide the country with greater energy independence. While important science has always been involved in these developments, we have concluded from our reviews of the Presidential Commission as well as those we have conducted internally, that our scientific community has not always had a strong enough voice. We are changing that.

This past September, Secretary Salazar issued a Secretarial Order establishing a Scientific Integrity Policy for the Department, which we as a bureau are wholeheartedly embracing. Scientific and scholarly information considered in our decision-making must be sound, of the highest quality, and be the product of rigorous scientific and scholarly processes. To achieve those goals, we must cultivate and reinforce a culture of scientific integrity.

This means that our employees, political and career, must never suppress or alter, without new scientific or technological evidence, scientific or technical findings or conclusions—period. Further, employees will not be pressured to alter or censor scientific findings, and they will be protected if they uncover and report scientific misconduct. This is not about finding fault with the past, because in fact, the agency's scientific work has often been unfairly maligned, but instead it is about a prescription for the future.

This also means that we have to devote greater resources to, and elevate the role of, our scientists within the offshore regulators. As I mentioned earlier, we are for the first time establishing the position of a Chief Environmental Officer for BOEM. This person will be empowered, at the national level, to make decisions and final recommendations when leasing and environmental program directors cannot reach agreement. The Chief Environmental Officer also will be a major player in setting the scientific agenda for the nation's oceans. And by creating an entirely new environmental compliance function for BSEE, we are providing for the first time regulatory oversight focused on the environment.

As we work to elevate science in our decision-making, it is critically important that we have the necessary resources to conduct scientific studies, complete NEPA reviews, and fill important positions in environmental compliance.

Beginning the week of April 4 and continuing through May, we are conducting a recruitment tour of the finest environmental programs in universities across the nation. I will personally be visiting schools along the West Coast, in the Midwest, Northeast, and Gulf of Mexico regions, including Louisiana State University. We will discuss not only the current opportunities for scientists in the bureau, but also the exciting new positions within the office of the Chief

Environmental Officer and positions in our new Environmental Compliance unit. In the coming weeks, we will finalize the list of schools and provide more details about dates and times.

We are serious about these fundamental reforms and about a renewed focus on science in decision-making. As you will see throughout this meeting, BOEMRE conducts world-class studies, and we employ some of the field’s leading experts. Our recruitment efforts will bolster our resources and ensure that our reforms are lasting and effective.

For those who might now be thinking that the pendulum is swinging too far to the other side, we believe this is not the case. We are mindful that industry must continue developing offshore energy resources. This development is crucial to the economy, employment, and energy independence. We strive to strike the appropriate balance between the imperatives of energy development and awareness of the potential environmental effects of energy development and to ensure that appropriate measures are taken to protect against those effects. Maintaining a culture of scientific integrity will enable us to make those decisions with greater confidence that we can pursue energy development with a thorough, science-based understanding of the risks it poses and of how we can reduce those risks.

IV. Implementation Teams and Other Reforms of BOEMRE Policies

Important, substantive work is going on within the agency to provide the tools, training, and changes to the culture to make sure that the reorganization will have the results that we are aiming for.

As part of our continuing reform efforts, we have created a number of Implementation Teams that have been hard at work for several months. They are the central focus of our efforts to analyze critical aspects of BOEMRE’s structures, functions and processes, and implement our reform agenda. These teams are integral to our reorganization effort and are considering the various recommendations for improvement that we have received from several sources, including the Oil Spill Commission, the National Academy of Engineering, and the Safety Oversight Board commissioned by Secretary Salazar, and the Department of Interior Inspector General. In short, these teams are laying the foundation for lasting change to the way BOEMRE currently does business and the way its successor agencies—BOEM and BSEE—will do business in the future.

We are reviewing our application of the National Environmental Policy Act (NEPA), including in particular the use of categorical exclusions. We have obtained public comments on our NEPA policy and we are reviewing and analyzing the comments we received. We are working closely with the Council on Environmental Quality (CEQ) on this evaluation. In the meantime, we are requiring that site-specific environmental assessments, as opposed to the categorical exclusion reviews performed in the past, be conducted for all new and revised exploration and development plans in deepwater. As I am sure many of you know, yesterday we approved the first deepwater exploration plan since *Deepwater Horizon*. It was submitted by Shell and as part of our review of the plan; we conducted the first of these site-specific environmental assessments.

To address conflicts of interest, we have issued a tough new recusal policy that will reduce the potential for real or perceived conflicts of interest. Employees in our district offices must notify their supervisors about any potential conflict of interest and request to be recused from performing any official duty in which such a conflict exists. Soon, we will be issuing a broader version of the policy that applies these ethical standards across the agency. I know that this will present operational challenges for some of our district offices in the Gulf region, which are located in small communities where the primary employers are offshore companies. But the need for tough rules defining the boundaries between regulators and the regulated is compelling. These rules are necessary to assure the public that our inspections and enforcement programs are effective, aggressive and independent.

Finally, we are staffing our new Investigations and Review Unit, a unit I created immediately on taking over the agency. This unit, which is composed of professionals with law enforcement backgrounds or technical expertise, has several important missions. First, it will promptly and credibly respond to allegations or evidence of misconduct and unethical behavior by Bureau employees. Second, it will pursue allegations of misconduct against oil and gas companies involved in offshore energy projects. And third, it will provide the Bureau with the ability to respond swiftly to emerging issues and crises, including significant incidents such as spills and accidents.

V. New Safety and Environmental Regulations

The reforms that we are pursuing to improve government oversight of offshore energy development and drilling are both substantial and necessary. However, as the report of the President's Commission makes abundantly clear, industry must change as well. Some of this work must be initiated and implemented by industry, but my agency has a clear and important role in helping to spur that change.

We are doing so through new prescriptive regulations to bolster safety and enhance the evaluation and mitigation of environmental risks. We have raised the bar for equipment, safety, and environmental safeguards in the drilling and production stages of offshore operations—and we will continue to do so in open and transparent ways in the coming months and years. We have also introduced performance-based standards similar to those used by regulators in the North Sea. We have done all of this through the development and implementation of the two new rules, announced last fall, that raise standards for the oil and gas industry's operations on the OCS.

The first, the Drilling Safety Rule, is an emergency rule prompted by *Deepwater Horizon*. It has put in place tough new standards for well design, casing and cementing, and well-control equipment, including blowout preventers. For the first time, operators are now required to obtain independent third-party inspection and certification of each stage of the proposed drilling process. In addition, an engineer must certify that blowout preventers meet new standards for testing and maintenance and are capable of severing the drill pipe under anticipated well pressures.

The second is the Workplace Safety Rule, which aims to reduce the human and organizational errors that lie at the heart of many accidents and oil spills. This rule was in development well before *Deepwater Horizon*, but as described in the Commission's report, the promulgation of these performance-based standards was frustrated for various reasons. Unfortunately, as was the case in other countries such as the UK and Norway, it took a major accident to provide the impetus necessary for these standards to be imposed.

Operators now are required to develop a comprehensive safety and environmental management program that identifies the potential hazards and risk-reduction strategies for all phases of activity, from well design and construction, to operation and maintenance, and finally to the decommissioning of platforms. Although many progressive, forward-looking companies had voluntarily developed such SEMS systems in the past, many had not. And our reviews had demonstrated that the percentage of offshore operators that had adopted such programs voluntarily was declining.

In addition to these important new rules, we have issued what we call Notices to Lessees (or NTLs) that provide additional guidance to operators on complying with existing regulations.

In June, we issued NTL-06, which requires that operator's oil spill response plans include a well-specific blowout and worst-case discharge scenario, and that operators also provide the assumptions and calculations behind these scenarios.

In November, we issued NTL-10, a document that establishes informational requirements, including a mandatory corporate statement from the operator that it will conduct the applied-for drilling operation in compliance with all applicable agency regulations, including the new Drilling Safety Rule. The NTL also confirms that BOEMRE will be evaluating whether each operator has submitted adequate information to demonstrate that it has access to, and can deploy, subsea containment resources that would be sufficient to promptly respond to a deepwater blowout or other loss of well control. This information will help us evaluate operators' compliance with current spill response regulations.

Regulatory changes have been rapid, especially compared to the historical pace of change, and there have been, understandably, a number of questions from industry. These questions have been about our new regulations, about the NTLs, and about how we will apply NEPA going forward with respect to deepwater drilling operations.

We have held dozens of meetings, both in the Gulf region and in Washington, D.C., with federal and state representatives, industry groups, non-governmental organizations, and individual operators, to answer questions about the new rules and to provide clarity about the post-*Deepwater Horizon* regulatory environment.

The fact that continuing guidance is necessary should not come as any surprise to anyone. With the volume of new rules and formal guidance we have issued in recent months, the need for additional clarification was inevitable. It reflects no more than the fact that these are complex issues to work through, which is exactly what we have been doing.

We need to distinguish this kind of discussion and consultation, which is necessary to the enterprise of regulating a complex industry, from the type of relationship in which a regulatory agency forsakes its institutional independence and becomes the captive of the regulated industry. We are in favor of constructive engagement and continuing dialogue. But we will not permit any sacrifice of our institutional independence.

We are working hard to ensure that this important industry continues to be able to operate fully and successfully. Since February 17, when the groups organized by industry established that they had developed a suite of resources capable of dealing with a subsea blowout, we have approved four deepwater permits. And more will be approved in the coming weeks and months. That said, one thing that the Secretary and I believe firmly is that a retreat on drilling safety is not an option.

VI. The Path Forward

The challenge facing government and industry in the months and years ahead is to ensure that we do not once again become complacent, but rather that we continue to make progress in developing state-of-the-art safety, containment and response capabilities. Government, industry, and the best minds in our universities must continue to collaborate on ongoing research and development to create cutting-edge technologies in areas such as well condition sensor capabilities and remote BOP activation, among others. These initiatives are vitally important to pursue—by individual companies and by industry as a whole.

This is why we have established the new Ocean Energy Safety Advisory Committee, which will include federal agencies, industry, academia, national labs, and various research organizations. The 15-member committee will work on a variety of issues related to offshore energy safety, including drilling and workplace safety, well intervention and containment and oil spill response. This will be a key component of a long-term strategy to address on an ongoing basis the technological needs and inherent risks associated with offshore drilling, and deepwater drilling in particular.

We recently announced the membership Advisory Committee, and I'm happy to report that we have top-notch members from the oil and gas industry, as well as from academia, NGOs, and the government. As you know, Secretary Salazar has asked Dr. Tom Hunter, the former head of the Sandia National Lab, to chair the Committee.

The Ocean Energy Safety Institute, which will be nurtured and shaped by the Advisory Committee, will foster collaboration among all key stakeholders to increase offshore energy safety. The Institute will focus on a broad range of matters relating to offshore energy safety, including drilling and workplace safety, well intervention and containment, and oil spill response. It will also help spur collaborative research and development, training and execution in these and other areas relating to offshore energy safety.

Most importantly, this Institute is a key component of a long-term strategy to address on an ongoing basis the technological needs and inherent risks associated with offshore drilling, and deepwater drilling in particular.

As you can tell, we have been busy, and have been busily engaged with the industry, to make offshore drilling as safe as possible. We hope this constructive engagement continues and that in the very near future we will see a fully occupied offshore drilling industry that is operating more safely—and with greater environmental safeguards—than ever before.

I hope you find this year's Information Transfer Meeting to be informative and invigorating. I thank you for your time and attention.

On June 21, Secretary of the Interior Ken Salazar swore in former Justice Department Inspector General Michael R. Bromwich as Director of the Bureau of Ocean Energy Management, Regulation and Enforcement to lead reforms that will strengthen oversight and regulation of offshore oil and gas development. Mr. Bromwich is overseeing the fundamental restructuring of the former Minerals Management Service, which was responsible for overseeing oil and gas development on the Outer Continental Shelf. Mr. Bromwich was previously a litigation partner in the Washington, D.C. and New York offices of Fried Frank, where he headed the firm's Internal Investigations, Compliance and Monitoring practice group. From 1994 to 1999, Mr. Bromwich served as Inspector General for the Department of Justice. As Inspector General, he headed the law enforcement agency principally responsible for conducting criminal and administrative investigations into allegations of corruption and misconduct involving the 120,000 employees of the Department of Justice. He was also responsible for conducting independent audits of the Department's programs and operations.

DEEPWATER HORIZON: UNIFIED AREA COMMAND'S ROLE

Rear Admiral Mary Landry
U.S. Coast Guard, Eighth District

During the *Deepwater Horizon* oil spill in 2010, the U.S. Coast Guard served as the lead federal agency and oversaw the response effort through the Unified Area Command. Rear Admiral Mary Landry, former Commander of the Eighth Coast Guard District, was appointed as the first Federal On-Scene Coordinator and was charged with coordinating the response between various Federal agencies and BP. The Eighth Coast Guard District, which comprises all or part of 26 states between the Gulf of Mexico and the U.S./Canadian border and from the Appalachian Mountains in the east to the Rocky Mountains in the west, responds to disasters such as hurricanes, oil spills, and accidents in the District's navigable waterways and Federal waters.

During the oil spill, the Coast Guard initiated search and rescue missions and established the Incident Command System and a series of strategically located command centers that enhanced the coordinated response effort. Activities associated with the response effort included subsea monitoring and containment, dispersant use, skimming, controlled burning, installation of protective boom, aircraft and satellite surveillance, shoreline clean-up and assessment technique teams, among other activities. As the response effort transitioned to the Natural Resources Damage Assessment process and long-term recovery, the Coast Guard continues to participate in the restoration of the Gulf Region. Lessons learned and identification of areas for improvement will be used to enhance the Coast Guard's response to future spills and other disasters.

Rear Admiral Mary E. Landry serves as the Commander of the Eighth Coast Guard District and Commander of Task Force 189.8, headquartered in New Orleans. As District Commander, she is responsible for U.S. Coast Guard operations covering 26 states, more than 1,200 miles of coastline and 10,300 miles of inland waterways from Florida to Mexico and including the entire navigable lengths of the Mississippi, Ohio, Missouri, Illinois, and Tennessee River systems. RADM Landry arrived in the Eighth District having served as the Coast Guard's Director of Governmental and Public Affairs stationed at Coast Guard Headquarters in Washington, D.C. Most recently she served as the Federal-On-Scene Coordinator for the *Deepwater Horizon* response in the Gulf of Mexico. A native of Buffalo, New York, she graduated from the State University of New York at Buffalo. She completed Officer Candidate School in 1980. She holds Master's degrees in management from Webster University and in marine affairs from the University of Rhode Island. She received an Honorary Doctoral Degree from Hilbert College in Hamburg, New York, in May 2009, and in 2010 received the Distinguished Achievement Award from the University of Rhode Island's College of Environmental and Life Sciences. Her military decorations include the Legion of Merit (three awards), Meritorious Service Medal, Coast Guard Commendation Medal (three awards), 9-11 Medal, and Achievement Medal.

Click here to view the slideshow that accompanied this presentation.

DEEPWATER HORIZON: BOEMRE'S ROLE

Lars Herbst
Regional Director, Gulf of Mexico OCS Region
Bureau of Ocean Energy Management, Regulation and Enforcement

The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE; formerly Minerals Management Service) served an important role in the coordinated federal response to the *Deepwater Horizon* event and oil spill in 2010. Management and staff from BOEMRE, to be split into the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement, were stationed at the Unified Area Command and Incident Command centers during efforts to contain the hydrocarbon flow and permanently seal the Macondo well. Serving in an advisory role, BOEMRE engineers, geologists, and scientists participated on teams that were assigned specific response-related tasks. Multiple techniques were utilized to control the blowout, from a large containment device and riser insertion tube to a containment cap, relief wells, and static kill that ultimately succeeded in stopping the free flow of hydrocarbons into the Gulf. Lessons learned from the successes and failures of these engineering techniques will inform future decision-making for the response to an emergency loss of well control.

In October 2007, Lars Herbst was named as the new Regional Director of the MMS (now BOEMRE) Gulf of Mexico Outer Continental Shelf (OCS) Region. As the Gulf of Mexico Regional Director, Mr. Herbst manages the leasing of OCS lands off five Gulf Coast states for oil, gas, and other mineral development, and supervises the regulation of operations and protection of the environment on more than 7,000 leases, which involve more than 4,000 platforms. He manages a staff of 550, including geologists, geophysicists, petroleum engineers, biologists, environmental scientists, and offshore inspectors. Mr. Herbst began his career with BOEMRE in 1983 as a staff engineer. He has served as District Manager of the New Orleans district, as Deputy Regional Supervisor and Regional Supervisor of Field Operations. He is a registered professional engineer in the State of Louisiana and holds a B.S. degree in petroleum engineering from Louisiana State University.

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SCENARIO BUILDING FOR THE *DEEPWATER HORIZON* OIL SPILL

Gary Machlis
U.S. National Park Service

In October 2009, the National Park Service (NPS) Director announced the appointment of Dr. Gary Machlis as the first-ever Science Advisor to the Director. In his role as Science Advisor to the Director (NPS), Dr. Machlis provides his expertise and advice on matters of science and assists with the effective delivery of scientific information to NPS managers, decision makers, the Department of the Interior (DOI), Congress, stakeholders, park visitors, and citizens. He helps to assure that NPS uses the best available science to address the complex natural and cultural resource challenges facing the Service, from climate change to science education for youth. Dr. Machlis received his B.S. and M.S. in forestry at the University of Washington and his Ph.D. in human ecology at Yale University. He is Professor of Conservation at the University of Idaho and has served as the NPS Visiting Chief Social Scientist, and as the National Coordinator of the Cooperative Ecosystem Studies Unit (CESU) Network. He has written several books on conservation, and his recent research has been published in journals as varied as *Climatic Change*, *Society and Natural Resources*, *BioScience*, and *Conservation Biology*. Dr. Machlis is a member of the American Association for the Advancement of Science's (AAAS) National Committee on Opportunities for Women and Minorities in Science and the Advisory Board to the AAAS Center for Advancing Science and Engineering Capacity.

REGULATORY CHANGES POST-MACONDO

Michael Saucier
Deputy Regional Supervisor for District Operations
Gulf of Mexico OCS Region
Bureau of Ocean Energy Management, Regulation and Enforcement

As a result of the *Deepwater Horizon* event, the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE, formerly the Minerals Management Service) enacted a number of significant regulatory reforms to address gaps and strengthen oversight of the offshore oil and gas regulatory program. New safety initiatives included the issuance of a Drilling Safety Rule, Notices to Lessees (NTL) for Blowout and Worst Case Discharge and Spill Response and Well Containment among other revised information requirements, and the Safety and Environmental Management System (SEMS) Rule. NTL 2010-N06, issued in June 2010, which requires that any new or supplemental Exploration Plan, Development Operations Coordination Document, or Development and Production Plan must include a blowout scenario, the assumptions and calculations used to determine volume of worst case discharge, and the proposed measures to prevent a blowout. The Drilling Safety Rule, effective as of October 2010, imposes a variety of requirements that address well bore integrity and well control equipment and procedures. NTL 2010-N10, issued in November 2010, applies to subsea and surface blowout preventers on floating facilities, and requires operators to submit information demonstrating that they can deploy containment resources promptly after a blowout, and to submit a signed statement of compliance with all applicable regulations. Finally, the SEMS rule, effective as of November 2010, requires operators to develop their own safety and environmental management systems that also apply to their contractors and those performing maintenance, repairs, or other work.

Michael Saucier was selected as the Regional Supervisor for the Office of Field Operations for the Gulf of Mexico OCS Region in July 2008. After receiving a Bachelor of Science degree in Petroleum Engineering from Louisiana State University, Saucier began his career with the MMS (now BOEMRE) in 1984 as a staff engineer in the Houma, Louisiana District Office where he worked on production and drilling issues. In 1988, he became the Drilling Engineer and in 1995, he was promoted to the position of District Supervisor, Houma District in the Gulf of Mexico OCS Region. He was promoted to Deputy Regional Supervisor for District Operations in 2007. As Regional Supervisor for Field Operations, Saucier oversees a staff of 170 engineers, technicians, inspectors, and administrative support that are responsible for safe and environmentally responsible oil and gas operations throughout the Gulf of Mexico Region.

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MOVING FORWARD: EMERGING FROM THE *DEEPWATER HORIZON* EVENT: COOPERATIVE RESEARCH OPPORTUNITIES

James Kendall, Rodney Cluck, Pat Roscigno, and Alan Thornhill
Bureau of Ocean Energy Management, Regulation and Enforcement

During the coordinated response to the *Deepwater Horizon* event in 2010, previous and ongoing partnerships proved to be invaluable for facilitating data acquisition and use by scientists, federal and state managers, and responders in the field. Interagency and inter-sector partnerships are important for the following reasons:

1. To address critical national priorities that cannot be accomplished by a single agency or sector;
2. To address priority issues that bridge the mandates of individual agencies;
3. To contribute to the cutting edge of interdisciplinary and inter-sector science and technology;
4. To help ensure that institutional resources are invested and leveraged wisely while planning for the future; and
5. To provide the necessary flexibility for supporting new, emerging issues that may not yet be part of a "mandate" but are of interest and value to many.

Coordination, cooperation, and collaboration allow various agencies and sectors to share information and work together while accomplishing their objectives. For example, collaboration among BOEMRE, NOAA, and USGS allowed rapid modifications to ongoing interagency-funded studies that collected real-time data to inform and support decision-making during the response effort. While building upon previously established partnerships, the interagency and inter-sector partnerships reinforced during the *Deepwater Horizon* response have paved the way for future cooperative research opportunities.

In May 2011, Dr. James Kendall was selected as the Regional Director of the Alaska OCS Region, directing all Offshore Energy and Minerals Management programs within the Region and serving as the focal point for the State of Alaska; Alaska Natives; industry; private and public interest groups; and other federal agencies. Kendall formerly served as the Chief of the Environmental Division of the Department of the Interior's Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE). He was responsible for overseeing the Bureau's $30 million applied environmental and socioeconomic research program, its responsibilities under the National Environmental Policy Act, its environmental compliance metrics, and the Department's Coastal Impact Assistance Program. Prior to joining the BOEMRE Headquarters Office, Kendall served as the Chief of the Environmental Sciences Section of the Gulf of Mexico OCS Region office in New Orleans. He received his Bachelor's degree in biology from Old Dominion University, Norfolk, Virginia; his Ph.D. in oceanography from Texas A&M University; and a Post-doctoral Fellowship in marine biology from the

Hebrew University of Jerusalem, Israel. Kendall has conducted marine research in the Gulf of Mexico, the Caribbean, and the Red Sea; in recent years he has focused his attention on providing the best possible environmental information for regulatory, policy, and stewardship decisions as we move towards an adaptive and ecosystem-based management approach to our nation's ocean and coastal resources. He is a graduate of the Federal Executive Institute, Charlottesville, Virginia, and the Senior Executive Fellows Program of the John F. Kennedy School of Government, Harvard University.

Dr. Rodney Cluck is the Chief of the Environmental Sciences Branch at the BOEMRE Headquarters office in Herndon, Virginia where he leads the Environmental Studies Program, the scientific backbone that supports BOEMRE decision-making concerning offshore energy development. He holds a Ph.D. in sociology from Mississippi State University and a Master's degree in rural sociology from the University of Arkansas, Fayetteville. For six years, Dr. Cluck served as the Headquarters' social scientist for the Environmental Division. In 2005, Dr. Cluck joined the Office of Offshore Alternative Energy Programs and was the project manager for the United States' first offshore wind facility.

Dr. Pat Roscigno is Chief of the Office of Environmental Studies for BOEMRE's Gulf of Mexico OCS Region. He is responsible for managing the region's Environmental Studies Program and has over 20 years of experience in managing multi-disciplinary environmental projects. Previously, he held several different research and program management positions with the Minerals Management Service (now BOEMRE) and with the Department of the Interior's U.S. Fish and Wildlife Service. He attended Fordham University in New York City.

In March 2010, Dr. Alan Thornhill was hired as Science Advisor to the Director of MMS (now BOEMRE). From 2001 to 2010, he was the Executive Director of the Society for Conservation Biology—an international society of 12,000 conservation professionals working to advance the science and practice of protecting life on Earth. Previously, he was the Director of Learning and Communications for the Science Division for The Nature Conservancy (the global organization), and a Professor of Ecology and Evolutionary Biology at Rice University in Houston, Texas. In his role as the first Executive Director of the Society for Conservation Biology, he launched the executive office, oversaw the development of a professional staff, and initiated programs that have seen the global membership triple in seven years. Among these programs is the David H. Smith Conservation Research Fellowship Program, a two-year postdoctoral research grant for outstanding early-career scientists. The Smith Program seeks to develop future world leaders and entrepreneurs who are successful at linking conservation science and application. Dr. Thornhill earned his Bachelor's and Ph.D. degrees in ecology from the University of California, Irvine.

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SESSION 1A

PHYSICAL OCEANOGRAPHY

Chair: Rebecca Green, BOEMRE

Co-Chair: Alexis Lugo-Fernández, BOEMRE

PHYSICAL OCEANOGRAPHY IN THE GULF OF MEXICO

Rebecca Green and Alexis Lugo-Fernández
Oceanographers
BOEMRE Environmental Studies Program

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THE LOOP CURRENT STUDY: OVERVIEW AND PRELIMINARY RESULTS

Peter Hamilton
Science Applications International Corporation
Raleigh, North Carolina

Introduction

In September 2009, the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE, formerly the Minerals Management Service [MMS]), initiated a study into the dynamics of the Loop Current in the eastern Gulf of Mexico. This is an ongoing cooperative program with the Centro de Investigación Científica y Educación Superior de Ensenada (CICESE) making measurements in Mexican waters, and SAIC's scientific team making measurements in U.S. waters. This brief report discusses the work being performed in the U.S. EEZ. The SAIC team consists of Drs. Kathleen Donohue and Randy Watts from the University of Rhode Island (URI), who are responsible for the pressure equipped inverted echo sounder (PIES) array, Dr. Leo Oey from Princeton University, who is responsible for the numerical modeling component, Dr. Robert Leben from the University of Colorado, who is responsible for the satellite remote sensing component, and Dr. Peter Hamilton, who is responsible for the mooring component, and is also the Program Manager. James Singer is Chief Scientist for all the at-sea work.

The overall objective is to increase our knowledge of the dynamics of the Loop Current (LC) in the Gulf of Mexico through analysis and synthesis of observations and numerical modeling output. The Loop Current has been extensively studied, primarily through remote sensing, since the 1970s; however, there have been few long-term *in-situ* measurements of its subsurface current and density structure, and the dynamical processes that are largely responsible for the circulation in the deep basins of the Gulf. These include upstream and downstream influences; upper- to lower-layer coupling; the generation of lower-layer eddies and topographic Rossby waves (TRW); the dynamics of eddy shedding; the role of peripheral cyclones; and types of LC variability.

The major part of the observational program was the establishment of a moored array consisting of nine (9) full-depth moorings, measuring currents, temperature, salinity and pressure through the water column, six (6) near-bottom moorings with a single current meter 100 m above the seabed, and 25 bottom-mounted PIES. Figure 1A.1 shows the positions of these moorings, along with similar full-depth moorings deployed by CICESE in the Mexican EEZ. The PIES and near-bottom current measurements comprise a mapping array from which three-dimensional spatial fields of temperature, salinity, dynamic height, and absolute geostrophic velocity can be extracted.

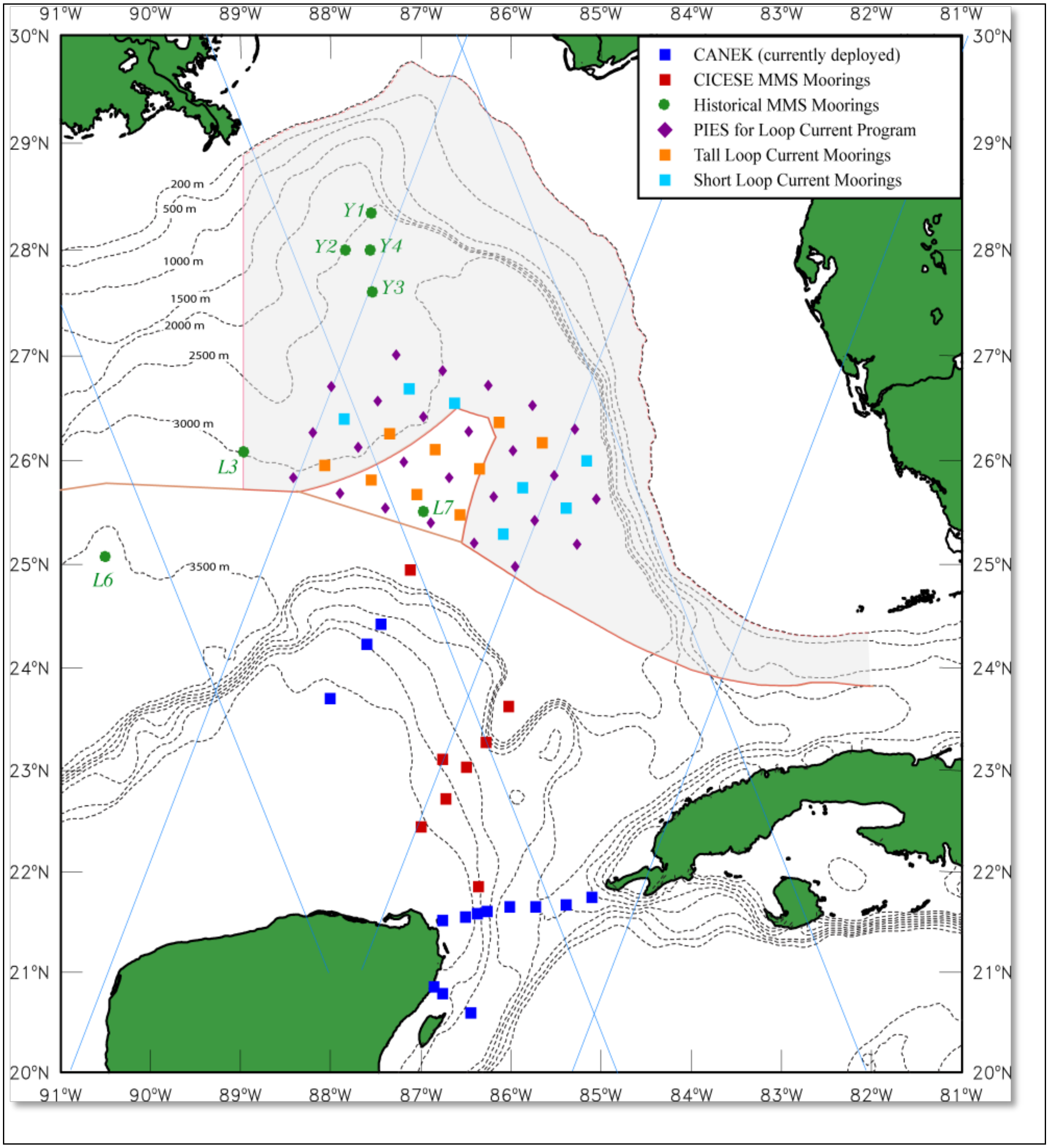

Figure 1A.1. Loop Current dynamics array and CICESE's arrays. Deployment: April 2009. Rotation: July and November 2010. Retrieval: November 2011.

Preliminary Results

The LC array was deployed in March and April 2009, and serviced and rotated in July 2010. In the July 2010 rotation cruise, two tall moorings were missed because of weather delays but were subsequently serviced in November 2010 with no loss of data that could have been caused by depleted batteries. The redeployed mooring array is due to be retrieved in November 2011. In the first deployment (April 2009–July 2010), the data return was ~ 93% for the moorings and 100% for the PIES.

The array was deployed about a month after the separation of eddy Darwin (Loop Current eddies are alphabetically named by an oil-industry consortium), by which time the northern LC front was within the array. The formation of eddy Ekman occurred over the next few months, and it eventually detached and separated at the end of August 2009, after which the LC retreated very far south and took a "port to port" mode directly connecting the Yucatan Channel and the Florida Straits. In the first few months of 2010, the LC began to extend northwards, and by April 2010, the northern front was advancing through the array. Subsequently the next eddy (Franklin) begins to form, with its first detachment at the end of June 2010. Eddy Franklin was initially large and fairly far south so that its westward trajectory was blocked by the Campeche Bank. Franklin underwent a complex series of detachment and reattachments through the summer, eventually separating as a much smaller LC anticyclone in September 2010.

The 13-month mean fields for selected isotherm depths (these have been corrected for mooring draw down caused by strong currents), 40-hour low pass filtered currents, and SSH from the altimeter gridded products, are shown in Figure 1A.2. In the upper layer, the mean currents follow the mean LC front, as given by the 15 cm SSH contour, quite closely. The strong vertical shears in the upper layer currents, above 1,000 m, are reflected in both the means and the standard deviation ellipses that show a rapid decrease in mean eddy kinetic energy (EKE) with increasing depth. As has been observed before from moored current data in the deep Gulf, the layers between ~ 900 and 1,100 m show a minimum in EKE and the weakest currents in the water column (Hamilton 2009). The 6 °C isotherm is a good representation of the bottom of the upper layer (Bunge et al. 2002), and it is similar to the shape of the 15 °C isotherm with a more prominent low in the west, and bulge north northeastward that have little expression in the lower resolution 15 cm SSH contour (Figure 1A.2).

In the lower layer, the mean and standard deviations of the currents increase from 1,300 m downward to the 2,000 m level, and then remain essentially constant in amplitude from there to 100 m above the bed. The variability, as represented by the standard deviation ellipses, is rather more uniform spatially than the surface layer, which shows large increases from the center of the LC towards the mean frontal boundary. Lower-layer mean flows show evidence of a cyclonic (counter clockwise) circulation to the east and an anticyclonic circulation to the west. This is compatible with the conservation of potential vorticity, as the LC has a tendency to extend in a northwestward direction that squeezes the lower and thus induces a clockwise circulation, with the opposite occurring on the trailing eastern edge (Figure 1A.2). The western anticyclone is apparently stronger than the eastern cyclone, and this is probably a consequence of the shoaling topography to the northwest (the Mississippi fan), which will squeeze the lower water column more effectively as the LC extends. Such lower-layer eddy pairs have been associated with the LC in numerical models (Welsh and Inoue 2000).

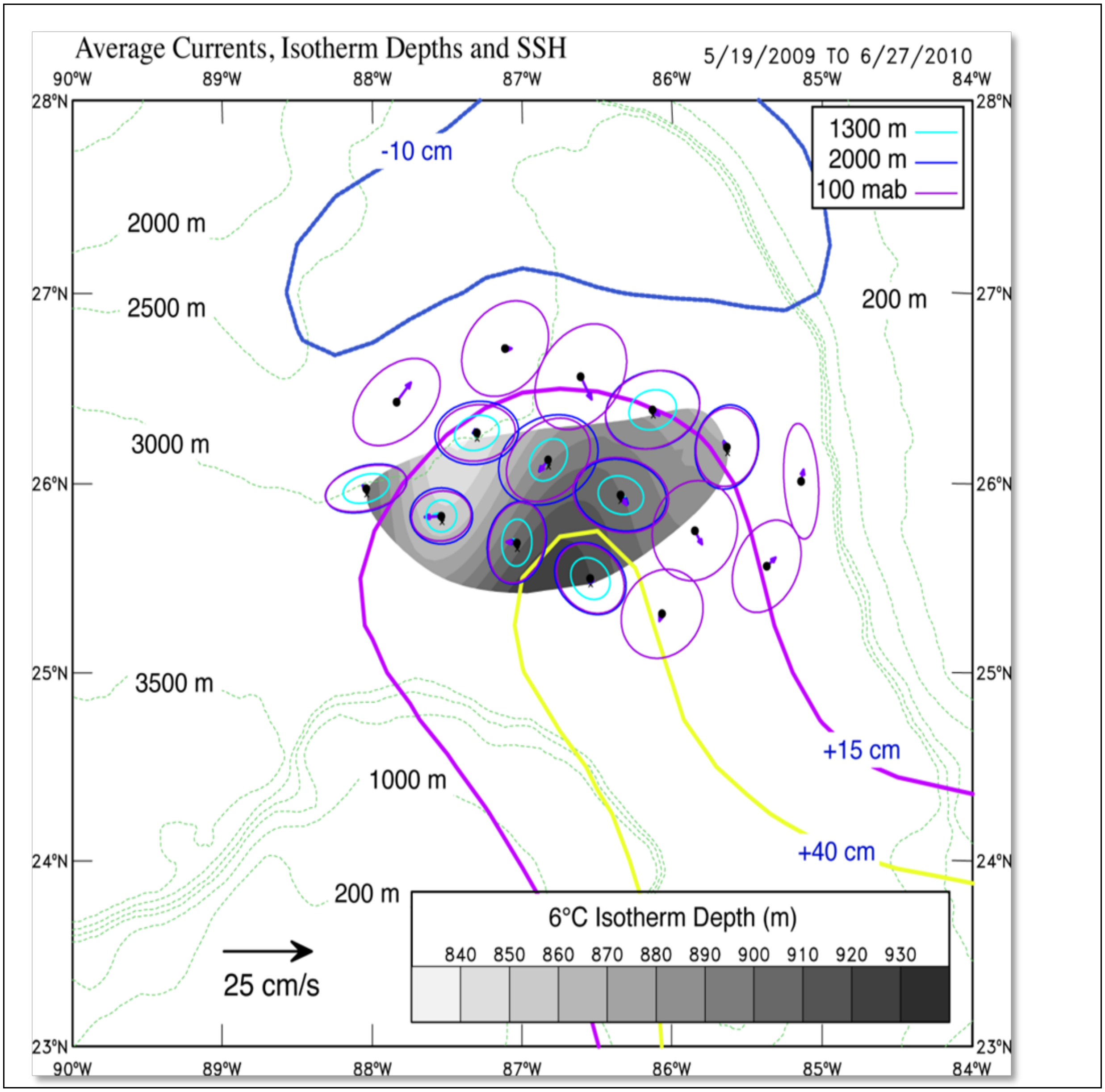

Figure 1A.2. 13-month mean fields for selected isotherm depths (corrected for mooring draw down caused by strong currents), 40-hour low pass filtered currents, and SSH from the altimeter gridded products.

There is also good evidence of coupling between the layers on the time and space scales of the LC frontal eddy variability. Frontal cyclones are commonly observed on the edge of the LC where they propagate in a clockwise direction and have a major role in some types of LC eddy separation processes (Zavala-Hidalgo et al. 2003; Schmitz 2005). Figure 1A.3 shows a sequence of bottom pressure anomaly maps with dynamic heights from the two months just prior to the separation and detachment of eddy Ekman. The troughs and crests (inward and outward bulges) of the LC frontal region are preceded by smaller scale cyclonic (low pressure) and anticyclonic

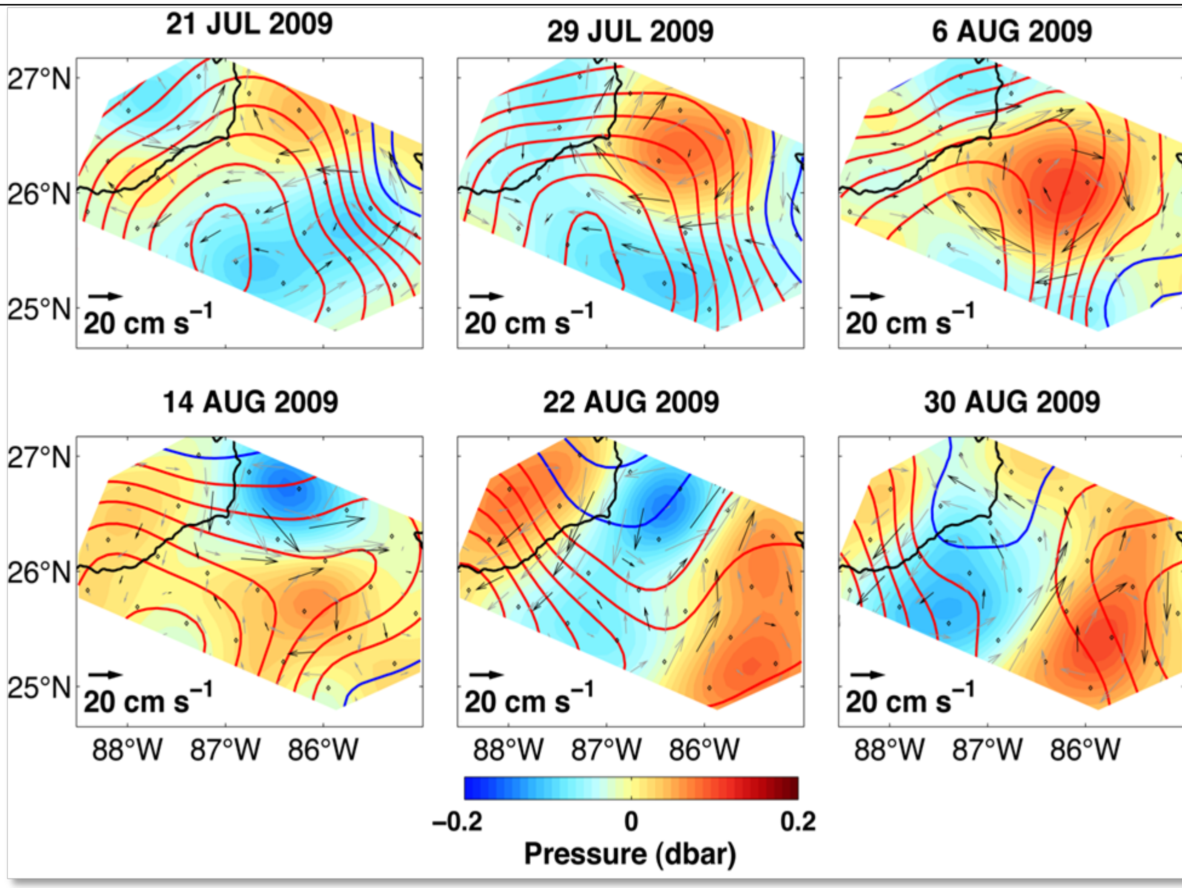

Figure 1A.3. Crest-trough upper-lower layer coupling, July–August 2009.

(high pressure) anomalies that track the clockwise propagation of the frontal anomalies. These lower-layer lows and highs are displaced from the troughs and crests in the clockwise direction of the frontal anomaly propagation by approximately a quarter wavelength. This is very similar to classic baroclinic instability of a strong surface layer jet (McWilliams 2006). The separation of eddy Ekman occurs towards the end of August 2009 when the northern lower-layer cyclone strengthens and moves southwestward through the array, still preceding the upper-layer low that effects the detachment.

Summary

This study is the first time that LC dynamics have been observed at high spatial resolution over periods longer than the typical LC eddy shedding cycle. Only the first 15-month deployment data have been recovered at this time, with the second deployment being scheduled to end in November 2011. Preliminary analysis shows rich variability in both upper and lower layers with some lower-layer phenomena being coupled to the LC frontal variability consistent with classic theory of baroclinic instabilities. Statistics of mean lower-layer flows are also consistent with the principle of potential vorticity conservation. For the first time, the three-dimensional spatial structure of a LC eddy separation, from near surface to near bottom, has been observed with the almost canonical detachment of eddy Ekman in August 2009. New important results are expected to emerge as the analysis and numerical modeling synthesis proceeds over the next few months.

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Dr. Peter Hamilton is a Senior Oceanographer with Science Applications International Corporation. For over three decades, he has participated, as a Principal Investigator, in many BOEMRE (previously MMS) programs in the Gulf of Mexico and other coastal seas. He is currently serving as a Principal Investigator and Program Manager for two ongoing deepwater BOEMRE studies that are investigating the Loop Current and the general circulation, using Lagrangian floats, of the deep Gulf of Mexico, respectively. He received his Ph.D. in physical oceanography from the University of Liverpool (UK) in 1973.

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LOOP CURRENT CYCLE AND TRIGGER MECHANISM FOR LOOP CURRENT RING SEPARATIONS

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[This document is available online:
http://www.aos.princeton.edu/WWWPUBLIC/PROFS/PUBLICATION/LCCycleTriggerMechanismv8.pdf]

Abstract

This note is part of the talk presented at the BOEMRE ITM by the senior author to review recent advances in our theoretical understanding of the Loop Current, ring separation and propagation, mass and heat balances, and the closely-related but previously not-too-well-understood coupled dynamics of the upper-layer and deep flows. While reviewing recent literature, we came across a paper by Sturges et al. (2010) who present cable data in the Straits of Florida and argue that the Loop Current ring separation may be triggered downstream by fluctuations in the Straits' transport. Considering this argument healthy in the context of recent theoretical advances of Loop Current dynamics (Chang and Oey 2010a, b) and in particular the idea of Loop Current Cycle (Chang and Oey 2011), however, shows that "downstream trigger" mechanism is not theoretically necessary for Loop Current ring separations. This does not, however, preclude the possibility that the downstream-trigger mechanism is real; it just means that the evidence presented thus far is incomplete. The senior author hopes that this note will motivate Loop Current aficionados with bright young minds to perhaps pursue this interesting research.

Introduction

Sturges et al. noted pulses of increased and decreased transports inferred from cable data at the northern end of the Straits of Florida (Jupiter to Settlement Point). The authors suggested that the pulses originated as SSH fluctuations in the open Atlantic Ocean and that they triggered Loop Current ring separations in the Gulf of Mexico. Although transport pulses appeared throughout the time series, the authors suggested that only those pulses seen just before eddy shedding were responsible for the ring separations. They concluded that "if the Loop Current is in a position where a ring-shedding event is poised to happen—but the separation has not yet occurred… these pulses provide the mechanism that causes the instability to go forward and the rings to separate" (2010). One infers from above conclusion that the "downstream trigger mechanism" is insufficient for Loop Current ring separations; however, the authors seem to suggest that it is necessary.

Sturges et al.'s notion of a "downstream trigger mechanism" may be possible, but their conclusions are misleading, as illustrated by recent theoretical advances of Loop Current dynamics (Chang and Oey 2010a, b) and in particular with the idea of Loop Current Cycle (Chang and Oey 2011).

Why do we think that the downstream-trigger mechanism as presented by Sturges et al. is misleading?

First, occurrences of transport pulses do not necessarily cause ring separations. The pulses may be part of the natural Loop Current's variability, or they may reflect transport variations through side channels (e.g. the Old Bahamas Channel) rather than through the western end of the Straits of Florida between Key West and Cuba (Hamilton et al. 2005). Hamilton et al. (2005) observed little correlation between transports through the two ends (western and northern) of the Straits of Florida. Second, and perhaps more important, while it is almost impossible from observations to show that the downstream trigger mechanism is not necessary,[1] several model calculations from existing literature prove just that. In other words, models cited below produce eddy-shedding without necessarily invoking a downstream trigger in the Straits of Florida.

If downstream trigger is indeed the mechanism that causes Loop Current rings to separate, then existing models without an active Atlantic Ocean would not produce eddy separation. These include, for example, the models of Hurlburt and Thompson (1980), Oey (1996), Pichevin and Nof (1997) and others (see Oey et al. 2005 for a review) which specify (various) open-boundary, outflow conditions downstream of the Straits of Florida. There are also models that include an inert or passive Atlantic Ocean, e.g. Oey et al. (2003, experiments A and B) and Oey (2004), as well as the more recent works by Chang and Oey (2010a, b; henceforth CO10a, b). That these models could produce eddy-shedding at a reasonable rate (one eddy per 6~11 months) suggests that the downstream trigger mechanism is not necessary. Sturges et al. (2010) also cited Pichevin and Nof's (1997) Figure 8 (which shows a rise and fall in those authors' modeled outflow i.e. Florida transport) as a supporting theoretical evidence of the downstream trigger mechanism. However, since Pichevin and Nof's (1997) model does not have an active Atlantic Ocean, their results are actually inconsistent with the downstream trigger mechanism.

The occurrences of pulses of Atlantic Ocean's origin are therefore neither necessary nor sufficient to trigger Loop Current ring separations. Whatever transport variations that may exist in the above idealized models must originate upstream. We use a simple mass balance analysis to show why these transport variations arise (when they arise) in the idealized model.

Method

We use CO10a's Gulf of Mexico model based on the Princeton Ocean Model (POM); see that paper for details. The model domain covers the western Caribbean Sea and the Gulf of Mexico west of 78oW. Steady transport and T/S values (plus radiation conditions, etc. are specified at 78oW. All surface fluxes are nil, and transport through the Yucatan Channel is nearly constant at

[1] For that one has to find a sufficiently long period (months ~ years) when the Atlantic Ocean is void of storms, eddies and other disturbances that may cause SSH fluctuations.

approximately 24 Sv. The model's horizontal resolution is variable approximately 3–5 km and it has 25 terrain-following vertical levels. The model was integrated for 12 years initialized from a previous model that was run for about 25 years (c.f. Oey et al.'s (2003) Experiment A). A quasi-equilibrium state, in which the model Loop Current sheds eddies at a nearly constant rate of 1 eddy per 8.1 months, was reached in 4–5 years. The analyses below are based on the last 8 years of the model data with 12 Loop Current ring separation events. The near-regularity of the separation events allows us to define a "Loop Current Cycle" with a period of ~240 days (Chang and Oey 2011, henceforth CO11) over which ensemble averaging is then computed for transports across the faces of a control volume. The control volume encloses the eastern Gulf of Mexico: the western face is across the central Gulf at longitude = 90^{o}W from Yucatan Peninsula in the south to Mississippi Delta in the north; the eastern face is the Straits of Florida at longitude = 80.6^{o}W from the northern coast of Cuba to the southern tip of Florida; the southern face is the Yucatan Channel and the northern face is the U.S. coastline.

The analysis is simplified by focusing on the deep control volume below z = -1,000 m (see discussions in CO11). Since the sill depth of the Straits of Florida at 80.6^{o}W is shallower than 1,000 m, that boundary is closed. Vertical mass transport across the z = -1,000 m horizontal plane (henceforth z1,000m-plane) then is balanced by the (difference) transports through the deep portions of the lateral boundaries at 90^{o}W and Yucatan Channel. Figure 1A.4 shows deep transports across 90^{o}W (this transport is denoted by "90w"), the Yucatan Channel (denoted by "yuc") and the z1,000m-plane (denoted by "z1,000"), ensemble-averaged over all 12 eddy-shedding events. Figure 1A.4 also shows the total (i.e. from surface to bottom) transport at the western end of the Straits of Florida at 80.6^{o}W (denoted by "Flo," = total transport through the Yucatan Channel), as well as the difference between area-mean SSH in the eastern Gulf and the Caribbean Sea (denoted by "EG-CB"[2]). Usual sign convention is used for the transport, e.g. negative is westward or southward, etc.

Results

In the eastern Gulf of Mexico, the Loop Current and rings are generally dominant; their movements and strengths force vertical fluxes across the z1,000m-plane (as well as horizontal fluxes). Since the idealized model has no other forcing except a steady transport (and T/S etc) specified in the Caribbean Sea, deep flows across lateral boundaries respond passively to the Loop Current and rings. As the Loop expands (or reforms after each shedding), it forces downward flux, z1,000 < 0, across the z1,000m-plane. This period of downward flux is Stage A1 in Figure 1A.4 which shows that, in response, the deep flow is divergent (both "90w" and "yuc" are negative). It is also a period when "EG-CB" increases (days 0–70 and 180–240).

As the Loop Current expands northwestward in accordance to Rossby wave dynamics (Hurlbut and Thompson 1980), it forces a deep return flow across 90^{o}W ("90w" turns positive)—this is Stage B. A large portion of the Loop Current has now moved westward away from the entrance

[2] This is dominated by EG (i.e. EG $\approx$ EG-CB), the SSH in the eastern Gulf.

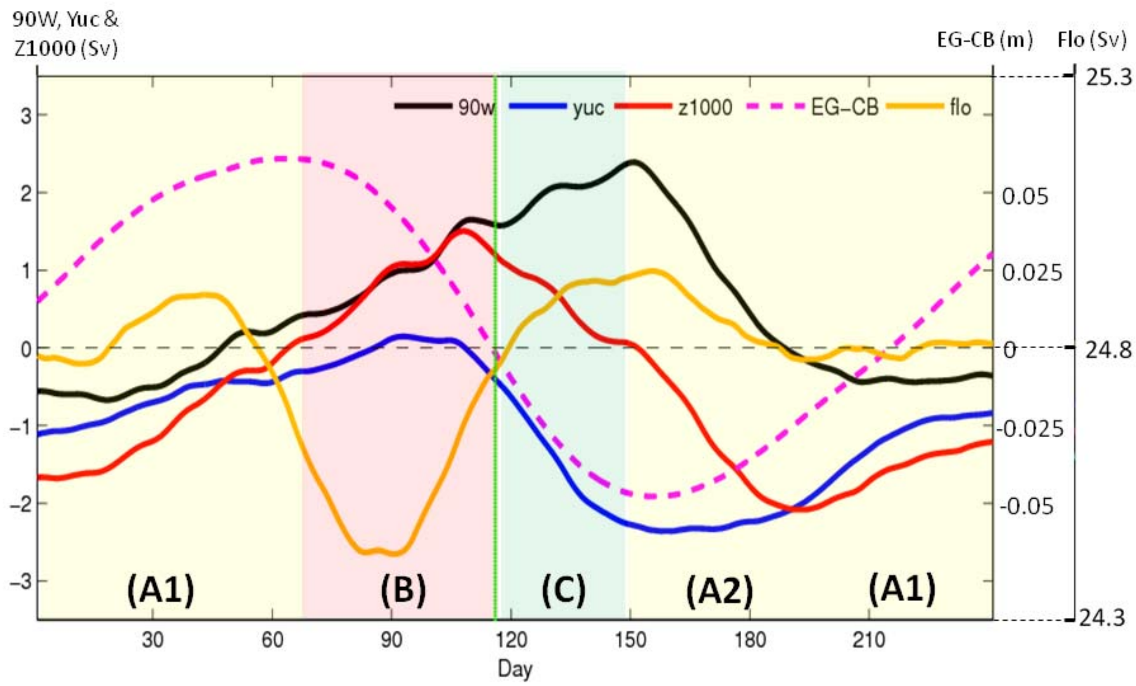

Figure 1A.4. Ensemble averaged time-series of transports across the boundaries of the deep eastern Gulf control volume (see text) across 90°W (black), Yucatan Channel (blue), and z = -1,000m horizontal plane (red). Also plotted are the Florida transport (gold curve) and the difference between the area-mean SSH in the eastern Gulf and the Caribbean Sea (dashed). The time-axis is over the Loop Current Cycle of 240 days with Stages A, B and C as discussed in text (see also Chang and Oey 2011). To show more clearly the relationship between the different variables during a Loop Current Cycle, a 30-day running-average has been applied to all the time series.

to the Yucatan Channel, the deep flow in the channel becomes weak ("yuc" ≈ 0), and the deep return flow across 90°W is nearly wholly balanced by upwelling across the z1,000m-plane, i.e. 90w ≈ z1,000 > 0 (e.g. days 80~115). The resulting deep-layer stretching produces cyclonic anomaly in the eastern Gulf as well as a drop in "EG" (hence also in "EG-CB") prior to eddy-shedding. Before this drop, however, the peak pressure (near day 70) due to "EG" decelerates the Yucatan Channel's northward inflow which (because the deep channel's flow is weak at this Stage B) is mainly confined in the upper layer, and which supplies the transport to the Straits of Florida. That is why the minimum "Flo" lags the peak in "EG-CB" and Figure 1A.4 shows that the lag is 20–30 days (i.e. near day 90 in Figure 1A.4). The phase lag *very roughly* follows a one-dimensional (Yucatan) channel-flow balance: $\partial v/\partial t = -g\partial\eta/\partial y$, so that minimum "v" lags the peak in SSH gradient $\partial\eta/\partial y$. [3]

The "EG" drops steeply during eddy-shedding (days 90~125), and our model follows closely Pichevin and Nof (1997) and Nof (2005) that eddy is shed when the westward Rossby wave speed based on the matured eddy overcomes the growth rate due to inflow through the Yucatan Channel (see CO10a,c). After eddy-shedding, in Stage C, the deep eastward flow across 90^{o}W continues to rise as eddy transports mass westward—since the western Gulf is closed, eddy forces a return deep flow (CO10a, b).[4] The upward flux across the z1,000m-plane weakens (days 115~150). The resulting strong convergence in the deep eastern Gulf then forces a correspondingly strong outflow through the Yucatan's deep channel, i.e. yuc < 0 (which has been observed, CO11), hence also a strong upsurge in the inflow transport in the upper layer of the channel. The strong upsurge is apparently sufficient to cause the transport "Flo" through the Straits of Florida to "overshoot" after eddy-shedding (days 120~150).

Conclusion and Discussion

The rise and fall of "Flo" is a natural variation of the Loop Current ring separation, and it agrees well with Pichevin and Nof's (1997) Figure 8, though the two models are very different; it is not due to a "downstream trigger mechanism." The minimum in "Flo" before an eddy is shed is closely tied with the peak SSH (around day 70) that builds up in the eastern Gulf some 40 days before an eddy is shed. If the Loop Current Cycle is considered as an "oscillator" of the Gulf of Mexico (CO11), the subsequent rise in "Flo" would be an "overshoot" after the pressure is released – after the eddy is shed. In both our and Pichevin and Nof's (1997) time series, the time scales are longer than Sturges et al.'s (2010). Hamilton et al. (2005) observed that transport through the western end of the Straits of Florida is dominant of longer periods and is uncorrelated with the transport at the northern end where the variation is of shorter periods (~10 days). Hamilton et al.'s (2005) observations are consistent with (though are not proof of) our view that, to the "leading" order, Loop Current ring separation is perhaps not triggered by downstream transport pulses. If daily time-series (instead of 30-day running averaged as in Figure 1A.4) is used for the ensemble, we obtain short-period, small-amplitude oscillations (not shown) of "Flo" superimposed on the dominant slow variation shown in Figure 1A.4. Though these oscillations have similar time scales as Sturges et al.'s (2010), about 10–20 days, we do not consider them to be significant. The idealized model has the dominant 240-day Loop Current Cycle that is also reflected in the ensemble in Figure 1A.4. In the real ocean, the Loop Current Cycle has variable periods, from 3–18 months, which tend to cancel when they are ensembled about the shedding times; this may explain why no slower variation can be seen in Sturges et al.'s (2010) ensemble (their Figure 4). If the time-axis is scaled by the shedding period T or some

[3] This formula is very rough because the flow is not one-dimensional, and SSH gradient also drives flow through the Straits of Florida. That explains why "Flo" in Figure 1A.4 rises prior to $\partial\eta/\partial y$ changes sign.

[4] Note that the deep transport "90w" cannot be neglected when assessing the relation between Loop Current's expansion and deep transport in the Yucatan Channel. The neglect explains why in previous studies the Loop's expansion and deep Yucatan flow were not always correlated (CO10c).

power of it, T^{α}, for some α which may be fractional, it will be interesting to see if observational points may be made to collapse about a common curve of the Loop Current Cycle.

Acknowledgments

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THE RELATIONSHIP BETWEEN LOOP CURRENT SEPARATION PERIOD AND RETREAT LATITUDE REVISITED

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Introduction

Funding of the University of Colorado as the remote sensing component of the ongoing Bureau of Energy Management, Regulation and Enforcement (BOEMRE) Loop Current (LC) study is being used to extend the Colorado Center for Astrodynamics Research (CCAR) archive of ocean color, sea surface temperature (SST), and altimetry measurements to include additional historical satellite missions. This archive is being used to quantify LC variability over the 30-year time period from January 1, 1980 through December 31, 2009 in order to provide a historical perspective for the LC study observational and modeling components. Preliminary analyses of LC separation periods and retreat latitudes observed in the 30-year record are presented.

Data and Methods

Continuous sampling of the Gulf of Mexico by satellite altimeters since 1992 allows objective tracking of the LC intrusion and separation events. The automated technique described in Leben (2005) uses the 17-cm sea surface height (SSH) contour in CCAR SSH maps to track the high-velocity core of the LC. Separation events are identified by the changes in LC length associated with breaking of the tracking contour as a LC eddy separates. The separation period and retreat latitude are defined, respectively, as the time interval between LC eddy separation events and the most northerly latitude along the LC tracking contour following an eddy separation. Herein, we use ocean color and sea surface temperature (SST) imagery and industry feature maps to extend the record of LC separation periods and retreat latitudes back in time before 1992. Ocean color images are NASA 8-day composite Coastal Zone Color Scanner (CZCS) chlorophyll images from November 1978 through December 1985 (GSFC 2011). SST images are from the NOAA Pathfinder Version 5.1 7-day composite AVHRR SST from September 1981 through 1992 (NODC 2011). HMI Eddy Watch™ charts (Nowlin et al. 2001) are used to identify several LC separation events from 1984 through 1991 not readily observed in ocean color or SST imagery. Each weekly Eddy Watch™ map shows the estimated location of the LC and LC eddy fronts and is based on expert analysis of satellite-tracked drifting buoy locations, ship-of-opportunity transects, and SST imagery. The combined time series of color and SST images, and Eddy Watch™ charts is used to manually identify LC separation events and the LC retreat following separation.

Results

Color imagery was sufficient to determine that there were no separation events in 1979. A continuous 30-year record of separation events and retreats, however, could be identified beginning with the first LC separation event detected in color imagery in January 1980 (Table 1A.1). A total of 18 sequential separation events were detected in the time period from

Table 1A.1.

Loop Current eddy separation and retreat latitude statistics from the 30-year observational record, 1980 through 2009.

No.	Year Letter	Industry Name	Separation Date	Confirmation Dataset	Latitude Retreat (°)	Separation Period (days)
1	1980a	-	18 Feb 1980	Chlorophyll	26.15	-
2	1980b	-	16 May 1980	Chlorophyll	26.40	88
3	1980c	-	08 Aug 1980	Chlorophyll	26.00	84
4	1981a	-	04 Jul 1981	Chlorophyll	25.50	330
5	1981b	-	24 Oct 1981	Chlorophyll	26.40	112
6	1982	-	21 Aug 1982	Chlorophyll	26.00	301
7	1983a	-	08 Mar 1983	SST	26.80	199
8	1983b	-	23 Aug 1983	SST	26.00	168
9	1984a	-	25 Jan 1984	SST	25.80	155
10	1984b	Arnold	28 Aug 1984	Chlorophyll	25.60	216
11	1985	Fast	18 Jul 1985	Eddy Watch™	25.55	324
12	1986a	Hot Core	16 Jan 1986	SST	25.65	182
13	1986b	Instant	22 Aug 1986	Eddy Watch™	25.40	218
14	1987	Kathleen	06 Nov 1987	SST	25.60	441
15	1988	Murphy	28 Apr 1988	SST	24.45	174
16	1989	Nelson	01 Sep 1989	Eddy Watch™	25.25	491
17	1990	Quiet	14 Sep 1990	Eddy Watch™	25.00	378
18	1991	Triton	01 Nov 1991	SST	26.40	413
19	1992	Unchained	16 Aug 1992	SSH	25.08	289
20	1993a	Whopper	11 Jul 1993	SSH	27.00	329
21	1993b	Xtra	10 Sep 1993	SSH	26.46	61
22	1994	Yucatan	27 Aug 1994	SSH	26.15	351
23	1995a	Zapp	18 Apr 1995	SSH	26.79	234
24	1995b	Aggie	08 Sep 1995	SSH	25.66	143
25	1996a	Biloxi	14 Mar 1996	SSH	26.25	188
26	1996b	Creole	13 Oct 1996	SSH	24.59	213
27	1997	El Dorado	30 Sep 1997	SSH	25.48	352
28	1998	Fourchon	22 Mar 1998	SSH	24.70	173
29	1999	Juggernaut	02 Oct 1999	SSH	24.87	559
30	2001a	Millennium	10 Apr 2001	SSH	25.76	556
31	2002a	Pelagic	28 Feb 2002	SSH	27.28	324
32	2002b	Quick	14 Mar 2002	SSH	24.70	14
33	2003a	Sargassum	05 Aug 2003	SSH	26.67	509
34	2003b	Titanic	31 Dec 2003	SSH	25.96	148
35	2004	Ulysses	24 Aug 2004	SSH	25.11	237
36	2005	Vortex	13 Sep 2005	SSH	26.74	385
37	2006a	Walker	06 Feb 2006	SSH	27.53	146
38	2006b	Xtreme	18 Apr 2006	SSH	26.52	71
39	2006c	Yankee	29 Sep 2006	SSH	25.64	164
40	2007a	Zorro	03 Jun 2007	SSH	26.25	247
41	2007b	Albert	16 Nov 2007	SSH	26.24	166
42	2008a	Brazos	06 Mar 2008	SSH	26.27	111
43	2008b	Cameron	30 Jun 2008	SSH	25.99	116
44	2009a	Darwin	05 Mar 2009	SSH	25.75	248
45	2009b	Ekman	27 Aug 2009	SSH	26.08	175

January 1, 1980 through December 31, 1991. Seven were identified in color images, seven in SST images, and four in Eddy Watch™ reports. LC retreat latitudes following eddy separation were determined for all intrusion events. Table 1A.1 lists both the results from the subjective manual analysis and the results based on automated altimetric tracking of the LC through 2009. Eddies are listed with a year-letter designation for years with multiple separations per year, since many of the earlier eddies were not named. Beginning in 1984, industry names are also listed. We also list the date of the source image or data product used to determine separation and retreat latitude and the estimated LC separation period.

Preliminary Analyses

A total of 45 LC separation events (Table 1A.1) were observed over the 30-year record. A histogram of separation times binned by month (Figure 1A.5) shows a clear seasonal signal in the monthly distribution with separation occurring more often in late winter/early spring and late summer/early fall, with a preference for fall separation events. The average separation period is 8 months, and fall separation events are 50% more likely than spring events. Over a dozen dynamical mechanisms have been proposed to explain eddy separation; however, no LC eddy separation precursor had been identified until Leben (2005) first showed that LC retreat after eddy separation is a good predictor of the subsequent eddy shedding period. A simple LC vorticity model (Lugo-Fernández and Badan 2007) provides a theoretical basis for this empirical relationship. After suitable scaling approximations, the theory predicts that the LC separation period is a linear function of retreat latitude, which agrees well with altimeter-derived empirical results (Lugo-Fernández and Leben 2010). The regressions results (Figure 1A.6) show that this relationship is statistically stable over the 30-year record, as would be expected of a physically controlled phenomenon. The statistical stationarity of the LC separation period and retreat latitude statistics, including the seasonality of the separation times, over the 30-year record is remarkable and is the most significant result found in this preliminary analysis of the combined 30-year historical and altimetric record.

Acknowledgments

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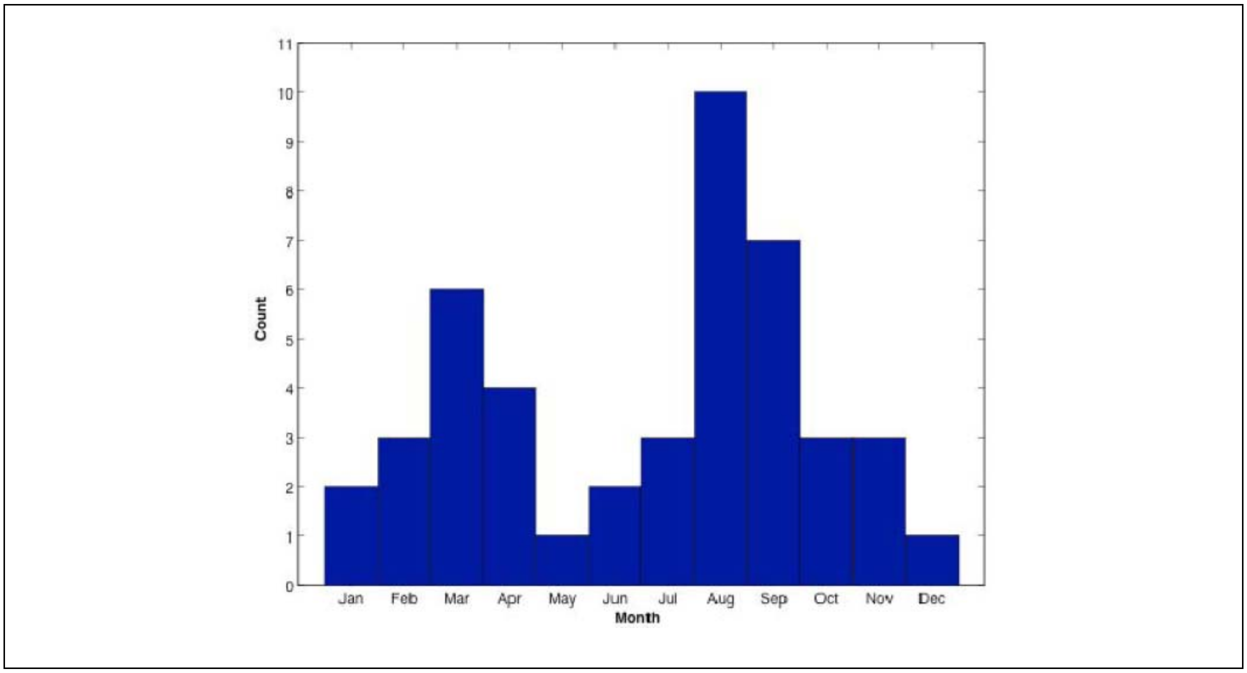

Figure 1A.5. Monthly-binned histogram of the Loop Current eddy separation times for the 45 separation events observed in the 30-year record, 1980 through 2009.

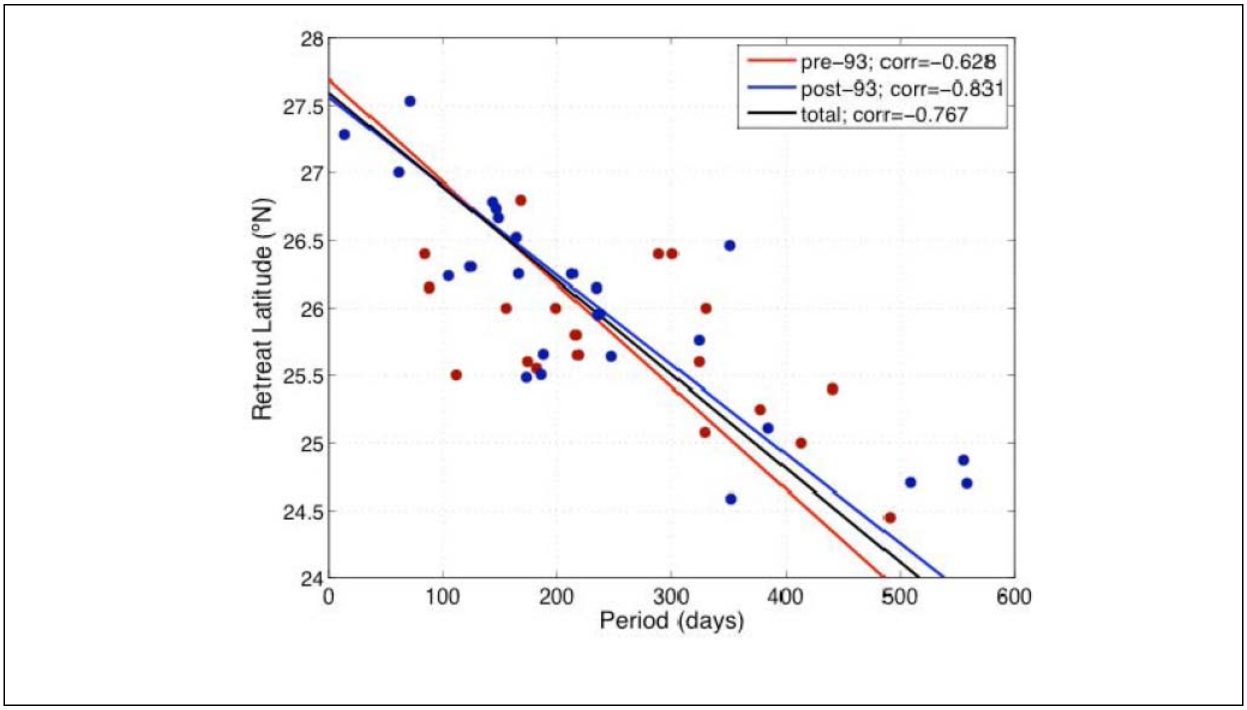

Figure 1A.6. Scatterplot of retreat latitude versus separation period of the following Loop Current eddy separation event. Regression lines for various subsets of the data record are shown along with the prediction regression model (black line) for the entire record.

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THE LOOP STUDY IN MEXICAN WATERS: THE LOOP CURRENT ALONG THE YUCATAN

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Moored current measurements between January 2005 and July 2009 on the western branch of the Loop Current, the Yucatan Channel, and the Caribbean coast of Mexico, along with AVISO altimetry, are used to evidence the presence of positive horizontal shear throughout the Yucatan Current in the eddy shedding events. These observations indicate that eddy detachments were preceded by marked eastward displacements of the Loop Current's core at 23°N latitude, which, in turn, were associated with cyclonic anomalies propagating northward along the Caribbean coast of Mexico. Once entering the Gulf of Mexico, these cyclonic anomalies generate and/or enhance existing Campeche Bank cyclonic eddies, which have been proved to be related to the Loop Current release events (Zavala-Hidalgo et al. 2003; Schmitz 2005). Observations thus clearly suggest that cyclonic eddies in the Western Cayman Sea contribute significantly to the eddy shedding process, which is complex and multimodal. Using numerical models and dynamical systems analysis techniques, a method is proposed to determine unambiguously when a Loop Current Eddy will separate.

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His work is related to observations and modeling in the Gulf of Mexico and Caribbean Sea (CS-GOM), data assimilation in ocean models and theoretical work on stability theory, turbulence and model development. In 1996, he joined with Drs. Julio Candela, José Ochoa and Antonio Badan to create a research group (the CANEK group) focused on measuring, modeling and understanding ocean dynamics in the CS-GOM region. Since 1999 the group has been involved in large observational programs deploying moorings in different parts of the region. Particularly well known are the measurements carried out in Yucatan Channel during 1999–2001 (Sheinbaum et al. 2002; Candela et al. 2002). Since 2002 they have maintained with no interruptions an array of moorings along the Mexican Caribbean and have collaborated with BOEMRE on two observational programs in the Gulf of Mexico (central and western Gulf regions). In 2007 the group embarked on an intensive observational program financed by the Mexican oil company (PEMEX) within the GOM and work as active participants in the Loop Current Experiment of BOEMRE.

On the modeling side, strong collaboration has been established over the years with several researchers, particularly Professor Bernard Barnier and his group at LEGI-Grenoble France and Dr. Laurent Debreu of the Jean-Kuntzman Laboratory of Applied Mathematics also at Grenoble, developing two-way nested general circulation models for the CS-GOM region (Jouanno et al. 2008). They have also worked with professor Andrew Moore (UCSC), Dr. Brian Powell (University of Hawaii) and Hernan G. Arango (Rutgers University) on variational assimilation in the GOM using ROMS.

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OVERVIEW OF THE DEEP GULF LAGRANGIAN STUDY

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Introduction

In September 2010 the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) initiated a major physical oceanographic field study of the deep circulation, below 1,000 m, of the whole of the Gulf of Mexico using autonomous subsurface Lagrangian drifters. The overarching goal is to increase knowledge of the dynamics of the deep circulation of the Gulf of Mexico through analysis of observations of subsurface tracked drifters. Specific objectives are to:

1. Deploy subsurface and profiling drifters over three years inside the Gulf of Mexico;
2. Analyze these data to produce maps of currents in the deep waters of the Gulf;
3. Estimate Lagrangian statistics of these current fields such as length and temporal scales;
4. Estimate particle horizontal dispersion and explore the feasibility of estimating vertical dispersion of pollutants and biological material; and
5. Provide information for BOEMRE to fulfill its regulatory mission and comply with NEPA requirements.

A team of scientists from Woods Hole Oceanographic Institution (WHOI, PI: Dr. Amy Bower), Centro de Investigación Científica y Educación Superior de Ensenada (CICESE, PI: Dr. Paula Perez-Brunius), University of Colorado (PI: Dr. Robert Leben), and SAIC (PI and Program Manager: Dr. Peter Hamilton) will be carrying out the study.

Outline of the Study

Briefly, the study will map circulation throughout the deep Gulf with a large number of floats, producing new knowledge on circulation features and processes, and deep water-parcel transport and dispersion. The study includes the deployment of a total of 120 RAFOS floats over the three-year field study period. A RAFOS drifter is an instrument that floats at a prescribed depth and locates its position by listening for and recording sound pulse arrival times, at regular intervals (every eight hours), from two or more sources deployed on moorings in the study area. At the end of a prescribed deployment period, the RAFOS drifter surfaces and broadcasts its location, depth and temperature data to the laboratory via a satellite relay. In this program, the Iridium satellite system will be used.

The field effort will begin in July–August of 2011 with the deployment of three Teledyne Webb Research RAFOS sound sources and one WHOI-URI designed sound source (261 kHz), 40 RAFOS and 6 APEX profiling floats. The sound source locations have been optimized for coverage and redundancy, with one location selected within the Mexican Exclusive Economic Zone (EEZ) and three within the United States EEZ. Of the first 40 RAFOS floats that will be deployed, eight to ten will be ballasted to reside at a water depth of 2,500 m, and the remainder at a depth of 1,500 m. The objective of the initial deployment cruises is to spread RAFOS and APEX floats over all locations of the deep Gulf basin, with emphasis on the Bay of Campeche and the central western basin which were not covered by float trajectories in the previous BOEMRE Lagrangian study (the Exploratory program, April 2003–May 2004, Figure 1A.7). The six APEX profiling floats will profile the water column at 15-day intervals with a rest depth of 1,500 m, adding to the Lagrangian database as well as providing approximately 430 CTD and optical parameter profiles. The latter will provide profiles of chlorophyll, particle concentration, and dissolved organic matter (CDOM) to provide valuable biogeochemical data in the deep Gulf. APEX profiling floats are very good random samplers of the water column and are extensively used in the global ocean ARGO program. Again the Iridium satellite system will relay the profiles and location data every time the float surfaces. In addition, the profiling floats will act as monitors of the sound sources, providing monthly updates on their functionality.

The deployment strategy for the RAFOS floats will be to deploy in pairs so that short time scale (one to ten days) Lagrangian dispersion can be characterized in different parts of the deep Gulf. This is clearly an important component in modeling transport and dispersion of deep pollutants and other water properties. In the first deployments of the RAFOS floats, 30 will be set to surface in two years, and 10 will surface and report after one year. These latter floats will be used to monitor the reliability of the floats and give the PI's some feedback for the second year of float deployments. In the second year of the field program, a total of 80 RAFOS floats will be deployed (July–August, 2012), with all floats having two-year lifetimes in order to investigate circulation over longer time scales. In the third year of the field program (2013), the 30 floats deployed July-August 2011 that had two-year lifetimes will surface and the data analyzed. In year four, the 80 floats deployed in year two will surface and report. The advantages of this deployment scheme are increased resolution of time scales greater than one year, and two years with increased spatial coverage of between 80 and 110 active floats. Once all remaining RAFOS floats have surfaced and reported at the end of the third field year, the sound sources will be recovered, marking the end of the field program. Vessels utilized will be the R/V *Pelican* and R/V *Acadiana* (LUMCON), and R/V *Bellows* (USF) in the U.S. EEZ, and the R/V *Justo Sierra* (UNAM) in the Mexican EEZ. A preliminary sketch of the deployment cruises and sound source locations is given in Figure 1A.8.

Therefore, the program will produce a maximum of 230 float-years of trajectories. The complete program database will be rigorously analyzed in terms of circulation mapping, Lagrangian statistics, kinematic models, and dynamic processes. There is also a remote sensing component to the study, and Dr. Leben will be mapping surface layer eddies using altimetry and radiometry. Because sea surface height (SSH), measured by satellite altimeters, has been shown to map surface layer eddy circulations with time scales of order a week, and space scales of order 50 km, one of the aims of the study is to relate these time variable eddy flows to the deep circulations. Previous studies (Hamilton 2009) using moored current observations have shown that the lower layer is dominated by topographic Rossby waves (TRW) with time scales of ~ 10 to 100 days

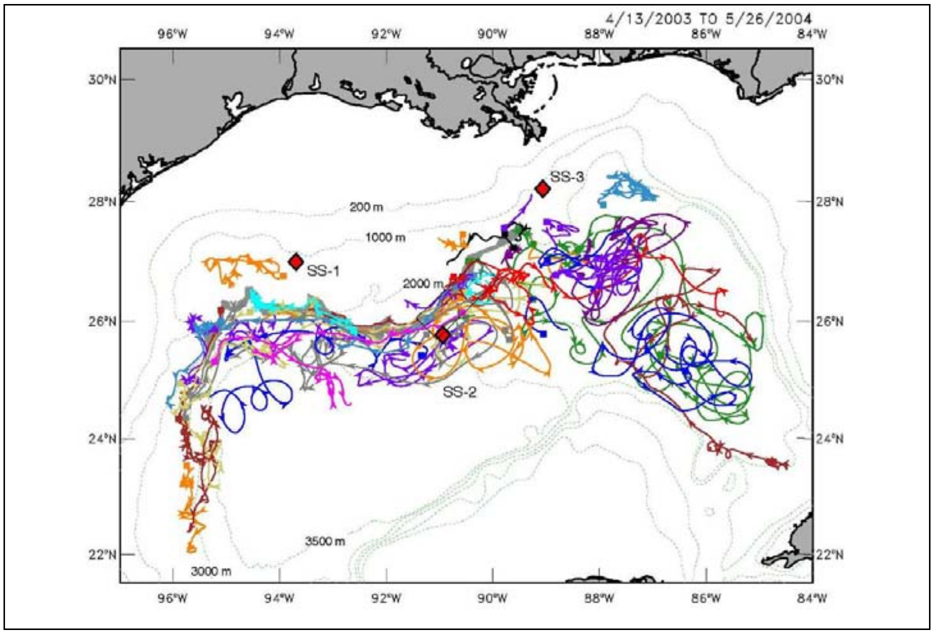

Figure 1A.7. RAFOS float trajectories from the Exploratory Program (April 2003 to May 2004). The floats were deployed at various depths from 1,000 m to 3,000 m at 500 m intervals. The sound source locations are marked by the red diamonds, and the steep S Sigsbee escarpment at the base of the northern continental slope is shown by the gray shading. Note the concentration of floats and their westward transport along the escarpment.

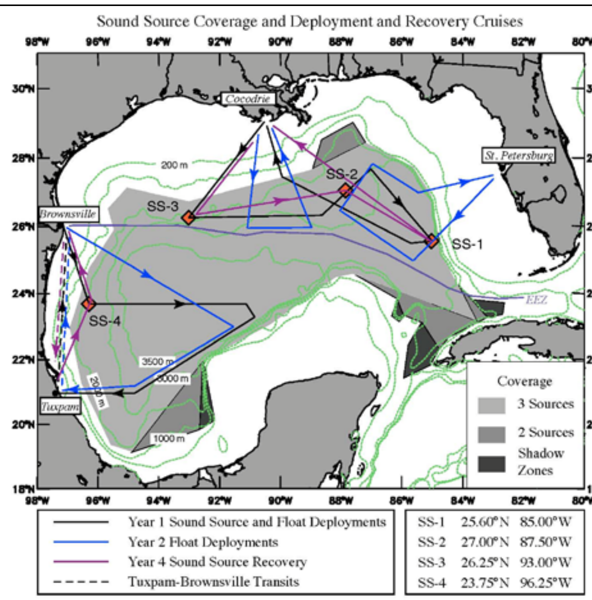

Figure 1A.8. Sound source locations (red diamonds) and preliminary deployment cruise tracks for the three-year field study. The gray shading represents the sound source coverage for depths greater than 1,500 m. Shadow zones are the small areas where only one source can be used and therefore location fixes are not available.

and wavelengths of 75 to 200 km. The generation of these lower-layer waves by upper layer eddy activity, including most prominently the Loop Current, is at present not understood.

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Dr. Peter Hamilton is a Senior Oceanographer with Science Applications International Corporation. For over three decades, he has participated, as a Principal Investigator, in many BOEMRE (previously MMS) programs in the Gulf of Mexico and other coastal seas. He is currently serving as a Principal Investigator and Program Manager for two ongoing deepwater BOEMRE studies that are investigating the Loop Current and the general circulation, using Lagrangian floats, of the deep Gulf of Mexico, respectively. He received his Ph.D. in physical oceanography from the University of Liverpool (UK) in 1973.

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THE FLOWER GARDEN BANKS TOPOGRAPHY/TURBULENCE: OVERVIEW AND EXPERIMENTAL DESIGN

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Introduction

This work addresses interrelated scientific questions concerning the ocean dynamics and bio-optical properties over the Flower Garden Banks National Marine Sanctuary (FGBNMS). The main objective is to understand the ocean processes over the East Flower Gardens Bank and to examine the importance of these topographic induced processes on shelf edge circulation on longer (e.g., monthly to seasonal) time scales. This project, "Current-Topography Interaction and its Influence on Water Quality and Contaminant Transport over Shelf-Edge Banks," is referred to in short by the name "Currents Over Banks (COB)." Moorings have been deployed in conjunction with a closely related research effort of the Naval Research Laboratory (NRL) referred to as "Mixing Over Rough Topography (MORT)" which has an intensive field effort scheduled for summer, 2011. All field work requires close coordination among NRL, Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), and FGBNMS to determine sharing and contribution of resources, timing of the field work, and specific study site selection.

Field Experiments

Three cruises have been planned, all utilizing the UNOLS vessel, R/V *Pelican*. The first was completed last year (December 7–13, 2010). During this cruise, moorings were deployed to measure the currents and density structure around the East Flower Garden Bank. These moorings are scheduled to take measurements for about one year. They will be recovered, serviced, and redeployed during the intensive MORT experiment scheduled for May 26 to June 16, 2011. Their final recovery cruise is scheduled for December 6–12, 2011. The cruises are conducted out of Cocodrie, Louisiana, approximately 190 nm from the East Flower Garden Bank and require approximately 19 hours of transit time to the bank.

Over the entire experiment, NRL will deploy a total of ten Barny and six string moorings. The Barny mooring (Perkins et al. 2000) is shaped like a "barnacle" and is about 2 m in diameter. It rests on the sea floor. An acoustic Doppler current profiler (ADCP) is contained in the Barny and is located at the top in a small buoy. The Barny contains either a wave/tide gauge or a high-frequency pressure p-pod sensor, temperature, and conductivity sensors in the body. An outer ring of reinforced cement provides impact resistance and ballast. The overall smooth profile shape minimizes the risk of being fouled by fishing gear and makes a Barny mooring highly resistant to trawling. The mooring is not dropped but rather is lowered to the bottom and then released, after a level determination. The entire mooring is recovered at the end of the deployment via an acoustic release of the small buoy that carries a recovery line and the ADCP to the surface. The main body of the mooring is hauled up using the recovery line. The string moorings consist of eight to ten MicroCats and measure temperature and conductivity. Some will also measure pressure. The string moorings are anchored on the bottom and use subsurface floats to make the mooring taut. None will have a surface marker.

During the first of the three cruises, five Barny moorings and four strings were deployed at the East Flower Garden Bank at depths between 80 and 150 m. Four were located just east, west, north, and south of the bank and one Barny was located just north of the coral reef zone on top of the bank. The Barny moorings will monitor the currents for a period of about a year and will provide almost full water column velocity profiles every 15 minutes. Four temperature/ conductivity string moorings were also deployed near the moorings on the perimeter of the bank to provide density profiles every 6 minutes over the year. Mooring positions are shown in Figure 1A.9.

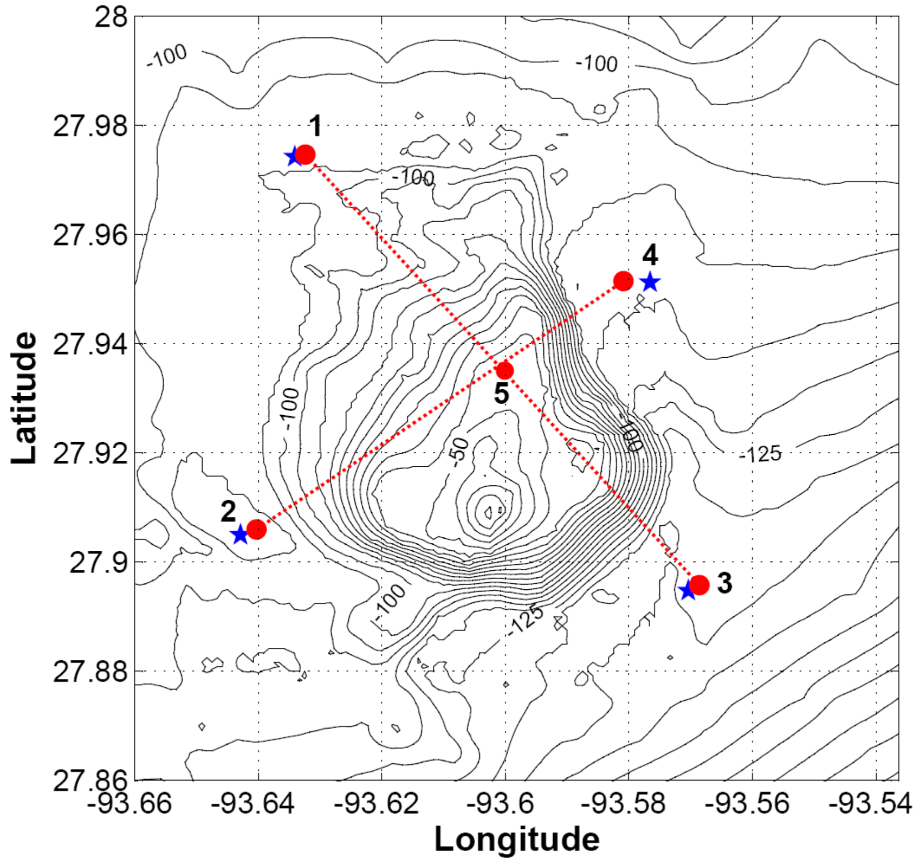

Figure 1A.9. Five Barnys equipped with ADCPs (red dots) are moored at the East Flower Garden Bank. Four temperature/conductivity string moorings (blue stars) are located next to Barny moorings 1–4. Bathymetry contours are shown every 5 m.

In addition, during the first cruise, one section of microstructure profiles using NRL's Vertical Microstructure Profiler (Rockland Scientific VMP500) was completed from south to north over the southeast side of the bank to study turbulence levels. The VMP is equipped with state-of-art microstructure velocity shear probes, high-resolution temperature and conductivity sensors, and external high-accuracy CTD sensors. More microstructure measurements were planned but these measurements were stopped due to declining weather conditions. Measurements of temperature and turbulent kinetic energy dissipation rate are shown Figure 1A.10. This snapshot may not reflect the true nature of mixing over the bank. However, there is a well-mixed layer of about 60 m that penetrates to the top of the bank with high mixing near the surface during early December wind events.

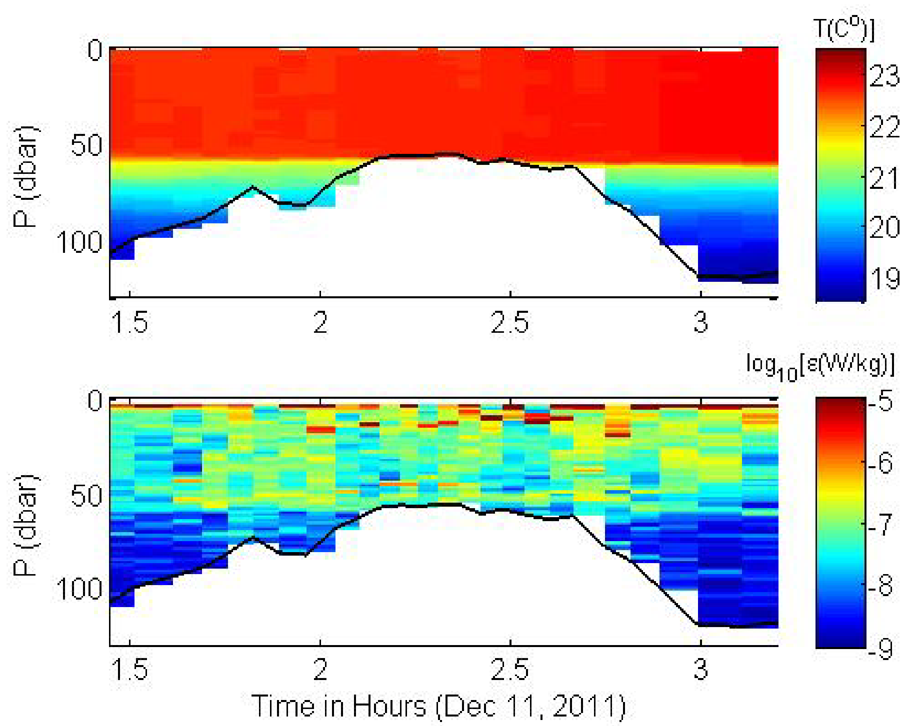

Figure 1A.10. Time–Depth section of temperature (top) and turbulent kinetic energy dissipation rate (ε) observed during December 11, 2011, over the southeast side of the bank.

During the second cruise (summer), an additional five Barny moorings and two string moorings are planned to measure high frequency processes. These moorings will be located very near the other moorings and will take measurements every minute. Additional measurements made from the ship will include conductivity, temperature, and depth (CTD), VMP, ADCP, Biosonic echosounder, optics, and ScanFish measurements. Vertical profiles of acoustic backscatter will be measured with the 120 kHz echosounder. The ScanFish is towed behind the ship in either profiling or level modes and measures temperature and salinity and inherent optical properties (IOP). The ScanFish has a Sea-Bird 49 CTD, Wetlabs C-Star (10 cm transmissometer), AC-9 (9 channel absorption and attenuation meter), BB3, and FL3. A REMUS with similar instrumentation will be deployed via an ONR contract. Standard shipboard observations will also be made and include ADCP, meteorological sensors, and underway water flow-through system. A streak of dye (fluorescein) will be released at different depths and ScanFish and REMUS-AUV surveys will be conducted along with a profiling microstructure survey to capture the downstream distribution of the dye. The dye patch will reveal finescale to mesoscale features, and can be used to quantify horizontal (isopycnal) and vertical (diapycnal) diffusion. A schematic of mixing and entrainment is shown in Figure 1A.11 to illustrate interactive processes over a small bank on the continental shelf. Several aspects of mixing and fine-scale variability have been identified including hydraulic jumps, high-frequency internal waves, and eddies on the lee side of a bank.

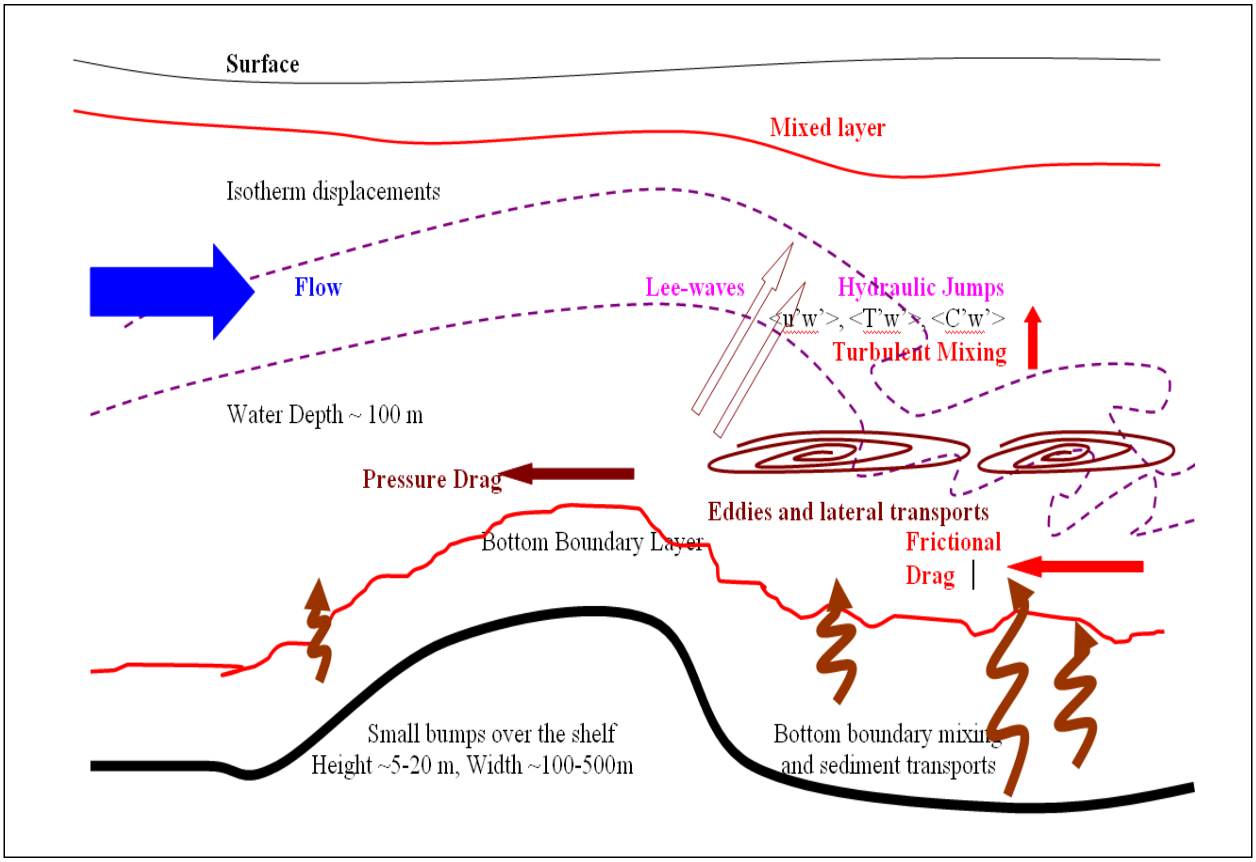

Figure 1A.11. Possible mixing processes over a small bank on the continental shelf.

During the third cruise, scheduled for December 2011, the long-term Barny and string moorings will be recovered. If time and weather allow, additional VMP and CTD measurements will also be acquired.

Collaborations

J. Moum and J. Nash (Oregon State University): will provide pressure sensors (P-PODs) to investigate the pressure fields associated with topographically generated internal waves.

M. Moline (Cal Poly State): ONR funded to deploy REMUS-AUV on our cruise—main focus on the detection of dye patches.

Michael Gregg and Tim McGinnis (APL, UW): ONR funded to tow SWIMS3 (microstructure) on separate vessel during summer experiment.

J. Jolliff (NRL): NASA funded high-resolution physical-optical mapping and modeling.

Acknowledgments

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William J. Teague is the section head for the Physical Oceanographic Processes Section at the Naval Research Laboratory (NRL) located at Stennis Space Center, Mississippi. He has a Master's degree from the Rosenstiel School of Marine and Atmospheric Science at the University of Miami. He was principal investigator for NRL's SEED field project that focused on shelf exchange in the Northeastern Gulf of Mexico. Hurricane Ivan passed directly over his SEED current moorings.

Hemantha W. Wijesekera is a principal investigator in the Physical Oceanographic Processes Section at the Naval Research Laboratory (NRL) located at Stennis Space Center, Mississippi. He has a Ph.D. from Oregon State University. He served as a program officer in the physical oceanography program at National Science Foundation from 2006–2008. Main research activities are centered on mesoscale to sub-mesoscale to turbulent scale processes in both coastal and deep ocean regimes. He is the lead PI for the MORT project at NRL.

Ewa Jarosz is a principal investigator in the Physical Oceanographic Processes Section at the Naval Research Laboratory (NRL) located at Stennis Space Center, Mississippi. She has a Ph.D. from Louisiana State University. Her research has focused on internal wave dynamics, circulation in marginal and semi-enclosed seas, coastal current dynamics, strait dynamics, and mixing processes. Currently, she leads Exchange Processes in Ocean Straits, an NRL project in which a successful field program in the Bosphorus and Dardanelles Straits was recently completed.

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AIRBORNE OCEAN SURVEYS OF THE LOOP CURRENT COMPLEX FROM NOAA WP-3D IN SUPPORT OF THE DEEP WATER HORIZON OIL SPILL

Lynn K. Shay[1]

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Introduction

On April 20, 2010, the *Deepwater Horizon* (DWH) oil rig, located in 5,000 feet, along the northern continental slope of the Gulf of Mexico (GOM) and adjacent to the DeSoto Canyon, exploded, killing 11 workers. The well started to leak crude oil until it was capped on July 15. During that time, NOAA's Office of Response and Restoration (NOAA-OR&R) modeling team generated daily trajectory forecasts for 107 days, beginning April 21, to determine the possible pathways in the current configuration of the GOM. At the time of the explosion, the Loop Current (LC), a warm ocean current in the GOM that feeds the Florida Current and Gulf Stream, extended far north to about 27.5°N south of the spill site. Emergency responders were concerned that this energetic, clockwise rotating LC would be a major transport mechanism for the oil and would redistribute it southward towards the Florida Keys. Moreover, this was a spill in deep water compared to a surface spill where the ocean's surface current is of more concern than upper ocean currents through the thermocline.

In this context, the Upper Ocean Dynamics (UOD) Lab at the University of Miami was tasked with measuring the LC properties using available NOAA research aircraft to acquire useful ocean data for assimilation into operational models used by OR&R in collaboration with scientists from NOAA's AOML. These flights provided primarily thermal structure data on a seven- to ten-day basis for ocean models at the Naval Oceanographic Office to predict possible pathways of the oil from the northern Gulf of Mexico. These measurements provided the important data to vector ships to regions of mesoscale variability and are being used to evaluate satellite-based products such as oceanic heat content derived from satellite altimetry (Mainelli et al. 2008; Shay and Brewster 2010).

The oceanographic structure of the Gulf of Mexico is dominated by the LC, an extension of the Caribbean Current that moves through the Yucatan Straits into the Gulf of Mexico, and exits east through the Florida Straits between the Florida Keys and Cuba. The LC, a dynamic entity which reaches speeds of 3 knots, has two forms, a retreat phase where the LC makes a direct link between the Yucatan Straits to the Florida Straits, and a bulging phase, where the LC meanders deep into the GOM before exiting to the east. The bulging LC is surrounded by an eddy field including both clockwise and counterclockwise rotating eddies. The bulge of the LC can pinch off and form an eddy which moves to the west. The conditions during the oil spill were characteristic of the bulging stage. Such behavior could facilitate oil transport to the Florida Keys and out to the Gulf Stream via the Florida Current which would impact the eastern seaboard.

Airborne Ocean Surveys

Nine flights on NOAA WP-3D Orion aircraft (RF-42) were conducted between May 8 and July 9, 2010 (Figure 1A.12) in the region south of the DWH rig, and over the Loop Current (LC) and its associated eddy field. In addition, there were four flights in support of the hurricane field program in August and September. Airborne expendable profilers measured atmospheric and oceanic properties every seven to ten days over the northeastern GOM. In total, 777 Lockheed Martin airborne ocean profilers were deployed (Table 1A.2), of which 538 were bathythermographs (AXBT), 158 current-temperature profilers (AXCP), and 81 conductivity-temperature-depth profilers (AXCTD). *Note that all flights included the mooring array deployed in support of BOEMRE's Dynamics of the Loop Current Study (DLCS).*

Table 1A.2

Summary of ocean profilers deployed during 2010 over the LC system. Values in parenthesis indicate good probes. In addition, 78 atmospheric dropsondes were deployed during DWH and *HFIP/IFEX* flights from NOAA WP-3D RF-42 aircraft (H). The overall success rate is 83% for ocean probes.

Flight	Event	AXBT	AXCP	AXCTD	TOTAL
100508H	DWH	52 (46)	0	0	52 (46)
100518H	DWH	29 (28)	26 (10)	11 (10)	66 (48)
100521H	DWH	42 (41)	22 (11)	2 (2)	66 (54)
100528H	DWH	41 (37)	22 (12)	2 (1)	65 (50)
100603H	DWH	37 (33)	23 (9)	6 (6)	66 (48)
100611H	DWH	53 (48)	15 (10)	0	68 (58)
100618H	DWH	34 (23)	22 (11)	8 (7)	64 (41)
100625H	DWH	58 (53)	0	6 (6)	64 (59)
100709H	DWH	59 (54)	12 (11)	6 (3)	77 (68)
100724H	*T.S. Bonnie*	35(33)	0	0	35 (33)
100812H	*Test*	6 (6)	6 (5)	0	12 (11)
100909H	*Pre Matthew*	62 (58)	0	20 (17)	82 (75)
100924H	*Pre Matthew*	30 (30)	10 (5)	20 (20)	60 (55)
Total	**538 (490)**	**158 (84)**	**81 (72)**	**777 (646)**	**777 (646)**

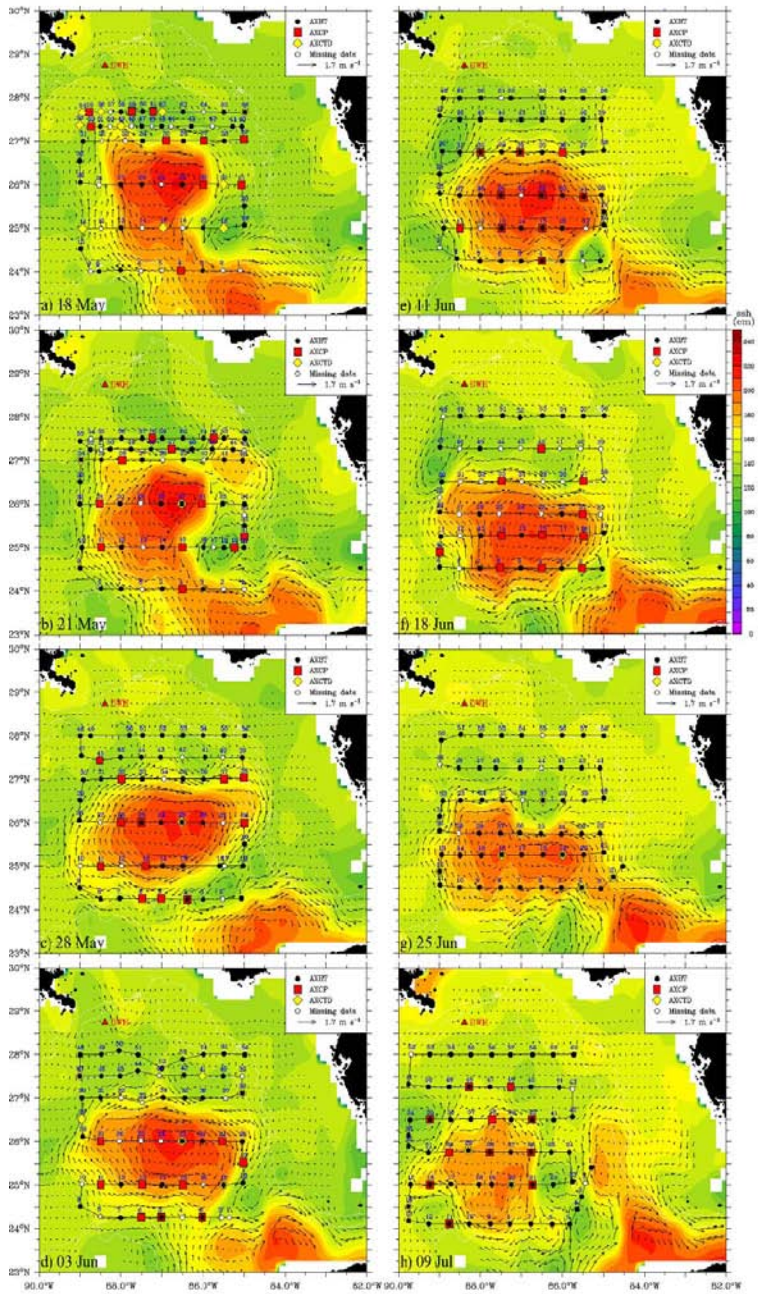

Figure 1A.12. Tracks of the WP-3D and profiler drop points overlaid on sea surface height (color) and altimetry derived geostrophic currents (arrows) using Rio and Hernandez mean surface height. Black circles correspond to AXBT, red squares to AXCPs, yellow diamonds to AXCTDs, and white circles to missing data drops; the red triangle is the position of the DWH rig.

Flights originated at and returned to MacDill United States Air Force Base (in Tampa, Florida) with a duration of 8 to 10 hours. During a typical mission, the aircraft flew at 5,500 feet at an indicated air speed between 185 to 195 knots. This slower speed was required for optimal deployment of the AXCPs and AXCTDs from an unpressurized cabin. Oceanic profilers were deployed in lawnmower style grids shown in Figure 1A.12. These flights sampled essentially the same grid points, to as deep as 1,500 m, to provide the evolving oceanic variability of the LC and the eventual shedding of eddy Franklin. The atmospheric dropsondes were deployed along a middle transect line during an AXCP deployment, with others over important areas of investigation, such as the edge of the LC. On several flights, AXCPs and AXCTDs were deployed at the same points as AXBTs to compare T(z) profiles in the upper 350 m. Despite differing fall rates, thermal structures measured at the same point by different probes are consistent. A point-by-point comparison of temperatures produced slopes of 1.02 and 1.03 for all AXCTD/AXBT and AXCP/AXBT combos, respectively. *RMS* temperature differences were 0.40°C and 0.41°C for AXCTD/AXBT and AXCP/AXBT combos, respectively.

Preliminary Results

The intrusion of the LC and the associated growing and shedding of warm core eddy (WCE) Franklin influenced the ocean currents south of the rig. Several cold core eddies (CCE) developed along the LC periphery during the growing of Franklin; frontal CCEs are thought to play an important role during the shedding of LC WCEs (Schmitz 2005). Northern frontal CCEs directly impacted the circulation patterns near the rig during most of the observational period (Figure 1A.12). Franklin first detached from the LC by May 28 (Figure 1A.12c). Then, it reattached to the LC by June 3 (Figure 1A.12d); a series of partial detachments and reattachments occurred during the rest of June. Franklin finally separated from the LC by July 9 (Figure 1A.12h). During this separation sequence, the LC bulge , similar to that observed during Katrina and Rita in 2005 (Jaimes and Shay 2009), experienced a series of stretching and squeezing processes represented by fluctuations of the depth of the 20 °C isotherm. Minimum values of H20 of about 250 m were measured on May 21 at the LC bulge, just before the first separation of Franklin; a series of frontal CCEs simultaneously developed along Franklin periphery, where H20 levels were ~80 m. Minimum values of H20 of ~240 m were observed during the second separation of Franklin on July 9.

One of the more salient aspects in the thermal structure near the DWH rig is the presence of a subsurface thermostad that extended between the 30 and 200 m depth levels on May 8; homogeneous temperatures of about 19 °C characterized this thick layer (Figure 1A.13). Surface waters on top of this thermostad were strongly stratified, and temperatures decreased nearly 7 °C over the upper 50 m of the water column. By May 18, the thermostad thickness was reduced by ~50 m, and remained nearly constant until June 3. By July 9, the thermostad was nearly absent. Although this thermostad could be the remnant of a deep mixed layer potentially produced during winter by strong cold fronts (Nowlin and McLellan 1967), it is not clear that the evolution of this thermostad from May 8 to July 9 was driven by mixed layer dynamics, as temperatures below the 100-m depth level were cooler over time. In a typical mixed layer deepening, surface waters cool while subsurface waters warm by the effect of vertical mixing as observed during

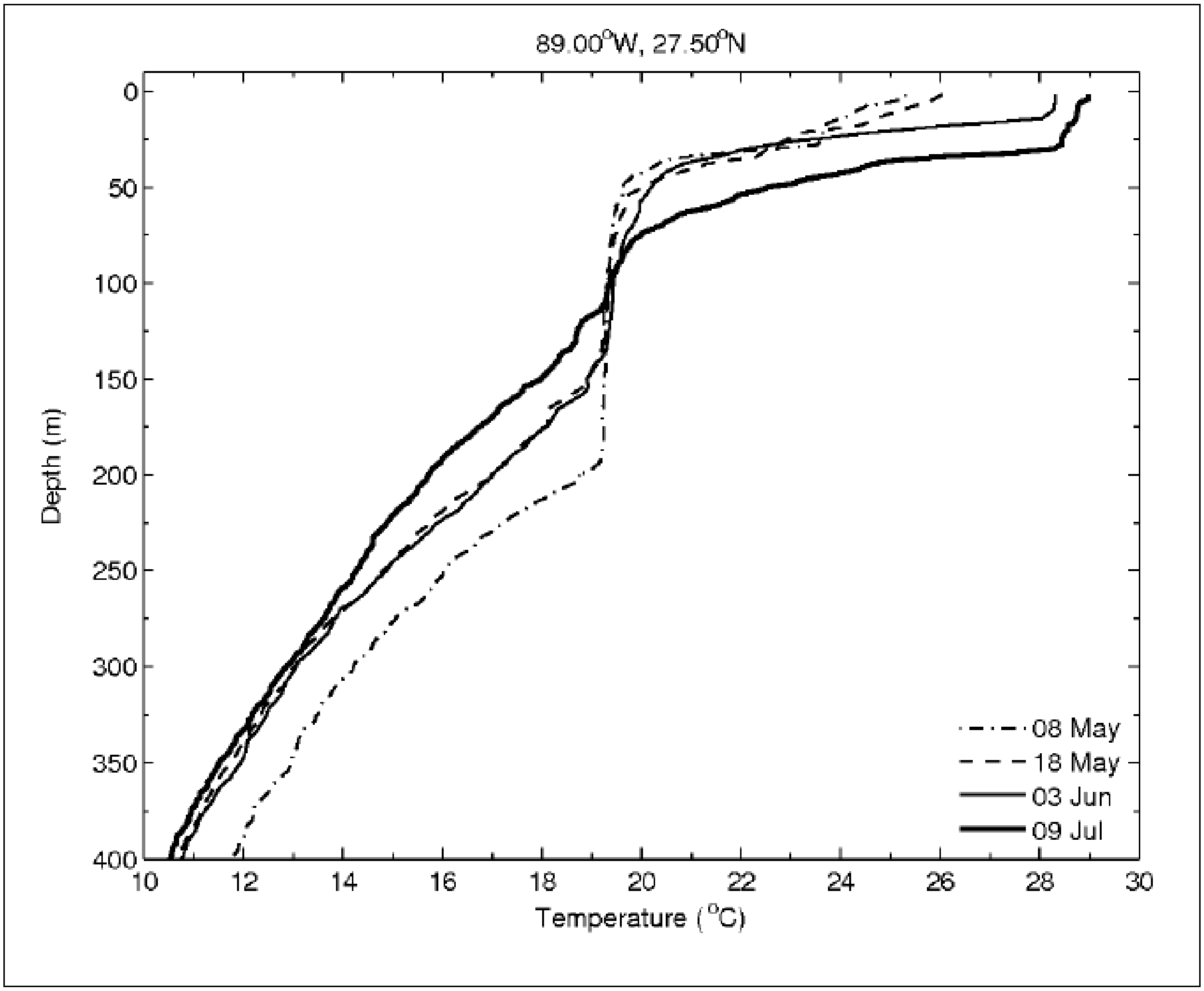

Figure 1A.13. Evolution of temperature at a point (~89.0°W, ~27.5°N) situated south of the DWH rig, from airborne profilers.

tropical storms and hurricanes. It is more likely that these changes in thermal structure near the DWH rig were influenced by the mesoscale and synoptic scale variability discussed above. In particular, the development of CCEs is one mechanism that explains the progressive cooling of waters below the 100-m depth level. Note that the temperature profile from July 9 was measured at the edge of a CCE (drop point 51, Figure 1A.12h). The gradual warming of surface waters is caused by insolation.

Another striking aspect of the thermal structure near the DWH rig is the horizontal distribution of the thermostad. From May 8 to June 11, the thickness (*dh*) of a nearly homogeneous water column, bounded by the 19 and 20 °C isotherms, shows consistent maximum values between 80 and 120 m just south of the rig (not shown). The variability of the horizontal distribution of *dh* is constrained by the isotachs, represented here by the topography of H20, which is a proxy for the main thermocline depth in the GOM (Shay et al. 1998). Intermediate levels of *dh* between 40 to

60 m originated at the regions of maximum *dh* and extended along the LC periphery, which suggests advection of these nearly homogeneous waters by the background flow.

A water mass analysis, based on AXCTDs deployed on May 18, reveals the presence of unusual low salinity levels (<36.2 psu) at two sampling points (53 and 54) situated at the region of maximum *dh* (not shown). These low salinity levels extended on top of the thermostad, where temperatures ranged from 20 to 28 °C. These anomalous salinity levels do not correspond to water mass characteristics commonly observed in offshore stations over the LC, WCEs, CCEs, or Gulf Common Water (GCM). In Nowlin and McLellan (1967), salinity levels between 32.5 and 36 psu were measured over the Louisiana-Texas continental shelf where maximum depths were less than 75 m and were associated with Mississippi river runoff.

Summary

While the DWH well was eventually capped, the three months of aircraft operations provided a comprehensive dataset to study the Gulf of Mexico's ocean current system during a bulging of the LC and subsequent eddy-shedding event. Despite a hurricane season that did not see many land-falling storms in the GOM, the data set gathered will help study the dynamically evolving ocean current system that will affect future hurricane seasons. The experimental objective was to provide data over a large scale to measure the possible shedding of a warm core eddy from the LC and provide oceanic structural data for predictive ocean models at the NAVOCEANO. In addition, these measurements provide the important data to correlate with surface images and data from satellite measurements. From a scientific perspective, these data are useful in improving our understanding of the complex eddy shedding processes. These measurements are of equal importance for the hurricane season for calibration of the radar altimeter-derived oceanic heat content variability using in the Statistical Hurricane Intensity Prediction Scheme for intensity forecasting (DeMaria et al. 2005; Mainelli et al. 2008).

Acknowledgments

The research team gratefully acknowledges support from the NOAA Oil Spill Grant from Office of Oceanic and Atmospheric Research and Office of Response and Restoration through NOAA's Cooperative Institute for Marine and Atmospheric Studies (CIMAS) at the University of Miami. We also would like to acknowledge the Department of the Interior's Bureau of Ocean Energy Management, Regulation and Enforcement agency for funding the Dynamics of the Loop Current Study (Contract M08PC20052) directed by Drs. Ronald Lai and Alexis Lugo-Fernández. The project continues to be grateful to the NOAA Aircraft Operation Center (Dr. Jim McFadden and Capt. Brad Kearse) and NOAA's Hurricane Research Division (Dr. Frank Marks) who make it possible to acquire high quality data DWH and hurricanes through the Hurricane Forecast Improvement Project (Dr. Bob Gall) and the Intensity Fluctuation Experiment (IFEX) from NOAA research aircraft.

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2010 OIL SPILL: TRAJECTORY PROJECTIONS BASED ON ENSEMBLE DRIFTER ANALYSES

L.-Y. Oey, Y.-L. Chang, F.-H. Xu, H.-F. Lu, and A. Fujisaki
Princeton University

An accurate method for long-term (weeks to months) projections of oil spill trajectories based on multi-year ensemble analyses of simulated surface and subsurface (z = –800 m) drifters released at the northern Gulf of Mexico spill site is demonstrated during the 2010 oil spill. The simulation compares well with satellite images of the actual oil spill which show that the surface spread of oil was mainly confined to the northern shelf and slope of the Gulf of Mexico, with some (more limited) spreading over the north/northeastern face of the Loop Current, as well as northwestward toward the Louisiana-Texas shelf. At subsurface, the ensemble projection shows drifters spreading south/southwestward, and this tendency agrees well with ADCP current measurements near the spill site during the months of May through July, which also shows southward mean currents. An additional model analysis during the spill period (April–July 2010) confirms the above ensemble projection. The 2010 analysis confirms that the reason for the surface oil spread to be predominantly confined to the northern Gulf shelf and slope is because the 2010 wind was more southerly compared to climatology, and also because a cyclone existed north of the Loop Current which, moreover, was positioned to the south of the spilled site.

Oey is a geophysical fluid dynamicist and physical oceanographer at the Atmospheric & Oceanic Sciences Program of Princeton University. He has done work for MMS/BOEMRE since 1992 and has authored and co-authored several papers dealing with the circulation in the Gulf of Mexico.

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SESSION 1B

CATASTROPHIC EVENTS AND ASSESSMENT OF COASTAL IMPACTS OF THE NORTHERN GULF OF MEXICO: STUDY APPROACH, BASELINE DETERMINATION, AND STUDY COMPABILITY

Chair: Larry Hartzog, BOEMRE

Co-Chair: Arie Kaller, BOEMRE

SALINITY AND CURRENT VELOCITY STRUCTURE IN THE HOUMA NAVIGATION CANAL (HNC)

Gregg A. Snedden
USGS National Wetlands Research Center
Coastal Restoration and Assessment Branch
Baton Rouge, Louisiana

Saltwater intrusion can occur through a variety of processes, including wind-driven estuary-shelf exchanges, baroclinic exchanges brought about by horizontal density gradients, and dispersive processes such as tidal diffusion. Understanding these processes is important to accurately anticipate the effects that future actions and circumstances such as channel deepening, lock installation, altering freshwater inflows, increasing vessel traffic, and sea level rise may have on salt transport in estuarine settings. One such setting is the Houma Navigation Canal (HNC), which serves as a major conduit for salt to the marshes that surround it. Data collected July 2010–February 2011 indicate that salinity intrusion distance and vertical salinity stratification are highly variable. While currents in the HNC are overwhelmingly barotropic (depth-independent), strong but ephemeral outbreaks of baroclinic currents occur when horizontal density gradients between the HNC and the coastal ocean are large and tidal stirring power is minimal. A strong fortnightly cycle of salinity stratification occurs in the HNC, with stratification occurring during equatorial tides when tidal stirring power is low. The strength of this fortnightly cycle diminishes when freshwater inflows are minimal. Additional data are being collected to quantify salt fluxes into the surrounding marshes. After collection of those data, salinity in and salt flux to those marshes will be examined for relationships to salt flux processes that are occurring in the HNC itself.

Gregg A. Snedden is an ecologist with the U.S. Geological Survey (USGS), National Wetlands Research Center. He received his B.S. in aquatic ecology from the University of Illinois (1993), his M.S. in fisheries science from Louisiana State University (1997), and his Ph.D. in oceanography and coastal sciences from Louisiana State University (2006). Before joining USGS, he worked as a Post-Doctoral Research Fellow at the University of North Carolina-Wilmington Center for Marine Science, a Research Associate at the Coastal Ecology Institute, Louisiana State University, and a Research Assistant at the School of Forestry, Wildlife and Fisheries, Louisiana State University. His research interests include estuarine transport processes, hydrologic impacts of Mississippi River diversions, and linkages between wetland hydrology and vegetation community structure.

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ECOLOGICAL ROLE AND HOW OCS ACTIVITIES AFFECT THE GULF COAST

Larry Hartzog and Arie Kaller
BOEMRE

The importance of the coast is well accepted, from the ecological functions of its multiple habitats to its prime real estate for humans. It also houses the onshore infrastructure for the oil and gas industries. The Gulf of Mexico coast has important ports, facilities, fisheries, and is highly populated. Different habitats and ecosystems found throughout the GOM coast include beaches, barrier islands, wetlands, and estuarine systems with seagrasses and submerged aquatic vegetation (SAV). These areas offer protection to the mainland from storms and other disturbances and provide essential fish habitat (EFH) for important fisheries species, not to mention habitat and food sources for many mammals.

The impacts of the coastal communities' oil and gas activities on the Outer Continental Shelf (OCS) and oil and gas activities are generally considered to induce small direct effects. However, coastal ecosystems, and even the human communities that rely on the coast for their livelihood, are important portions to our National Environmental Policy Act (NEPA) documents. Specific information about ecological function and general health, effects from numerous disturbances and the resilience of these areas help us better analyze and make conclusions about the different resources we cover in these documents. These resources include wetlands, beaches, barrier islands, seagrasses, fisheries, and socioeconomics.

The past decade has taught us that we are in a dynamic area in which both nature and anthropogenic disturbances are unpredictable, and the effects upon and responses of the different communities are variable. We need to acknowledge how this type of unpredictability will continue to affect the Gulf Coast. Therefore, we should generate useful robust research during these disturbance events. Such research will help not only with future planning and restoration efforts, but will add to our abilities to hypothesize about different perturbations impacts on specific resources.

Larry Hartzog is a biologist with the Bureau of Ocean Energy Management, Regulation and Enforcement's, Office of Leasing and Environment, Biological Science Unit, Gulf of Mexico Region. He received an M.S. in 1974 in fisheries limnology from Louisiana State University and a B.S. in 1969 in zoology and wildlife sciences, also from LSU. Before joining the MMS (now BOEMRE) as a biologist in 2005, he worked as a bioassay/chemist for Hercules Chemical Company, in Plaquemine, Louisiana; a research associate for the U.S. Fish and Wildlife Service Cooperative Fisheries Unit, Louisiana State University; a fisheries biologist for the Florida Game and Freshwater Fish Commission; and a fisheries biologist for the U. S. Army Corps of Engineers, Environmental Assessment, Planning and Impacts Section for Federal Projects.

Agatha-Marie (Arie) Roth Kaller is a biologist with the Bureau of Ocean Energy Management, Regulation and Enforcement's Office of Leasing and Environment, Biological Science Unit, Gulf of Mexico OCS Region. She received a Ph.D. in 2009 in oceanography and coastal sciences from Louisiana State University, an M.S. in 2003 in biological sciences from Southeastern Louisiana State University, and a B.S. in 1999 in marine sciences and biology from the University of Alabama. Before joining the MMS (now BOEMRE)as a biologist in 2009, she worked as a research assistant for the Fish Ecology Laboratory in the Department of Oceanography and Coastal Sciences, Louisiana State University; as a research assistant for the Freshwater and Marine Ecology Laboratory in the Department of Biological Sciences, Loyola University; and as a research assistant for the Schlieder Endowed Chair for Environmental Studies, Department of Biological Sciences, Southeastern Louisiana University.

THE LOUISIANA COASTLINE AND OIL — PARTICULARLY THE CASE STUDY OF THE *DEEPWATER HORIZON* OIL SPILL

David A. White
Department of Biological Sciences
Loyola University

The immediate coast shoreline vegetation of Louisiana can be generally divided into four distinct regions based upon the dominant (nearly ubiquitous) plant species of each area and attributed to distinct geologies. From west towards the east the coastline begins in the (1) Chenier Plain, then is interrupted by the (2) deltas of the Atchafalaya River (both the Wax Lake and Atchafalaya); then continuing east, the coast transitions into the (3) Delta Plain all the way to the most eastern coastline and finally, the Delta Plain is interrupted by the unique (4) Mississippi River Delta (MSRD). The immediate coastline of each of these regions supports distinct plant communities that are the first land to experience an oiling event from offshore. Both the Chenier and Delta Plain coastlines are dominated by nearly monospecific marshlands of *Spartina*, and the deltas of the Atchafalaya support a more diverse oligohaline (usually fresh) marsh front of a small number of species (particularly *Sagittaria* spp.), while the shoreline delta of the Mississippi River is nearly monospecific stands of *Phragmites*. All of these wetlands are of enormous economic importance to the state and region for storm protection to inland areas and for the benefits to the seafood and the recreational industries.

Regions of the MSRD shoreline were impacted by the *Deepwater Horizon* oil spill, and because they are unique in their marshes of *Phragmites* (roseau cane), special consideration of them is important. It is important to realize that these peripheral marshes of the MSRD are the *vital* physical barrier protecting the interior freshwater areas from the energy of the most violent tropical storms. Except during times of tropical storms, freshwater sheet flow keeps oil away from the interior freshwater wetlands—a vital bird habitat. Generally, the outer one half of the land area of the 14,000 km^2 MSRD is a permanent (year round) marsh of *Phragmites*. Most of this marsh is growing in water 10s of cms deep. Contrastlingly, the inner one half of the MSRD is an assortment of large ponds and emergent marsh mostly of inner deltaic “splays” covered by freshwater species with only (but expanding) isolated stands of *Phragmites*—much of which are newly colonized introduced European forms (haplotypes).

My firsthand knowledge of the impacts of *DeepwaterHorizon* oil spill comes from several boat trips summer, 2010, into the wetlands near and around South Pass and a single flyover winter, 2011, along the entire southern coastline of the MSRD. I have secondhand knowledge gained by conversations with professionals from LSU whose research west of the MSRD focuses on the central eastern coastline particularly within the southern end of the *Spartina*-dominated Barataria Basin. The following information on the oil incident is the best I can offer at this time.

- Current knowledge on plant tolerance and recovery from oil is mostly derived from field & lab research on *Spartina*.

- There has been little such work on *Phragmites*, and no work on freshwater to oligohaline species. This should be a concern.
- It is known that the spill has caused some loss of our coast. The exact amount of loss from the *Deepwater Horizon* oil spill is going to be difficult to quantify.
- Parish, state, and national politics has been playing a huge role in this case study.
- I would say without complete certainty that the total wetland loss is remarkably low. Any loss is bad. It seems that only about 200 to 300 miles of the coast line has had any contact with oil; most of the affected coast had contact with oil along only the immediate shoreline. This is in a state with a total coastline of 7,000 miles.
- Some of the fringe marsh loss has occurred from sloughing from wave action that would have happened anyway absent the spill because of the constant wetland loss the state is experiencing. Marsh loss is the current norm for this region.
- I have observed that some fringe *Phragmites* marshes in the MSRD have already resprouted stems (culms) and more regeneration from oil damage could continue. This can continue through the summer portion of the upcoming growing season.
- Some *Spartina* marshes in the Barataria Basin are now in the stubble stage, and researchers there are hoping these areas resprout from the hoped-for living underground rhizomes.
- As for the *Phragmites* marshes in the MSRD, a much better idea of total loss in *Spartina* marshes should be determined by the end of summer 2011 after another full growing season.
- Finally, there is a whole lot that we do NOT know about the impact of oil on our coastline generally and particularly on specific marsh types, e.g., *Phragmites* and other oligohaline marshes also dependent on oil quantity, quality, and timing. We know each plant species has a unique physiology and so should react differently if all else is held constant.

With these points made, I offer some suggestions.

- In the future, we need firsthand quick response (within weeks to at most a couple of months) ground surveys after an oil spill to check for damage assessment.
- This effort must take into account the different general marsh types (*Spartina*, *Phragmites*, freshwater—certainly *Sagittaria*) along the Louisiana coast.
- We need to know more about oil impacts and recovery especially to *Phragmites* and the freshwater marsh species. It is highly likely that each species reacts to oil differently. They certainly have different responses related to oil quality/quantity.
- The ground surveys immediately after a spill must be followed long-term by aerial surveys and GIS efforts to span the assessment to larger shoreline areas and to monitor the long term shoreline change.
- BOEMRE should direct resources immediately to highly knowledgeable regional researchers (government, university, and private) able and generally willing to quickly mobilize to assess field impacts. Delay is never good.

David White earned his Ph.D. in biology from Tulane University in 1979. He joined the Department of Biological Sciences at Loyola University in 1983. There he teaches primarily in the areas of ecology, evolution, and conservation biology. Dr. White is one of the region's leading natural historians with particular focus on wetland ecology. He is professionally trained in plant community and ecosystem ecology. He has published over 20 papers on the environs of coastal Louisiana. Recent research has focused on study of the establishment and spread of the marsh reed, *Phragmites australis*, within the Mississippi River Delta. He is also focused on marsh soil surface elevation dynamics within the wetlands of the Mississippi River delta and on the impacts of river water quality on marsh plant growth in the delta. Much of this work comes from several study sites within the Delta that he has been monitoring for nearly 30 years. The long-term data sets have become extremely valuable in understanding ecological "forcing" by the Mississippi River.

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REVIEW OF DISTURBANCES TO OYSTER RESOURCES ON LOUISIANA'S PUBLIC OYSTER SEED GROUNDS

Patrick D. Banks and Christy L. McDonough
Louisiana Department of Wildlife and Fisheries,
Office of Fisheries

The sedentary nature of oysters requires a unique ability to adapt to an ever-changing environment, including the ability to withstand a variety of natural and anthropogenic perturbations. Such disturbances have been documented to severely decrease oyster abundance, placing an extremely valuable resource at risk. Oyster resources on nearly 1.7 million acres of public oyster areas in Louisiana provide both an immeasurable ecological benefit as well as a significant economic value to the state. Louisiana began fostering the oyster industry at the end of the 19th century and it has grown into a nearly $50 million fishery (dockside value). The same reefs upon which harvesters rely are also home to a variety of estuarine species from transient fishes, such as spotted seatrout and red drum, to benthic animals such as blue crabs, worms, snails, and anemones. In addition to providing forage and shelter habitat for associated fauna, reefs provide ecological services including water filtration, denitrification, and shoreline stabilization. Natural perturbations such as freshets and hurricanes often inflict heavy mortalities upon oyster populations in the short-term, but oysters are well-adapted to such disturbances and usually rebound quickly. Anthropogenic disturbances and the resulting impacts on populations are not well-understood, and could lead to long-term recovery scenarios. These direct and indirect disturbances include alterations in hydrology, increased pollution, overharvesting, and sedimentation due to oil and gas activities (i.e. channel dredging, pipeline construction, etc.).

"At-risk" areas include any combined area where current environmental conditions are conducive for oyster production and where a propensity exists for anthropogenic and natural disturbances. One prime example is Black Bay in Plaquemines Parish east of the Mississippi River and south of the Mississippi River Gulf Outlet. This bay is a productive part of the public oyster seed grounds, yet is also home to an extensive and productive oil and gas field, and is also an area greatly influenced by Mississippi River flow via the natural bird-foot delta and man-made freshwater input sources. While monitoring of current oyster resources in "at-risk" areas is critical, significant development of future oyster resources (i.e. cultch planting) in such areas should be cautiously pursued.

Patrick Banks, a marine fisheries biologist with the Louisiana Department of Wildlife and Fisheries (LDWF), serves as program manager for the LDWF's Oyster Program and is in charge of oyster management on Louisiana's public oyster areas. He received his B.S. degree in environmental science from Mercer University in 1997 and his M.S. degree in zoology from LSU in 2000. His graduate work centered on determining impacts from oil on the recruitment of oysters, barnacles, and bryozoans in Louisiana. His current research interests focus on fisheries management topics such as stock assessment methods for oyster populations.

Christy L. McDonough is biologist supervisor in charge of running the LDWF Public Oyster Seed Ground Oversight Program out of Baton Rouge. After graduating from LSU in 2002 with a Bachelor's degree in environmental management, she was hired by LDWF to help get the Oyster Oversight Program up and running. The program is responsible for reviewing and providing official agency comments on environmental assessments completed for oil and gas projects located within the two million acres of state-owned and managed public oyster seed areas and modifying projects when necessary to minimize impacts to oyster resources and habitat.

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AN OVERVIEW OF NEKTON RESOURCES IN THE PONTCHARTRAIN ESTUARY: RESEARCH, BASELINE DATA, AND RECENT DISTURBANCES

Martin T. O'Connell
Director – Nekton Research Laboratory
Pontchartrain Institute for Environmental Sciences
University of New Orleans

The *Deepwater Horizon* oil spill of 2010 is just the latest major disturbance to impact the Pontchartrain Estuary in southeastern Louisiana. Over the last half century this ecosystem has experienced extensive dredging, habitat degradation, Bonnet Carre Spillway openings, dead zones created by artificial aquatic corridors, and the devastation of Hurricane Katrina. The Nekton Research Laboratory at the University of New Orleans has been collecting data on nekton (fishes, crabs, and shrimp) in the Pontchartrain Estuary since 2000 and has an extensive baseline database on local aquatic organisms, including economically important species such as blue crabs (*Callinectes sapidus*), brown shrimp (*Farfantepenaeus aztecus*), and Gulf menhaden (*Brevoortia patronus*). When disturbances occur, we use community analyses to compare the species composition of post-disturbance assemblages to those found in historical baseline data. Through this approach, we can determine the extent of the disturbance on the aquatic community and identify those species that have been most affected. In many cases, we have observed that the resiliency of estuarine species allows them to recover from these impacts in the short-term, but long-term changes in the ecosystem have also been identified. If we are to properly assess how and if the 2010 oil spill significantly impacted nekton resources in the Pontchartrain Estuary, we will need to conduct extensive monitoring at historical sampling sites to determine if the species composition of the local aquatic communities have changed.

Dr. Martin T. O'Connell is the Director of the Nekton Research Laboratory (NRL) at UNO's Pontchartrain Institute for Environmental Sciences. His research interests involve studying, managing, and conserving aquatic animals in freshwater, estuarine, and marine habitats. In particular, the researchers and graduate students in his lab examine long-term changes in fish assemblages, responses of aquatic communities to natural and anthropogenic disturbances, and ecological needs of organisms threatened by changing global conditions. While the focus of most of his research is southeastern Louisiana, he also works with ecological data and organisms from throughout the nation and the world. Since 2000, the NRL has generated ecological baseline data from Lake Pontchartrain, the Biloxi Marshes, and the Chandeleur Islands. Dr. O'Connell and his colleagues have published numerous papers based on these data and realize the value this information holds for protecting these ecosystems from disasters such as hurricanes, coastal land loss, and oil spills.

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UNIFIED APPROACH TO DATA MANAGEMENT AND PERSPECTIVES FROM A NORTHERN GULF OF MEXICO MARINE AND COASTAL RESEARCH LABORATORY

William Hawkins, Read Hendon, James Franks, Jay Grimes,
Jeff Lotz, Harriet Perry, Chris Snyder
Gulf Coast Research Laboratory
The University of Southern Mississippi
Ocean Springs, Mississippi

The *Deepwater Horizon* explosion and the crude oil that subsequently leaked into northern Gulf of Mexico (GOM) waters continually for more than 100 days focused unprecedented attention on the GOM. It became clear that the GOM is poorly understood, especially compared to other US marine ecosystems. Especially poorly understood are large scale ecological processes such as hypoxia, the decline of major fish stocks and the capacity of the ecosystem to respond to and overcome various stresses, such as a major oil spill. One outcome of the spill might be that programs will be implemented to better prepare us to predict and understand the effects of such events. The experience of the Gulf Coast Research Laboratory (GCRL) following the spill may be illustrative.

GCRL is an academic research institution focused on marine resources of the northern GOM. Soon after the spill, GCRL formed an oil spill operations team to manage its response and collect needed data to understand impacts. The team was comprised of marine and fisheries scientists, outreach specialists, and administrators whose objectives were to coordinate research logistics, explore approaches to obtain investigative research funding, and develop outreach strategies. Initially, we were required to comply with health and safety requirements through HAZMAT training and to coordinate with research partners to identify immediate sampling needs. Acquiring baseline samples not available through ongoing or historical datasets was also a priority and numerous sampling trips were funded through institutional resources to address those needs. GCRL activities were coordinated with NOAA and state resource management agencies to the highest extent possible. Research concept papers were solicited from scientists for both hypothesis-driven, investigative studies and descriptive resource assessment. Funding targets for investigative studies were the National Science Foundation (NSF) and the BP Ocean Trust Fund, while resource assessments might be part of the Natural Resources Damage Assessment (NRDA) process. The outreach strategy focused on GCRL scientists interpreting spill-related processes affecting marine resources and included a town hall meeting during which local citizens questioned GCRL scientists on spill-related issues. Our efforts and those of others point strongly to the need for long-term studies to understand the GOM ecosystem. To be of value, those approaches and objectives must be consistent among the various geographic and jurisdictional entities of the region.

William Hawkins is the Director of the University of Southern Mississippi Gulf Coast Research Laboratory (GCRL) and Professor in the Department of Coastal Sciences. His research interests include pathological effects of infectious agents and environmental toxicants on marine organisms and the use of marine animals as models for the study of diseases, particularly cancer and cancer-causing compounds. He has published more than 100 articles in the scientific literature. Hawkins received his bachelor's degree from Mississippi State University and his doctorate from the University of Mississippi School of Medicine.

Read Hendon is the Assistant Director of the Center for Fisheries Research and Development at the University of Southern Mississippi's GCRL. He started his M.S. work at the GCRL in 1996, and completed his advanced degree in fisheries ecology in 1998. Since that time, Read has worked in the fisheries discipline on a variety of programs, ranging from monitoring and assessment of important coastal species to juvenile spotted seatrout ecology. He is a Certified Fisheries Professional (FP-C) through the American Fisheries Society and a Certified Oyster Biologist through Louisiana's Department of Natural Resources. In 2009, the Gulf of Mexico Fishery Management Council appointed Read to two-year terms on its Standing Scientific and Statistical Committee, Coastal Migratory Pelagics (Mackerel) Advisory Panel and Red Drum Advisory Panel. He is also Field Party Chief for Southeast Area Monitoring and Assessment Program (SEAMAP) offshore trawl surveys and currently serves as the Chairman of and Mississippi Representative for the SEAMAP Gulf Sub-Committee. Other committees include: SEAMAP Shrimp and Groundfish Work Group, SEAMAP Reef Fish Work Group Leader, GCRL's Boat Operations Committee, and USFWS/NOAA Aquatic Nuisance Species Task Force Expert, Tier 2. Read is also a part-time doctoral student in USM's Department of Coastal Sciences working with juvenile spotted seatrout.

James Franks is a Senior Research Scientist at the GCRL and a fisheries biologist in the Center for Fisheries Research and Development. He has an M.S. degree from the University of Mississippi in biology. His primary research interests are in life history aspects of coastal and oceanic pelagic fishes and aquaculture of pelagic fishes. He has served as Chair, Board of Directors, Gulf and Caribbean Fisheries Institute; Board of Directors, Mississippi Wildlife Federation; and Vice-Chairman of the Steering Committee of the Fifth International Billfish Symposium. He has received the following rewards: 2005, Conservationist of the Year (Governor's Award) from the Mississippi Wildlife Federation; 2005, C. A. Shults Conservation Award, Mississippi Chapter of the American Fisheries Society; and 2003, American Fisheries Society Fisheries Administrator's Sport Fish Award, Research and Surveys Category.

Jay Grimes is Professor of Marine Microbiology in the Department of Coastal Sciences at the Gulf Coast Laboratory. He is Chair of the Advisory Panel of the NOAA Oceans and Human Health Initiative. His laboratory is primarily focused on the Vibrios. The genus *Vibrio* now includes over 70 species and is considered by most marine microbiologists to comprise the dominant culturable bacteria in the ocean. His current research projects include forecasting the abundance and distribution of *V. parahaemolyticus* and *V. vulnificus* in coastal waters by using satellite remote sensing; examining the abundance and distribution of virulent strains of *V. parahaemolyticus* in the Northern Gulf of Mexico; understanding the role of type 3 secretion systems (T3SS) in the ecology of *V. parahaemolyticus*, determining the role played by sediment in harboring *V. parahaemolyticus* and *V. vulnificus* in Mississippi Sound; viable but nonculturable Vibrios; naturally occurring Vibrios and other bacteria in elasmobranch fishes; examining the distribution and function of the enzyme urease in *V. parahaemolyticus* strains and understanding the role of Vibrios in biodegradation of wastes in the ocean. Finally, because the GCRL has a large research and development program in marine fish aquaculture, the Marine Microbiology laboratory works with the GCRL marine aquaculture team to study bacterial diseases, especially vibriosis.

Jeff Lotz is Professor and Chair of the Department of Coastal Sciences, at the GCRL. His primary research areas are ecology and epidemiology of parasites and diseases of marine organisms, marine aquaculture, and marine stock enhancement. Active research programs include laboratory, field, and theoretical epidemiological studies of pathogens of marine shrimp, crabs, and finfish, development of water-recycle systems for reproduction and aquaculture of penaeid shrimp (primarily *Litopenaeus vannamei*) and finfish (spotted seatrout *Cynosion nebulosis*). Marine stock enhancement research uses *Lutjanus campechanus* to develop principles for marine stock enhancement and spotted seatrout *Cynosion nebulosis* for inshore stock enhancement.

Harriet Perry is Director of the Center for Fisheries Research and Development, GCRL and Assistant Professor, Department of Coastal Sciences. She received her B.S. in biology from Florida State University and an M.S. in zoology from the University of Southern Mississippi. Her major research interests are in fishery development, management of marine fisheries, blue crab aquaculture, population dynamics of estuarine and marine invertebrates, invertebrate taxonomy and invasive marine species. She is a recipient of the Gulf Guardian Award.

Chris Snyder is head of the Public Information Department as well as Director of the Marine Education Center at the GCRL. He has a B.S. degree in biology from the University of Southern Mississippi and is enrolled in the doctoral program in Human Capital Development. He has served in the following positions: Wetlands Specialist, Mississippi Department of Wildlife, Fisheries and Parks, Bureau of Marine Resources; Media Coordinator, Mississippi Department of Wildlife, Fisheries and Parks, Bureau of Marine Resources; and producer/editor for *Mississippi Outdoors*, Mississippi Educational Television's number one rated program. He has received the Mississippi Tourism Award for best televised program, *Mississippi Outdoors*.

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SESSION 1C

WHERE IS THE PLACE IN SPACE? UNDERSTANDING THE ROLE OF GEOGRAPHY ON SOCIAL SCIENCE RESEARCH MODELING THE OUTER CONTINENTAL SHELF

Chair: Sindey Chaky, BOEMRE

Co-Chair: Harry Luton, BOEMRE

WHERE IS THE PLACE IN SPACE? UNDERSTANDING THE ROLE OF GEOGRAPHY ON SOCIAL SCIENCE RESEARCH

Sindey Chaky
BOEMRE

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GEOGRAPHIC UNITS USED FOR SOCIOECONOMIC IMPACT ANALYSIS IN THE GULF OF MEXICO REGION

Allan Pulsipher and Kathryn Perry
Center for Energy Studies, Louisiana State University

Does the composition of the geographic units used by BOEMRE for planning obscure or distort the potential socioeconomic impacts from offshore oil and gas activity in some of the regions or counties included in the geographic unit? The 132-county area identified by BOEMRE as the potential affected area for federal offshore activities on the Gulf of Mexico is currently organized into 13 Economic Areas (EA) and subdivided further into 23 Labor Market Areas (LMA). In this presentation we use location quotients to see if measures or characterizations at the EA level distort or obscure information at the LMA or county/parish level.

The primary objective of the study is to assist BOEMRE by delineating Economic Impact Areas (EIAs) in the Gulf of Mexico (GOM) states that are based on a clear, explicit, empirical rationale, reflective of the onshore effects of the offshore oil and gas industry and are able to guide and support social impact assessments of industry operations and activities.

Analysis of rather broadly defined industrial clusters relevant to socioeconomic impacts of offshore development indicated:

- Numerous instances where the values calculated for 13 Economic Impact Areas (EIAs) obscure or distort dimensions of the cluster that are observable at the level of the 23 Labor Market Areas or 132 counties or parishes in the affected area.

- Examples of this are presented for most of the EIAs in Texas and Louisiana where the fossil/renewable cluster is concentrated. The only EIA in this group where the dimensions of the clusters at the EIA group seem to accurately represent the bulk of the activity in the EIA is the LA-2 (Lafayette).

- Several EIAs are dominated by large counties that obscure the characteristics of the smaller counties in the geographic unit. However, there appear to be very few instances where the smaller county being obscured exhibits significant concentration in the cluster or a large increase in the concentration in the cluster over the period of the study.

- The EIAs where the dimensions or characteristics that we have measured indicate that characterization or analysis at the EIA-level may be significantly misleading include LA-3, LA-4, TX-1, TX-2, and TX-3. Information external to the analysis in the paper suggests that significant onshore activity in all of these EIAs may be further complicating the analysis.

Analysis of more narrowly-defined sectors based on NAICS employment categories in the oil and gas sector relevant to socioeconomic impacts of offshore development indicated:

- The pattern of data aggregated at the EIA level, distorting or obscuring data aggregated at the LMA or county level, is quite similar to the pattern observable when the same measurements are applied to categories for oil and gas in NAICS system.

- One type of distortion observable when data for EIAs is compared with data for LMAs is that some EAs are composed of very different counties with very different proportions of oil and gas activity that EIA-level measures tend to “cancel out.” The pattern is quite consistently observable in TX-1 where the Corpus Christi regularly is among the most concentrated and expansive LMAs but is cancelled out by Brownsville, which is regularly among the least concentrated and less expansive of the Texas LMAs. This same pattern is evident in the LA-3 EIA where the Houma LMA is usually the most concentrated and expansive LMA but is obscured by the larger and much less concentrated Baton Rouge LMA.

- A second type of distortion is observable in the TX-3 EIA where the Harris County is simply so much larger than all of the other counties in the EIA, that even extreme concentration or change at the county-level is not reflected in EIA-level measures.

- A third type of distortion is observable in the LA-4, the region surrounding New Orleans. This is a relatively large EIA that is not divided into LMAs but composed of counties in which the relative importance of oil and gas activity varies widely in their local economies. Some are relatively small counties with a substantial concentration of activity while others are quite large, with a substantial number of employees in oil and gas but composing only a relatively small percentage of total employment. EIA-level data may not represent any of the members of the EIA very closely.

- The relative internal consistency of LA-2 (Lafayette) observed in the cluster analysis in section 2 was also characteristic of the four employment categories discussed in this section. The individual parishes in the EIA show similar degrees of concentration and behavior and EIA-level data fairly accurately tracks parish level characteristics.

Allan G. Pulsipher is the Executive Director and Marathon Oil Company Professor of Energy Policy in the Center for Energy Studies and a Professor in the Department for Environmental Studies at Louisiana State University. He has been with the Center for Energy Studies since 1990. Before coming to LSU, he worked as the Chief Economist for the Congressional, Monitored Retrievable Storage Review Commission; the Chief Economist of the Tennessee Valley Authority; a Program Officer with the Ford Foundation's Division of Resources and the Environment; as a Senior Staff Economist with the President's Council of Economic Advisers; and on the faculties of Southern Illinois University and Texas A&M University. He is a member of the National Petroleum Council and Phi Beta Kappa. He has a B.A. from the University of Colorado and a Ph.D. from Tulane University, both in economics.

Kathryn Perry is a Research Associate with Louisiana State University's Center for Energy Studies in Baton Rouge. She has over 20 years' professional experience in the fields of environmental impact assessments, air permitting, economic studies and strategic plans, community planning, and offshore energy research. Prior to joining LSU in 2008, Kathryn worked as a Senior Planner for the Shaw Group, Senior Environmental Planner for URS Corporation and Economic Development Coordinator for the East Baton Rouge City-Parish Planning Commission. Kathryn is Co-Professional Development Officer for the American Planning Association's Louisiana Chapter, Treasurer for the APA LA Capital Section, and is a member of the American Institute of Certified Planners. She served as APA LA Chapter Secretary for two terms, and has served on several APA LA committees. She holds a Master of City and Regional Planning from Rutgers University and a B.A. in Economics from Williams College.

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LABOR MARKETS VERSUS TRADE: IDENTIFYING A ROADMAP TO DEFINING NEW REGIONS TO MEASURE OCS EFFECTS

J. Matthew Fannin, Ragu Kongari,
Arun Adhikari, and Ashok Mishra
Louisiana State University

The objective of the study is to develop an alternative regional clustering framework based on two approaches to define economic regions: labor markets and industrial trade. We use the county to county relationship between in-commuters and out-commuters and imports and exports between counties to calculate strength of linkages. We then apply a clustering methodology where the strongest counties are aggregated together into new multi-county regions. We then consider BOEMRE regions as base and select clusters with at least one BOEMRE county, and finally we add socio-economic variables for comparison. Major results show that the all industrial trade classification appear to combine both strength of fit to the oil and gas related location quotient variables and the demographic variables. Original BOEMRE on-shore areas also show reasonable fit on a portion of the LQ variables.

J. Matthew Fannin is an associate professor in the Department of Agricultural Economics and Agribusiness at Louisiana State University Agricultural Center where he conducts research and teaching activities related to regional, community, and/or rural development economics. He is currently serving as a technical operations advisory council in the Southern Rural Development Center (2010–2013). Dr. Fannin has received many awards for scholarly or artistic achievement. He has received more than $1.5 million of grants/funds.

Raghavendra Kongari worked as a graduate research assistant under the guidance of Dr. James M. Fannin at Louisiana State University Agricultural Center. He received his M.S. degree from the LSU's Department of Electronics and Computer Engineering (Spring 2011). His research focused on retrieving and extracting data and analyzing them by using SQL server and computational skills that include SAS, STATA, and MATLAB.

Arun Adhikari is a graduate research assistant in the Department of Agricultural Economics and Agribusiness at Louisiana State University Agricultural Center; he is working under the advisory committee led by Dr. J. Matthew Fannin. His research interest is concentrated in the area of regional, community, and/or rural development economics. He was awarded the Outstanding Ph.D. Student in the Department of Agricultural Economics and Agribusiness at LSU for the year 2009. He plans to graduate in May 2012.

Ashok K. Mishra is a Professor in the Department of Agricultural Economics and Agribusiness at Louisiana State University, where he conducts research and teaching activities related to how agricultural and environmental policies influence labor allocation decisions and how those decisions affect income from farming, and natural resource use. He has worked with European

countries on the importance of relevant and efficient data collection and use of data in the design of policies that are consistent with WTO and welfare enhancing for farm households.

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POPULATION RESPONSE TO EMPLOYMENT GROWTH IN THE GULF COAST REGION: ASSESSING THE OIL AND GAS RELATED EMPLOYMENT ON POPULATION CHANGE

Troy C. Blanchard, Brett Lehman and Lisa Winters
Department of Sociology
Louisiana State University

In this presentation we address the research question, "Are changes in oil and gas-related employment associated with population change in the Gulf Coast region?" This topic is a key issue for social scientists. For example, employment change may stimulate migration streams that alter levels of social cohesion among residents. In addition, researchers have sought to understand if job creation policies benefit local residents or stimulate in-migration and commuting from other regions. Analyzing employment data from the 1998 to 2008 County Business Patterns and U.S. Census Bureau population estimates, we examine this relationship using a Fixed Effect OLS regression techniques. Our findings provide evidence that growth in oil and gas employment in Gulf Coast counties is associated with population growth of specific demographics segments (less than 65) and suggest that new jobs may be attracting new residents directly or by creating vacancies in existing jobs.

Dr. Troy C. Blanchard is Associate Professor of Sociology at Louisiana State University. His research interests include social inequality, demography, and applied sociology focusing on the link between socioeconomic conditions and demographic outcomes within U.S. communities.

Brett Lehman is a Ph.D. candidate at Louisiana State University. His research examines education, inequality, and friendship groups.

Lisa Winters is a Ph.D. candidate at Louisiana State University. Her research examines race, class, and gender inequalities with an emphasis on health disparities. Her dissertation research examines the link between community income inequality and individual health outcomes by using multilevel modeling to investigate the pathways through which higher income inequality leads to poorer individual health and to illuminate potential mediators in this relationship.

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UNDERSTANDING FISCAL CONDITIONS AND IMPACTS OF LOCAL GOVERNMENTS UNDER INCREASED NATURAL DISASTER RISK AND CHANGING OCS ENVIRONMENT

Arun Adhikari and J. Matthew Fannin
Department of Agricultural Economics and Agribusiness
Louisiana State University Agcenter

The primary objective of the study is to model and evaluate the fiscal sector of OCS regions to understand the fiscal health and impacts of local government under increased natural disaster risk and changing OCS environment. Lafayette Parish is selected for the case study since it makes up more than half of the total mining and oil and gas extraction jobs in the LA-2 region (BOEMRE manuscript). Impacts from reduction in drilling are likely to be more in this region as employment could be measurably affected. A hybrid model of oil and gas was used to calculate the number of oil and gas wells forecasts. A MAGPLAN model is used to calculate the total number of jobs in the region. Results show that the revenue change exceeds expenditure change during the study period.

Arun Adhikari is a graduate research assistant in the Department of Agricultural Economics and Agribusiness at Louisiana State University Agricultural Center; he is working under the advisory committee led by Dr. J. Matthew Fannin. His research interest is concentrated in the area of regional, community, and/or rural development economics. He was awarded the Outstanding Ph.D. Student in the Department of Agricultural Economics and Agribusiness at LSU for the year 2009. He plans to graduate in May 2012.

J. Matthew Fannin is an associate professor in the Department of Agricultural Economics and Agribusiness at Louisiana State University Agricultural Center, where he conducts research and teaching activities related to regional, community, and/or rural development economics. He is currently serving as a technical operations advisory council in the Southern Rural Development Center (2010–2013). Dr. Fannin has received many awards for scholarly or artistic achievement. He has received more than $1.5 million of grants/funds.

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GULF COAST COMMUNITIES AND THE FABRICATION AND SHIPBUILDING INDUSTRY: A COMPARATIVE COMMUNITY STUDY 2007–2011

Tyler Priest
C.T. Bauer College of Business
University of Houston

The fabrication and shipbuilding enterprises in the Gulf of Mexico are unique. They were born as a local response to the development of offshore petroleum in the Gulf and still rely on this niche market.

They are specialized industries, not well described, yet are the most significant sector in OCS-program related employment. Also, like the offshore businesses that they serve, the Gulf's shipbuilding and fabrication businesses have evolved into an international industry, bucking a general decades-long trend in the U.S. of steady decline of heavy industries in the face of globalization.

This study describes the shipbuilding and fabrication industries, the services they provide, their labor demands and how they meet them, their environmental impacts, trends, dynamics, variation within the industries (e.g., large firms vs. small ones), geographic distribution, and demographic and socioeconomic significance.

The community profiles in this study examine the industrial histories of cities that border the northern Gulf of Mexico and that have one or more important shipbuilding and ship repair, platform fabrication, or offshore-support industries. Moving from west to east, the communities analyzed are Brownsville, Corpus Christi/Ingleside (the Coastal Bend), and Beaumont-Port Arthur-Orange (the oil industry's original "Golden Triangle") in Texas; Morgan City/Amelia and Lafourche/Terrebonne/New Orleans in Louisiana; Pascagoula in Mississippi; and Mobile/Bayou la Batre in Alabama.

Tyler Priest (Ph.D., University of Wisconsin-Madison) is Clinical Professor of Business History and Director of Global Studies and Clinical Professor at the C.T. Bauer College of Business, University of Houston. A specialist in the history of petroleum, energy, and globalization, he is a leading expert on the history of the offshore oil and gas. He is currently the principal investigator on two other collaborative studies for the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE): *Gulf Coast Communities and the Shipbuilding and Fabrication Industries* and the *History of Deepwater Gulf of Mexico*. During 2010–2011, he served as a senior policy analyst for the National Commission on the BP *Deepwater Horizon* oil spill and Offshore Drilling.

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AN ANALYSIS OF THE IMPACT OF SHIPBUILDING AND FABRICATION ON COASTAL COMMUNITIES: COMMON SENSE AND DATA LIMITATIONS

John Lajaunie
Nicholls State University

Joshua Stockley
University of Louisiana at Monroe

Gulf Coast Communities and the Fabrication and Shipbuilding Industry was a five-year study conducted with collaborators from the Bureau of Applied Research in Anthropology at the University of Arizona, Center for Public History at the University of Houston, and professors at the University of Louisiana at Monroe and Nicholls State University. This study described the shipbuilding and fabrication industry, the services they provide, their labor demands and how they meet them, their environmental impacts, trendsand dynamics, variation within the industries (e.g. large firms versus small firms), geographic distribution, and demographic and socioeconomic significance in the selected communities of South Mobile County, Alabama (including Mobile, Bayou la Batre, Coden, Grand Bay); Southeast Jackson County, Mississippi (including Pascagoula, Moss Point and surrounding areas); Lafourche and Terrebonne Parishes, Louisiana; East St. Mary Parish, Louisiana; Port Arthur/Orange, Texas; Corpus Christi/Ingleside, Texas; and Brownsville/Port Isabel, Texas. Our task was to refine the description of the places where the fabrication and shipbuilding industries were located, which entailed creating a massive database comprised of census, labor, fiscal, school, and employment data from 1970 to the present. We found that that the industry has had a significant local-level socio-economic impact, though the size and scope of these impacts varied from community to community. In collecting and analyzing data, we found limitations that inhibited researchers. This presentation focused on describing those limitations and gathering input from other researchers regarding best practices to overcome limitations.

John P. Lajaunie is a professor of finance and the Clarence J. Riviere Endowed Professor of Business at Nicholls State University. Professor Lajaunie earned a doctorate in financial economics from the University of New Orleans in spring of 1992. He has been a member of the faculty at Nicholls State University since the fall of 1991. Dr. Lajaunie has focused his research in the areas of international finance and applied banking issues resulting in the publication of 30 refereed journal articles and 30 plus conference presentations. Dr. Lajaunie teaches primarily in the senior finance seminars and MBA programs at Nicholls State. He has received recognition for his teaching accomplishments at both the college and university level. Dr. Lajaunie has recently served as a consultant to the BOEMRE Shipbuilding and Fabrication study.

Joshua Stockley is an Assistant Professor of Political Science and Director of the Honors Program at the University of Louisiana at Monroe. He received his B.A. in history and political science at Oklahoma Baptist University and his Ph.D. in political science at the University of

Oklahoma. Professor Stockley's teaching and research cover American government, state and local politics, campaigns and elections, political parties, Congress, Presidency, Southern politics, culture and politics, public policy, public administration, research methods, and demography. His works have appeared in the journal *Race, Class, and Gender* and edited volumes, such as *The Roads to Congress* and *Mediated Images of the South*. Professor Stockley has published several book reviews, presented numerous papers at professional conferences around the nation, and edited manuscripts for publishers and journals. He has worked on numerous grants at the local, state, and national levels.

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UNDERSTANDING THE FABRICATION AND SHIPBUILDING INDUSTRIES ALONG THE GULF OF MEXICO: AN ETHNOGRAPHIC PERSPECTIVE

Diane Austin, Tom McGuire, Ben McMahan,
Lauren Penney, and Preetam Prakash
University of Arizona

The fabrication and shipbuilding industries along the Gulf of Mexico are large, complex, and dynamic. The shipyards along the coast (1) build and repair large ships and platforms; (2) build and repair vessels such as patrol boats, tug and tow boats, supply boats, and fishing boats, and (3) design, develop, produce, and maintain the various subsystems and components required to support the shipbuilding industry. Most do the latter two; the majority are repair facilities with drydocking capabilities. Determining the "population" of workers and firms involved in the fabrication and shipbuilding industry is complicated because the industry is always in a state of flux due to mergers and acquisitions, withdrawals and entries, and bankruptcies and new startups. Using ethnographic research methods, researchers from the University of Arizona described the Gulf shipbuilding industry; identified satisfactions and concerns of both employers and workers at small, medium, and large yards; and placed these concerns in a larger context.

Dr. Diane Austin is an associate research anthropologist in the Bureau of Applied Research in Anthropology within the School of Anthropology at the University of Arizona. She received her Master's degree in environmental engineering from the California Institute of Technology in 1983 and her Ph.D. in environmental policy and behavior at the University of Michigan in 1994. An applied environmental anthropologist, Dr. Austin specializes in community dynamics in the midst of large-scale industrial activity, social impact assessment, and environmental education, as well as the development and maintenance of community-based, collaborative research and outreach programs. She has developed and maintained long-term, multisectoral partnerships with Native American communities, U.S. and Mexican border communities, and coastal communities along the U.S. Gulf of Mexico. Since the mid-1990s, she has studied the effects of the offshore petroleum industry.

Tom McGuire is a research anthropologist with the Bureau of Applied Research in Anthropology and professor, School of Anthropology, University of Arizona. Since 1996, he has participated in studies of the history and social impacts of the offshore oil and gas industry on the Gulf of Mexico coastal region, from Brownsville, Texas to Gulf Shores, Alabama. His interests also include fisheries, water resource development, and social theory.

Ben McMahan is a researcher with the Bureau of Applied Research in Anthropology and doctoral candidate in medical anthropology in the School of Anthropology at the University of Arizona. He received his M.A. from Idaho State University in 2004. His research interests include community-level preparedness and disaster prevention; production, use, and modification of nature/space/place; social memory of epidemics and ecological change; social

networks and flows within/between local/global networks; and GIS and participatory mapping within the ethnographic context. He has been involved in research on the offshore petroleum industry since 2007.

Lauren Penney is a doctoral candidate in the School of Anthropology at the University of Arizona. She received her M.A. in anthropology from that institution in 2006. Lauren, a medical anthropologist, does work that emphasizes the intersection of policy, practice, and experience, with a focus on labor. She has participated in a wide range of applied research projects in multiple sectors, including health care, criminal justice, and energy. Lauren began studying the petroleum and related industries in 2004.

Preetam Prakash is a researcher working for Bureau of Applied Research in Anthropology within the School of Anthropology at the University of Arizona. He received his M.A. from the University of Arizona in 2010. Preetam's work has focused on a range of issues, including uses and conceptualizations of space and place among immigrant communities in the U.S., trajectories of business ownership in the Gulf Coast shipbuilding and fabrication industry, and union politics and history in the oil and gas industry in Veracruz, Mexico. In 2008, he began working on projects related to the offshore petroleum industry.

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SESSION 2A

MARINE ARCHAEOLOGY — ASSESSING POTENTIAL IMPACTS TO HISTORIC RESOURCES ON THE OCS

Chair: Jack Irion, BOEMRE

Co-Chair: Chris Horrell, BOEMRE

ARCHIVAL INVESTIGATIONS FOR POTENTIAL COLONIAL-ERA SHIPWRECKS IN ULTRA-DEEP WATER WITHIN THE GULF OF MEXICO

Michael C. Krivor
Southeastern Archaeological Research, Inc.

The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), an agency of the U.S. Department of the Interior, is charged with considering the effects of its actions on significant submerged cultural resources on the Outer Continental Shelf (OCS). To protect such resources from the effects of oil and gas activity within the Gulf of Mexico (GOM), the BOEMRE sought to amass and assess primary archival material relative to early vessel losses (ca. sixteenth to eighteenth century) in ultra-deep water (UDW) (>5,000 feet) within the GOM. From 2008 through 2009, Southeastern Archaeological Research, Inc. (SEARCH) conducted archival research at a variety of national and international repositories thought to contain primary documents relative to early vessel losses within the GOM. Results of the investigation successfully identified previously unknown, early-colonial-period vessel losses located within the GOM. This presentation will discuss the methods, results, and recommendations of the investigation.

Michael C. Krivor is a Project Manager and Principal Investigator with the SEARCH Maritime Division. In 1990, Mr. Krivor received his B.A. degree in aquatic archaeology from Humboldt State University, and in 1998 he received his M.A. from the Program in Maritime History and Nautical Archaeology at East Carolina University. His academic research focused on shipwreck investigations along the east coast of the United States, Bermuda, and the Dominican Republic, and his thesis centered on the investigation of an 18^{th} century British Transport that foundered off Bermuda during the American Revolution. In 1996, Mr. Krivor began professional work as a maritime archaeologist, and has served on over 130 SCRM projects, authored over 73 reports, and presented 23 professional papers. Proficient in all aspects of underwater archaeology, Mr. Krivor's specialties include 18^{th}–19^{th} century New World ship construction, Western River steamboat construction, Civil War wreck sites, and small vernacular craft construction. He also has years of experience in remote sensing survey, data analysis, and archaeological site layout, scaled mapping, and measured sketching and photography. Mr. Krivor is on the Register of Professional Archaeologists (RPA) and has been certified by the U.S. Army Corps of Engineers, Dive Safety Program.

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SHIPWRECK RESEARCH IN THE NEW ORLEANS NOTARIAL ARCHIVES

John K. Rawls and Dayna Boker Lee
Earth Search, Inc.

In November 2009, Earth Search, Inc. (ESI) was contracted by the Minerals Management Service (MMS), now the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) to identify and obtain photocopies of sea or ship protests held by the New Orleans Notarial Archives (NONA) and to develop probability locations of shipwrecks based on the acquired historic data. The current research involved archival data collection to update, expand, and evaluate BOEMRE's existing shipwreck database. Since the 1970s, such studies have resulted in an in-house database containing over 3,000 entries, derived from secondary sources and other existing databases. Despite this research, several historic shipwrecks have been identified in industry surveys on the Outer Continental Shelf (OCS) that appear to have no corresponding analog in the BOEMRE database. It was long believed that these vessels were simply lost to the historical record and the documentation on the event of their loss was no longer extant. It now appears, however, that previous researchers overlooked the a potentially rich source of information at the NONA, which houses the City of New Orleans notary records from 1733 to 1970. A large number of these documents relate to bills of sale, wills, and property inheritance matters; however, among the documents are also sea protests. This archival source of information has not been accessed by previous researchers; it contains a wealth of previously unknown information about historic shipwrecks in the Gulf of Mexico. A total of 121 documents notarized by twelve individual notaries were photocopied. Of that number, 87 protests (72%) were filed in response to vessel losses in the interior continental riverways, and 34 (28%) documented maritime losses. Protest dates ranged from 1804–1900, the majority of which (117 or 96.6%) dated to the antebellum period (ca. 1812–1861). Three protests (2.4%) were recorded during the territorial period (ca. 1803–1812), and one (.008%) was recorded in 1900. The sheer volume of documents contained within the NONA would suggest that additional research is warranted. Only two shipwrecks already included in the GOMR database were discovered during the course of the present research, and only 15% of the indexed notarial records were reviewed due to time constraints. The information provided by the present study will aid BOEMRE in fulfilling its obligations to consider impacts to archaeological resources by energy industry activities under Section 106 of the National Historic Preservation Act (NHPA).

John K. Rawls is Project Manager, Senior Marine Archaeologist, and Director of Earth Search, Inc.'s (ESI) Marine Archaeology Division. He received an M.S. degree in history in 2004 from the University of West Florida and a B.A. degree in anthropology in 1997 from Northwestern State University in Natchitoches, Louisiana, focusing on Louisiana prehistoric and historic archaeology. Mr. Rawls joined ESI in February 2006. Since that time he has been project manager for numerous Phase I surveys and Phase II testing projects (terrestrial and maritime) throughout Louisiana. He has authored or co-authored 27 cultural resources reports and papers. Mr. Rawls is responsible for conducting all submerged cultural resources investigations at ESI.

He is RPA-certified (2007), has completed the Advisory Council's Section 106 Review Course (2008), and is fully familiar with the cultural resources compliance requirements (generally Section 106 of the NHPA) of federal agencies, including USACE and FERC.

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HURRICANE IMPACTS ON SHIPWRECKS

Robert Gearhart
PBS&J (an Atkins Company)

In 2005, the Gulf of Mexico was significantly impacted by Hurricanes Katrina and Rita, two of the costliest hurricanes in U.S. history. Combined, these storms destroyed over 100 offshore oil and gas platforms and damaged more than 500 pipeline segments. The extent of this damage raised concerns within BOEMRE's Historic Preservation Program regarding the potential effects to Gulf of Mexico shipwrecks that were subjected to the same destructive forces.

Ten wrecks were selected for investigation, based on their proximity to the hurricane paths and on the availability of prestorm archaeological data. Each of these wrecks was subjected to a remote-sensing survey, and, based on those results, four of the wrecks were selected for further investigation by divers to quantify the extents of storm-induced damage. Previously-published hindcast weather data were used to produce wave-current interaction models of the horizontal and vertical forces exerted on each of the four wrecks during peak-storm conditions.

Quantifiable hurricane impacts varied widely among the four investigated wrecks, despite wave-current interaction models that illustrated consistently severe environmental conditions at each site. Two wrecks exhibited no discernible effects, and the combined data were at best inconclusive. Conversely, a third site was heavily impacted by bottom currents that resulted in significant hull collapse. The fourth site was not negatively affected by the hurricane forces, but was instead returned to a protective anaerobic environment due to complete reburial. These results differ significantly from documented hurricane impacts to wrecks sunk as artificial reefs in other regions of the U.S. This discrepancy suggests an inverse relationship between the number of hurricanes a shipwreck has been subjected to over time and the damage caused by each subsequent hurricane event.

Robert Gearhart has worked as a nautical archaeologist since 1984 and has managed the PBS&J (now Atkins) Nautical Archaeology and Remote Sensing Program since 1998. He has worked on behalf of state, federal and private entities in thirteen states and the Gulf of Mexico. Mr. Gearhart has played a key role on five IDIQ contracts for historic properties investigations awarded by the U.S. Army Corps of Engineers, Galveston District since 1989, involving nearly 70 task orders. He has been Principal Investigator on three major archaeological studies for BOEMRE, including the following: *California, Oregon, and Washington Archaeological Resource Study* (MMS 90-0087); *Study to Conduct National Register of Historic Places Evaluations of Submerged Sites on the Gulf of Mexico Outer Continental Shelf* (MMS 2006-036), and *Impacts of Recent Hurricane Activity on Historical Shipwrecks in the Gulf of Mexico Outer Continental Shelf* (BOEMRE 2011-003).

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INVESTIGATION OF SHIPWRECK SITES IN THE NORTHWESTERN GULF OF MEXICO

Matt Keith, Amanda Evans, and Erin Voisin
Tesla Offshore, LLC

Greg Cook and Eric Swanson
University of West Florida

Shipwrecks represent approximately 500 years of maritime activity within the Gulf of Mexico coastal region. Vessels used in this area reflect a diversity of activities and changing cultural practices, and include early ships of exploration, vernacular fishing boats, commercial tankers, passenger ships, and ships of war. This paper discusses preliminary results of a BOEMRE-funded study to investigate unidentified wreck sites in the Gulf of Mexico. The study was designed to evaluate the sites for eligibility to the National Register of Historic Places and provide assessments of the environmental processes impacting the sites. Archival research, advanced geophysics, diver investigations, geotechnical analysis, and oceanographic modeling are being integrated to achieve the study objectives.

Matt Keith manages the Geosciences Division of Tesla Offshore, LLC, which is responsible for archaeological, geologic, and geophysical data interpretation and reporting. He holds a Master's degree from Florida State University.

Amanda Evans is Senior Marine Archaeologist for Tesla Offshore, LLC. Her research interests include Gulf of Mexico and Caribbean shipwreck archaeology, geoarchaeology, and submerged prehistoric archaeology. She holds a Master's degree specializing in marine archaeology from Florida State University and is completing a Ph.D. from Louisiana State University.

Erin Voisin is an Archaeologist, Geophysical Analyst, Regulatory Specialist, and Data Administrator for Tesla Offshore, LLC. She holds a Bachelor's degree in history from Loyola University of New Orleans and a Master's degree in Anthropology from Louisiana State University.

Greg Cook is a research associate and instructor with the University of West Florida's Archaeology Institute. His professional interests include shipwreck archaeology, Atlantic trade, and culture contact. He holds a Master's degree in Anthropology from Texas A&M University, and is completing a Ph.D. from Syracuse University.

Eric Swanson is completing a Master's degree at the University of West Florida. His thesis focuses on two possible World War II-era shipwrecks examined as part of the referenced BOEMRE study. He has a Bachelor's degree in anthropology from Georgia Southern University.

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LOPHELIA II RIGS, REEFS, AND WRECKS SHIPWRECK COMPONENT: 2009 AND 2010 FIELD SEASON RESULTS

Daniel J. Warren, Robert A. Church, Robert F. Westrick
C & C Technologies, Inc.

Following the 2008 reconnaissance cruise, two additional shipwreck documentation cruises were conducted, in 2009 and 2010, as part of the *Lophelia* II Study Shipwreck Component. During these cruises, a total of seven shipwreck sites were visited by the research team. This presentation will briefly discuss the findings of these two cruises. The discussion will include a summary of the investigation objectives, the wreck sites visited, and operations undertaken at each site. A review of preliminary findings and current research focus will be included in this presentation.

Daniel J. Warren is a Senior Marine Archaeologist and the Houston Assistant Geosciences Manager at C & C Technologies, Inc. (C & C). He has worked as a professional archaeologist for over 20 years and is trained in both terrestrial and underwater archaeology, as well as material culture analysis. Mr. Warren has worked on shipwreck projects in Bermuda, Australia, and the United States. Since 1998, he has been working at C & C interpreting high-resolution geophysical data for shipwreck investigations, oil and gas surveys, search and recovery operations, and cable route studies in the inland waters of the United States, the Gulf of Mexico, South America, and Asia. Mr. Warren has worked on numerous oil and gas exploration projects and written over 100 archaeological assessments based on high-resolution geophysical data, diver acquired video data, or ROV video data. In his capacity as a marine archaeologist at C & C, Mr. Warren has spent several hundred hours offshore monitoring diver and ROV investigations of potential archaeological targets for the oil and gas industry. Mr. Warren is one of two C & C archaeologists recognized by the oil and gas industry and the BOEMRE as among the most experienced deepwater marine archaeologists working in the Gulf of Mexico. Mr. Warren and his colleagues at C & C have worked to expand the multi-disciplinary investigations of deepwater shipwrecks in the Gulf of Mexico. This multi-disciplinary approach for deepwater shipwreck investigations is intended to provide a better understanding of deepwater shipwreck formation and distribution processes. Mr. Warren has authored or co-authored several professional publications and presentations related to deepwater shipwrecks and deepwater archaeological investigation methodology.

Robert A. Church is a Senior Marine Archaeologist at C & C headquarters in Lafayette, Louisiana. He has over 17 years' professional experience in underwater archaeology and historical research. He has served as a marine archaeologist with C & C for the past 12 years. He received his M.A. in maritime history and nautical archaeology from East Carolina University in 2001. Mr. Church has worked on submerged archaeological projects in Florida, North Carolina, Virginia, Maryland, Bermuda, and various locations in the Gulf of Mexico. He has participated as a principle investigator on 10 deepwater expeditions since 2001. He has been the chief scientist on three expeditions, which included the investigation of 11 deepwater shipwrecks. He has conducted field investigations of at least 14 deepwater shipwrecks, which included multiple year investigations of some of the most intriguing deep historic shipwrecks known in the Gulf of Mexico (i.e., *U-166*, *Robert E. Lee*, *Gulf Penn*, the Green Lantern Wreck, the Viosca Knoll Wreck, the Ewing Banks Wreck, the Mardi Gras Wreck, etc). Additionally, he has been involved with the investigation and documentation of numerous chemosynthetic community sites, deepwater unexploded ordnance, and other deepwater targets. While working for C & C, Mr. Church has been the archaeological principle investigator and authored reports on over 200 marine remote sensing surveys.

Robert F. Westrick is a marine archaeologist for C & C, one of the world's leading companies in deep-water geophysical survey. In 2008 and 2009, he served as an archaeologist on the Reefs, Rigs, and Wrecks Project. Mr. Westrick holds a Master's degree in maritime history and nautical archaeology from East Carolina University. He is a registered professional archeologist. Westrick has worked on numerous shipwreck projects over the past decade ranging from remote sensing surveys to complete excavation and mapping investigations. In 1997 he completed the first archaeological survey of the U.S.S. *Peterhoff*, a Civil War steamship lost off the coast of North Carolina. *Peterhoff* was the first shipwreck ever to be placed on the National Register Historic Places. Despite that distinction, no prior detailed archaeological survey had ever been conducted on the site. In addition to his work on various Civil War shipwrecks in North Carolina and Virginia, Westrick has worked on projects ranging from 17^{th}-century Spanish merchant ships off Bermuda to 19^{th}-century schooners in Lake Erie.

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THE ATLANTIC OUTER CONTINENTAL SHELF SHIPWRECK DATABASE: AN UPDATED INVENTORY AND DISTRIBUTION ANALYSIS

Jeffrey L. Holland
Senior Historian, TRC

To facilitate Section 106 cultural resources consultation for permitted undertakings, BOEMRE requested an updated study of shipwrecks for the Atlantic Outer Continental Shelf (OCS). For this study, TRC collected data from existing shipwreck inventory databases and examined primary and secondary sources to identify confirmed, reported, and potential historical archaeological resources within the boundaries of the OCS. The data were assembled into a Microsoft Access® database and an ArcGIS geodatabase that BOEMRE can use to identify known and likely historic sites within an area of concern. In all, there were 33,851 entries placed into the database through these efforts. In addition, an analysis of the resulting Atlantic Shipwreck Database (ASD) provided insight into the distribution of shipwrecks by vessel type, time period, and geographic location. The observed distribution of shipwrecks is consistent with the evidence of traffic volume and navigation hazards as major factors in vessel loss. Shipwreck density in BOEMRE lease blocks was used to establish zones of low, medium, and high probability for encountering recorded or unknown wrecks, guiding cultural resources management decisions related to site selection, budget considerations, and survey strategy.

Jeffrey L. Holland is Senior Historian for TRC (and formerly Garrow & Associates), a position he has held since 1988. He holds a master's degree in history from the College of William & Mary. Mr. Holland has conducted historical research for National Register assessments and nominations, archaeological investigations, and cemetery removals throughout the Southeast, Mid-Atlantic, and New England and has authored or co-authored hundreds of cultural resources reports. He has written historical contexts for projects ranging from a postbellum African-American farm on Hilton Head Island to millionaire "cottages" on Jekyll Island. He has documented Cold War resources on military bases in Tennessee and Texas, researched and written a popular history of Air Force Plant 6 in Marietta, Georgia, developed historic preservation plans, and conducted oral history for public housing projects and historic sites.

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BATTLE OF THE ATLANTIC FIELDWORK: PROMOTING THE PROTECTION OF MARITIME HERITAGE IN NORTH CAROLINA

Joseph C. Hoyt
NOAA's Monitor National Marine Sanctuary

Joe Hoyt is a maritime archaeologist serving as a field technician and researcher for the Monitor National Marine Sanctuary. He has worked on several NOAA projects in the Thunder Bay, Florida Keys and Monitor National Marine Sanctuaries since 2001. In 2004, he was awarded the North American Rolex Scholarship through the Our World Underwater Scholarship Society. He has worked on underwater archaeology projects in the Great Lakes, Atlantic and Pacific Oceans, and several inland rivers. Joe is also an avid photographer and diver, and has crewed documentary expeditions on BBC's Planet Earth and PBS. Joe holds an M.A. in maritime history and underwater archaeology from East Carolina University's Program in Maritime Studies.

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SESSION 2B

DEEP-SEA CORALS — *LOPHELIA* II: REEFS, RIGS AND WRECKS

Chair: Bill Shedd, BOEMRE

Co-Chair: James Sinclair, BOEMRE

(continued on next page)

LOPHELIA II: OVERVIEW AND MANAGEMENT
Deepwater Program: Exploration and Research of Northern Gulf of Mexico Deepwater Natural and Artificial Hard-Bottom Habitats with Emphasis on Coral Communities: Reef, Rigs and Wrecks

James M. Brooks
TDI Brooks International Inc., College Station, Texas

Program Objectives

Obtain robust predictive capability for the occurrence of rich hard-ground coral communities in the deep Gulf of Mexico

- Discover and describe new locations > 300 m with extensive coral community development including *Lophelia pertusa*
- Gain a more comprehensive understanding of processes that control the occurrence and distribution of *Lophelia* and other coral communities (<300m) through both laboratory and field data collection
- Document and understand the relationship between coral communities on artificial and natural substrates with respect to community composition and function, phylogeographic and population genetics, and growth rates of key foundation species

Biological Objectives

- To discover and characterize new sites
  - Characterize key sites at the largest scale with HR bathymetry, SSS, 3-D seismic data and current models
  - Characterize the coral density at the 10 to 100-m scale with randomized photo transects and general site descriptions
  - Characterize the community composition at the 1 to 10 m scale at significant coral sites (man-made and natural) with analysis of close-up imagery, replicate photomosaics and quantitative community collections
- Analyze connectivity among man-made & natural sites with comparative community, phylogeographic and population genetic analysis
- Compare the structure, species richness and diversity of communities tightly associated with *Lophelia* at man-made and natural sites
- Experimentally determine the tolerance and growth response of *Lophelia* to temperature, pH/alkalinity, dissolved oxygen and current.
- Characterize and constrain growth rates of key species of colonial cnidarinans (pioneer colonies) using analysis of images on man-made structures of known age
- Characterize key variables (temperature, currents, larval seasonal distribution development and sediment quality) at sites with the most significant coral communities over one year at two to four sites

Other Objectives

- Historical shipwreck component. Study of up to six (6) shipwrecks to determine identity, site boundaries, National Register eligibility, preservation state and stability, associated biological communities and artificial reef effects.
  - Determine rate of deterioration of test coupons at platforms or shipwrecks
- Coordination with USCG
- Deepwater commercial fisheries review that impact hard-bottom communities

Program Organization – Figure 2B.1

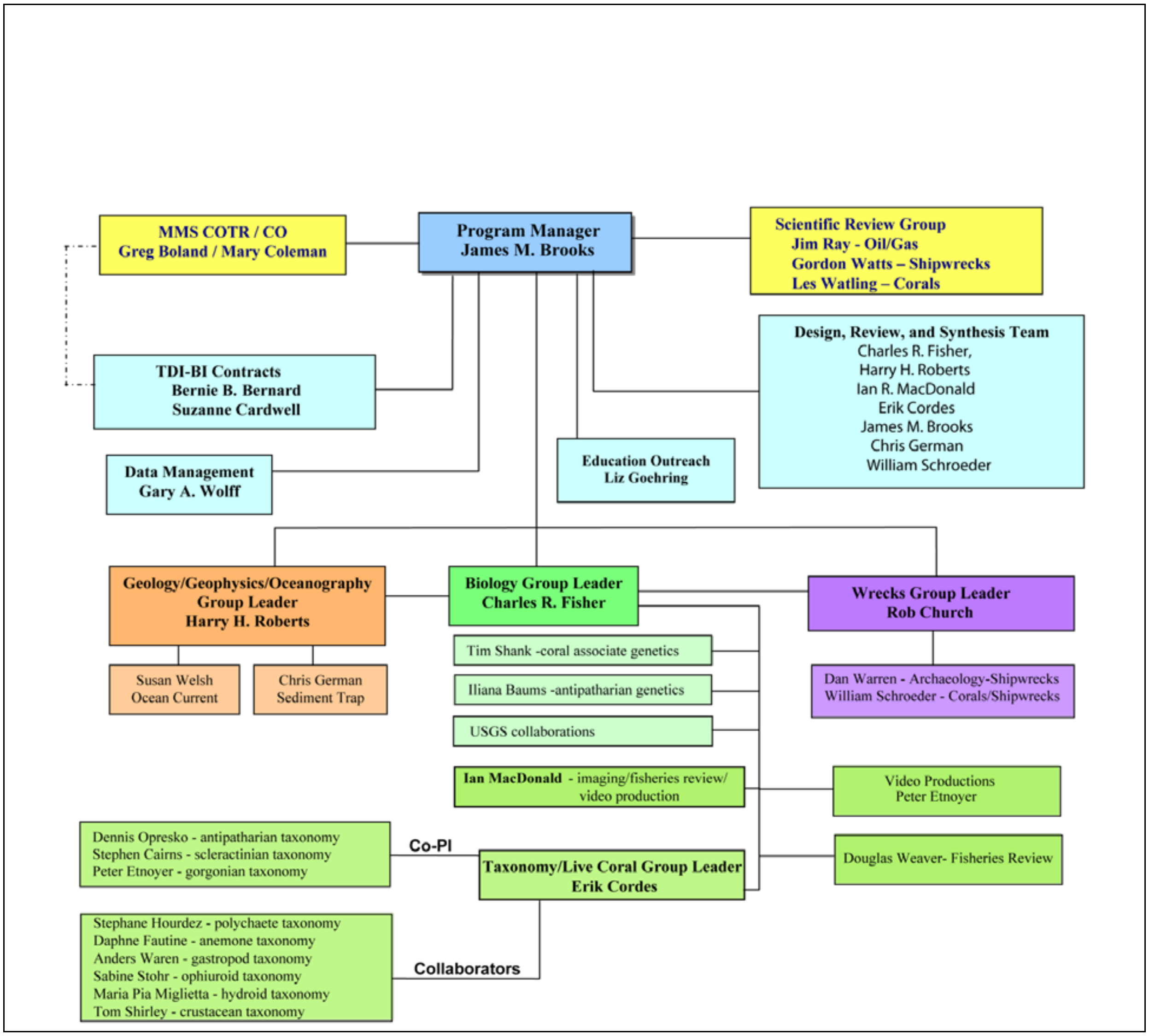

Figure 2B.1. Program organization.

Cruise1: September 5–October 2, 2008

Primary Objective: Conduct a reconnaissance of shipwreck sites and site reconnaissance of potential new hard-ground communities

- Conducted on NOAA research vessel *Nancy Foster*
- Mobilized and embarked from Galveston, Texas
- Leg 1: September 5–13, 2008
- Staged in Gulfport, Mississippi, for the second leg
- Leg 2: September 20–October 2, 2008
- Demobilized in Pascagoula, Mississippi

Leg 1

- Ewing Banks Wreck site confirmed historic 19th-century shipwreck site
  - More *Lophelia* on Ewing Banks Wreck than any other 19th-century wooden wreck known in the Gulf of Mexico
- Identity of *Gulfoil* was confirmed and substantial coral colonies were documented
  - *Lophelia* coverage at *Gulfoil* may be more substantial than that documented at *Gulfpenn* in 2004
- The dive on *Gulfpenn* allowed the identification of the stern section of the tanker
  - Microbial experiment placed on the site in 2004 was reexamined
  - Temperature logger was placed on *Gulfpenn* 's bow

Leg 2

- Multibeam data was collected at 13 sites
- Ten (10) lowerings of the ROV were completed over eight (8) different sites
  - 50 hours total bottom time, CTD collectons and 61 biological and geological samples collected
- Five (5) sites with adequate visual surveys
  - MC 751 (8 hrs) high abundance of live *Lophelia pertusa*—good candidate for future work
  - GC 140 (17 hrs) high diversity of gorgonians and antipatharians
  - GC 234 (5 hrs) discovered new area of *Lophelia pertusa* colonization north of previous site
  - VK 906 (10 hrs) coral mounds south of previously explored area
  - GB 201 (9 hrs) hard grounds covered in sediment, very low coral abundance
    - Eliminated as a potential site

Cruise 2: June 6–30, 2009

R/V *Brooks Mccall* and WHOI's AUV *Sentry*

- Cruise Duration: 14 days
- Somewhat similar activities as first cruise
- Survey remaining sites from Cruise 1 list
- Focus on site recon of unexplored sites and wrecks
- Increased sample capabilities greater than 1,000-m in such sites as GC-852 and other areas

- Based on data collection during the first two cruises, the key sites (both natural and artificial) for in-depth study during the subsequent cruises will be identified

Cruise 3: August 19–September 12, 2009

- Mapping out coral distribution
- Collecting the data necessary to fully describe the habitats of the corals, the communities associated with them, and the levels of genetic connectivity among the coral communities.
- Collecting live corals, and transporting them back to the laboratory to conduct experiments to better understand the factors controlling their distribution.
- Surveying shipwrecks to examine the coral communities in the wrecks, as well as to describe and preserve these potentially historic sites.

Accomplishments

- Conducted 20 dives with the ROV *Jason II* at 17 sites (including 5 shipwrecks), and an incredible 356 hours of bottom time
- Mapped out about 20 km2 of seafloor for the first time
- Using *Jason*, obtained high resolution maps of the seafloor in which we could identify individual coral colonies.
- Found some new *Lophelia* sites, including the "Roberts' Reef" site in Viosca Knoll 906.
- Contained huge, uninterrupted fields of *Lophelia* and also contained a high level of diversity of black corals that contributed to the heterogeneity of the habitat
- This site is also the first reported cold-water carbonate mound in the Gulf, a feature that is quite common at the *Lophelia* sites of the Atlantic. The features of this site will change the way we look for *Lophelia* in the future.
- Confirmed a previous sighting of *Lophelia* about 200 km further west in the Gulf than it had ever been reported, in Green Canyon 535. This site will provide a wealth of information on the population genetics and larval dispersal of *Lophelia* as we begin to work up our samples.

Cruise 4: October 13– November 4, 2010

ROV Cruise: *Ron Brown and Jason II*

- Focused on deepwater coral focus
- Returned to existing and new sites likely to host lush core or seep fauna
- Collected small pieces of coral for genetic studies to explore connectivity, how corals respond to stress
- Sampling associated with DW Horizon incident
- These "baseline" data included 18 photomosaics covering between 20 and 100 m^2 portions of 8 different coral community sites between 300 and 1,500 m depth in the Gulf.
- Each site is well marked, and the mosaics are so well navigated that we can return to specific corals to see if they are still alive, if they have grown and if there are any visible signs of damage since our last visit.

Accomplishments

- 17 dives with the ROV *Jason II* at 17 sites
- Detailed and methodical imaging of the site and fauna
- Dive to an area 7 miles to the SW of the site of the *Deepwater Horizon* disaster collected a variety of samples that may help us to understand what happened here. Sampled small pieces of coral from each apparently different species for genetic identification.
- Fixed some of the samples on the sea floor in a fixative that will allow investigation of the proteins the corals were expressing on the sea floor and investigations of genetic damage they may have incurred.
- Sampled both dead and live corals, brittle stars, anemones, and even mud for laboratory analyses and fingerprinting of hydrocarbons.
- Analyses will include tests to determine if there is still evidence of whatever chemicals may have impacted these animals in their tissues or the sediment beneath them.

Remaining Field Sampling

Oil Platform ROV Survey Effort using R/V *BROOKS McCALL* and NOAA-OE provided ROV

- At least six platforms to be selected for live coral colonization surveys/sampling
- Selected in areas of special interest to our studies of population connectivity amount known and potential deep coral communities
- Represent a range of ages in order to generate a range of growth rates for pioneer colonies

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James M. Brooks is President of TDI-Brooks International, Inc. a company specializing in offshore research and survey studies for federal/state agencies as well as the oil industry. Dr. Brooks founded the Geochemical and Environmental Research Group (GERG) at Texas A&M University in 1975 and served as director until 1995. He has been Project Director on many federal projects for the National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (USEPA), Office of Naval Research (ONR), the Minerals Management Service (MMS, now BOEMRE), the U.S. Fish and Wildlife Service (USFWS), and other state and federal agencies. He has extensive experience in the management of large environmental and oceanographic projects as well as the technical competency in environmental and geochemistry, surface geochemical exploration, oil spill assessment, gas hydrates, chemosynthetic ecosystems, stable isotope geochemistry, and oceanography.

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LOPHELIA II: GEOLOGICAL SETTING AND SITE SELECTION

Harry H. Roberts
Coastal Studies Institute, School of the Coast and Environment
Louisiana State University

William Shedd
Bureau of Ocean Energy Management, Regulation and Enforcement

Lophelia and other deepwater corals must have a hard substrate on which to attach and grow. Therefore, identifying areas of hard bottom on the continental slope is the key to identifying sites where coral communities have a reasonable probability of being present. The geology of the slope restricts hard bottom to four basic types: (1) salt exposure, (2) sand derived primarily from shelf edge deltas and lowstand fluvial systems, (3) old and compacted clay exposed by submarine erosion or faulting, and (4) authigenic carbonates formed as by-products of microbial oxidation of hydrocarbons at seep sites. By far the most numerous and widespread of these hard-bottom types associated with the modern seafloor are the carbonates. Since the early 1990s 3D-seismic surface reflectivity data have been used to locate hydrocarbon seeps. Hard bottoms are highly reflective and therefore produce an amplitude anomaly that can distinguish them from surrounding bottom sediments, which are generally much less reflective. The large database of industry-acquired 3D-seismic archived by the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) provides the opportunity for *Lophelia* II project researchers, under proprietary conditions, to search for potential coral community sites by identifying areas of hard bottom. Because a focus of the project is to investigate the habitat characteristics, geographic distributions, and depth limitations of deep-water corals, especially Lophelia, the seismic database is used to search for potential coral sites over the full depth range of the continental slope and from the Florida Escarpment to east Texas. Use of 3D-seismic data for surface attributes and geologic structure from profiles has been a successful methodology for locating and geologically characterizing the northern Gulf of Mexico hydrocarbon seeps for two decades. This same technology is now being used to locate and characterize sites of deepwater coral occurrence.

Dr. Harry H. Roberts is the former director of Coastal Studies Institute at LSU, an emeritus member of the Department of Oceanography and Coastal Sciences (School of the Coast and Environment), and a Boyd Professor. He has had a career in marine geology that spans more than 40 years and has worked in many foreign countries as well as in the United States. Recently, his research has focused on three themes: (a) modern deltaic sedimentation and processes, (b) shelf-edge deltas, and (c) surficial geology of the northern Gulf's continental slope. The latter research thrust has concentrated on building an understanding of the impacts of fluid and gas expulsion on the surficial geology and biology of the slope.

William (Bill) Shedd received his B.A. in geology from the University of Rochester and his M.S. in geology from Louisiana State University. He worked for Shell Oil Co. from 1977 to 1981 and co-founded Independent Energy Corp. in 1989. From 1994 to 1997 he consulted for several large and small independent oil companies in exploration, development, log analysis, geophysical interpretation, and well site analysis. He joined the Minerals Management Service (now BOEMRE) as a geophysicist in 1997. He has worked in the Resource Evaluation Division and Research Studies Section, where he has been active in the submersible dive program and the methane hydrate assessment study.

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LOPHELIA II: PHYSICAL OCEANOGRAPHY AND LARVAL DISPERSAL POTENTIAL

Susan Welsh
Department of Oceanography and Coastal Sciences
School of the Coast and Environment, Louisiana State University

In the northern Gulf of Mexico, deep-water coral communities have been observed on authigenic carbonates at seep sites, as well as on anthropogenic structures, ship wrecks, and oil platforms. Due to possible environmental damage to the reefs from human activity, the need exists to further predict where the deep coral communities are likely to occur for future management and protection. Potential sites for *Lophelia* coral larvae settlement on the northern slope in the Gulf of Mexico were examined using particle tracing analysis from a high-resolution, ocean circulation model. Instrumented moorings were positioned near two known *Lophelia* communities to collect information about the physical environments of established communities, such as the local circulation and hydrography. The mooring data were used to assess the skill of the numerical model, and the model in turn provided a means to understand the localized flow in the context of the large-scale circulation. The Viosca Knoll 826 (VK826) mooring was located east of the Mississippi Delta in 455 m water depth and featured a current meter at 5 m above bottom and an upward looking ADCP at 9 m above bottom with a range of 72 m. The near-bottom currents at VK826 were dominated by along-isobath flow toward the west-southwest with maximum current speed of 31 cm/s. The dominant current direction rotated toward the southwest with increasing height above the bottom and the current speeds increased to a maximum of 62 cm/s at 69 m above the bottom. The second mooring at Green Canyon 852 (GC852) was located southwest of the delta in 1,424 m water depth and had current meters at 5 m and 100 m above the bottom. The dominant direction of the currents at GC852 rotated from generally northwestward near the bottom to westward at 100 m above the bottom and the currents were considerably weaker than observed at VK826. The Lagrangian technique of seeding and tracking tracer particles was used to determine probable routes of coral larval dispersal given the geographic locations of the sources of reproductive propagules. There is strong agreement between the model currents and the observed currents. The geographic locations within the model where the particles became stranded were noted and may indicate probable areas for coral settlement. Animations of the particle positions superimposed on the model flow fields were made to visualize how the coral larvae are carried by the currents and how their trajectories are guided by the Loop Current and its eddies.

Dr. Susan Welsh held a variety of positions in the LSU Coastal Studies Institute (CSI) over a period of 20 years before moving to the LSU Department of Oceanography and Coastal Sciences in the School of the Coast and the Environment, where she is currently employed. Susan came to LSU in 1989 to work as a programmer for Dr. Masamichi Inoue on a model of the Indo-Pacific through flow. She soon became a Ph.D. student and focused on the paleocirculation of the Gulf of Mexico. Susan continued in CSI as Research Faculty and specialized in physical oceanography, numerical ocean models, and Gulf of Mexico circulation. Susan and Dr. Inoue had a deep sea mooring in the eastern Gulf of Mexico for eight years that provided much-needed data to verify her model of deep circulation as well as make one-of-a-kind observations in the deep Gulf. While a researcher in CSI, Susan had funding from the former MMS (currently BOEMRE) to use particle tracing methods in ocean circulation models to look at the potential impacts of deep water oil spills, which she applied to the current study of the predicting suitable areas for coral larvae settlement. Susan received her B.S. in earth and planetary sciences from The Johns Hopkins University, her M.S. in oceanography from Florida State University, and her Ph.D. in geology from Louisiana State University.

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LOPHELIA II: PARTICULATE FLUX TO COLD WATER CORAL SITES, SEPTEMBER 2009 – SEPTEMBER 2011

Chris German
Woods Hole Oceanographic Institution

Steve Manganini and Timothy Shank
Woods Hole Oceanographic Institution

Erik E. Cordes
Temple University

Chuck Fisher
Pennsylvania State University

In September 2009, two time-series sediment trap moorings were deployed in the northern Gulf of Mexico to investigate biogenic fluxes to the seafloor at sites of deep-water coral and chemosynthetic tubeworm communities. Each trap, set just above the seabed, collected one sample every two weeks from September 2009 until July 2010. In April 2010 it was recognized that these traps were located close to the *Deepwater Horizon* (DWH) incident, so we deployed a second pair of sediment trap moorings in June 2010 to continue the time series at each location until December 2010. Our program will recover the last of our sediment traps in December 2010. Upon recovery, all samples will be analyzed for standard biogeochemical contents and subsets will be further analyzed for larval studies. Additionally, we will quantify the bulk oil content present in all samples and determine the concentrations of select hydrocarbons using a combination of conventional and two-dimensional gas chromatography (GCxGC) to provide greater insight into the molecular composition of any oil present.

Christopher R. German is a Senior Scientist in the Geology and Geophysics Department at Woods Hole Oceanographic Institution where he also serves as the Chief Scientist for Deep Submergence, advising the National Deep Submergence Facility operators of the submersible *Alvin*, the ROV *Jason* and the AUV *Sentry* on behalf of the U.S. deep ocean research community. He has worked in the US and UK throughout a career spanning 25 years studying deep ocean biogeochemistry with a particular emphasis on low-oxygen marine environments including oxygen minimum zones, deep sea hydrothermal vents (his primary area of expertise to-date) and cold seeps. Before relocating to the U.S. in 2005, German was President of the Challenger Society for U.K. Marine Science and, more recently, has been Co-Chair of the InterRidge program and also Co-Chair of the Census of Marine Life program dedicated to understanding the biogeography and biodiversity of chemosynthetic ecosystems, ChEss.

Steven J. Manganini is a Research Specialist in the Department of Geology and Geophysics at Woods Hole Oceanographic Institution with a 35 year career studying biogeochemical fluxes to the deep ocean. As manager of the PARFLUX laboratory at WHOI, directed by Dr. Sus Honjo, he was a key part of the influential JGOFS program that pioneered our understanding of deep-ocean biogeochemical fluxes from high productivity ocean margins to the oligotrophic open ocean and from the tropics to the high latitude Southern Ocean. Recent work has included on-going studies in the high Arctic and, most recently, an adaptation of his expertise to investigate particulate biogeochemical fluxes associated with high temperature hydrothermal vents and lower-temperature cold-seep environments.

Dr. Tim Shank is an Associate Scientist in the Biology Department at Woods Hole Oceanographic Institution. His research interests focus on understanding the evolution of life in the deep sea and the ecological processes responsible for creating and maintaining biodiversity in the oceans. He combines molecular genetic approaches and ecological field studies to understand the conditions and adaptations that allow various species to migrate, evolve, and thrive along the global mid-ocean ridge, seamount systems, and most recently, in the Gulf of Mexico. His genetic approaches are aimed at understanding the evolutionary processes that drive patterns of diversity and connectivity in coral ecosystems have led to burgeoning insights on the co-evolution and co-dispersal of coral hosts and their invertebrate associates. This research has been driven both by the model system that coral hosts and associates provide for fundamental evolutionary biology and by the need to understand the impacts and sustainability of deep-sea fisheries and increasing mineral and oil exploration activities on these deep-water faunas.

Dr. Erik Cordes (Temple University) has nearly 20 years' experience with deep-water corals and hydrocarbon seep communities and has worked primarily in the Gulf of Mexico for over 10 years. Dr. Cordes's lab combines ecological and molecular techniques to investigate a wide variety of questions centered on these organisms and their habitats. The work on cold-water corals, funded by a 4-year grant from BOEMRE and NOAA OER, includes investigations of the habitat preferences of *Lophelia pertusa* and the genetic connectivity of deep-water gorgonian populations in the Gulf of Mexico. Ongoing studies of cold seeps include the biogeographic and bathymetric patterns in tubeworm- and mussel-associated communities and the influence of tubeworm tube-hosted microbial communities on seep biogeochemistry, particularly the sulfur cycle. Dr. Cordes is also involved in the assessment of the impact of the *Deepwater Horizon* incident on the cold-water coral and natural seep communities of the Gulf of Mexico. Of his 29 publications, 19 are focused on the communities of the deep Gulf of Mexico, and he has participated in 16 research cruises to the Gulf (four as Chief Scientist) using six different RVs, four different ROVs, and three different HOVs (30 dives), as well as the AUV Sentry.

Charles (Chuck) Fisher is a Professor and Chair of the Graduate Program in Biology at the Pennsylvania State University. He has participated in 57 oceanographic research expeditions, serving as chief scientist on 26 of them. Fisher became involved in research on deep-sea hydrothermal vent ecosystems shortly after their discovery in the late 1970s and in research on the hydrocarbon seeps of the Gulf of Mexico in 1986. He has published over 120 peer-reviewed papers on the biology of hydrothermal vents and cold seeps. He served as the chair of the US NSF Ridge 2000 program until 2005 and is currently the co-chair of the InterRidge Biology working group and a member of the Steering Committee for the Census of Marine Life ChEss (Chemosynthetic Ecosystems) program.

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DISTRIBUTION OF COLD-WATER CORAL COMMUNITIES IN THE GULF OF MEXICO

Erik E. Cordes
Temple University

Cold-water corals form ecologically significant habitats on the continental slope of the Gulf of Mexico, hosting a wide variety of associated species. There were a total 26 natural sites visited with a variety of submersibles during the course of the *Lophelia* II program. In general, community structure is most heavily controlled by depth, with different communities above and below ~1,000m. The presence of the scleractinian *Lophelia pertusa* and the gorgonian *Callogorgia americana,* as well as a diverse octocoral and antipatharian community, defines the upper slope, while the lower slope contains a variety of different octocoral species with only a few isolated scleractinian populations. The sites of the upper slope are commonly dominated by *L. pertusa*, which forms large reef-like structures on the seafloor. The largest of these sites is in the Viosca Knoll (VK) 826 lease block, an area that has been intensively studied over the last 10 years. The *Lophelia* II program collected the first high-resolution multibeam of this site, and located a new coral area within the larger site. The VK906 lease block contains a large cold-water coral mound primarily consisting of dead *Lophelia* framework that was discovered on our cruise in 2009. This is the largest cold-water coral mound known from the Gulf of Mexico. The MC751 site contains *L. pertusa* colonies along with *Callogorgia americana* that are found closer to active seeps than at any other site. Further to the west, the GC354 site contains a number of small *Lophelia* mounds with a diverse gorgonian community. The GB535 site consists of a series of similar small mounds along the top of a linear ridge and is the furthest west that *Lophelia* has been found in the Gulf.

Dr. Erik Cordes (Temple University) has nearly 20 years' experience with deep-water corals and hydrocarbon seep communities and has worked primarily in the Gulf of Mexico for over 10 years. Dr. Cordes's lab combines ecological and molecular techniques to investigate a wide variety of questions centered on these organisms and their habitats. The work on cold-water corals, funded by a four-year grant from BOEMRE and NOAA OER, includes investigations of the habitat preferences of *Lophelia pertusa* and the genetic connectivity of deep-water gorgonian populations in the Gulf of Mexico. Ongoing studies of cold seeps include the biogeographic and bathymetric patterns in tubeworm- and mussel-associated communities and the influence of tubeworm tube-hosted microbial communities on seep biogeochemistry, particularly the sulfur cycle. Dr. Cordes is also involved in the assessment of the impact of the *Deepwater Horizon* incident on the cold-water coral and natural seep communities of the Gulf of Mexico. Of his 29 publications, 19 are focused on the communities of the deep Gulf of Mexico, and he has participated in 16 research cruises to the Gulf (four as Chief Scientist) using six different RVs, four different ROVs, and three different HOVs (30 dives), as well as the AUV Sentry.

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LOPHELIA II: CORAL DISTRIBUTION & OCEAN CHEMISTRY

Jay Lunden, Samuel Georgian and Erik Cordes
Department of Biology, Temple University

One consequence of ocean acidification is the reduction of the $CaCO_3$ saturation state of seawater and the subsequent shoaling of the aragonite saturation horizon. This value is significant to aragonite-secreting organisms, and several investigators have reported a direct correlation between calcification and saturation state. In the northern GOM, the scleractinian *Lophelia pertusa* forms expansive bioherms at depths from 300 to 600 m. We recently sampled bottom waters and conducted CTD casts from surface to 2,100m at 14 stations across a range of 600 km. We measured total alkalinity and pH and discovered coral sites that are undersaturated with aragonite. In waters deeper than 300 m, pH ranged from 7.72 to 7.87, TA ranged from 2,216.38 to 2,344.29 µmol/kg-SW, and omega aragonite ranges from 0.57 (at 2100 m) to 0.99 (at 390 m). Furthermore, the aragonite saturation horizon in the northern GOM is presently at 290 m depth. Despite these low omega conditions, *L. pertusa* persists and sustains bioherm formation. These results suggest that omega aragonite may not be the best predictor of coral calcification, and complements data from recent studies that suggest coral calcification responds to factors other than omega aragonite.

Jay Lunden is a Ph.D. candidate in Dr. Erik Cordes' lab at Temple University. He is broadly interested in the dynamics of oceanic carbon chemistry and the effects of ongoing ocean acidification on coral physiology. He is also interested in the mechanisms of coral calcification, and uses the cold-water scleractinian *Lophelia pertusa* as a model in his research. Jay received his B.S. in biology from Temple in 2007 and plans to pursue research in marine invertebrate ecophysiology after graduation.

Samuel Georgian is a Ph.D. candidate in Dr. Erik Cordes' lab at Temple University. His research interests include community ecology and life history of deep-sea coral communities.

Dr. Erik Cordes (Temple University) has nearly 20 years' experience with deep-water corals and hydrocarbon seep communities and has worked primarily in the Gulf of Mexico for over 10 years. Dr. Cordes's lab combines ecological and molecular techniques to investigate a wide variety of questions centered on these organisms and their habitats. The work on cold-water corals, funded by a four-year grant from BOEMRE and NOAA OER, includes investigations of the habitat preferences of *Lophelia pertusa* and the genetic connectivity of deep-water gorgonian populations in the Gulf of Mexico. Ongoing studies of cold seeps include the biogeographic and bathymetric patterns in tubeworm- and mussel-associated communities and the influence of tubeworm tube-hosted microbial communities on seep biogeochemistry, particularly the sulfur cycle. Dr. Cordes is also involved in the assessment of the impact of the *Deepwater Horizon* incident on the cold-water coral and natural seep communities of the Gulf of Mexico. Of his 29 publications, 19 are focused on the communities of the deep Gulf of Mexico, and he has participated in 16 research cruises to the Gulf (four as Chief Scientist) using six different RVs, four different ROVs, and three different HOVs (30 dives), as well as the AUV Sentry.

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WITHIN COMMUNITY COMPARISONS OF *LOPHELIA PERTUSA* ALONG THE NORTHERN GULF OF MEXICO CONTINENTAL SLOPE

Brian DeSanti II and Ian MacDonald
Florida State University

Photographic transects were taken in 2009 and 2010 on the Viosca Knoll and Garden Banks lease block of the Department of Interiors (DOI) Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE). The photographic evidence documents the live-to-dead ratios of the deep-sea cold-water coral *L. pertusa* on the VK826, VK906 and GB535 reefs, as well as species composition. Water samples were collected to measure dissolved methane and carbonate coral skeletons were collected from the same reefs and will be analyzed for light hydrocarbons, $\delta^{13}C$, $\delta^{18}O$ and $\Delta^{14}C$ for coral ages. The photographic evidence shows the VK826 reef had 15% live coral coverage in areas that had coral in 2009 and 18% in 2010. VK906 showed 7% live coral coverage in areas containing coral in 2010, while GB535 showed no corals in the photographic evidence in 2010. The methane results show small amounts of light hydrocarbons in the water above the reefs. The $\delta^{13}C$ and $\delta^{18}O$ values are within the expected range for carbonate skeletons of the Gulf of Mexico.Δ ^{14}C results are currently being analyzed at Woods Hole AMS Laboratory.

Brian DeSanti has a Bachelor's degree in marine science from Florida Gulf Coast University and is working on his Master's degree in oceanography at Florida State University. His current study involves the comparison of *Lophelia pertusa* communities in the Gulf of Mexico.

Dr. Ian MacDonald is Professor of Biological Oceanography at Florida State University. He received his Ph.D. from Texas A&M University in 1990. His research interests focus on deep-ocean extreme communities, particularly physical settings that include natural hydrocarbon seeps, gas hydrates, and mud volcano systems. Dr. MacDonald uses satellite remote sensing to locate natural oil releases on the ocean surface; specialty cameras to provide high resolution and time-series imaging of seep fauna and processes at the ocean floor; and GIS techniques for assessing biological communities and geologic features with submersibles and towed cameras.

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HABITAT ASSOCIATIONS OF CORALS AND MEGAFAUNA — THE USE OF SEAFLOOR PHOTO MOSAICS

Pen-Yuan Hsing
Department of Biology, Pennsylvania State University

A method is presented for long-term monitoring of *Lophelia* coral communities in the deep Gulf of Mexico. We describe the use of downlooking photo mosaics at 29 monitoring stations set up during *Lophelia* II project cruises between 2009 and 2010. By repeating mosaics at each station after one year and comparing them, we were able to observe changes in associated fauna. We also describe the advantages of this non-intrusive approach over other experimental methods. For instance, monitoring stations at ship wrecks enabled us to estimate *Lophelia* minimum growth rates that are considerably higher than those obtained through direct manipulation. The process we describe is being used to monitor the impact of the *Deepwater Horizon* disaster on nearby deep coral communities, and can also be applied in the long-term observation of other deep-sea systems.

With an interest in ecology, Pen-Yuan "Pen" Hsing has participated in field research around the world. Whether it is surmounting a cliff to reach an owl's nest in South Africa, running transects in the tropical rainforests of Costa Rica, or measuring leatherback sea turtle nest temperatures in Trinidad, Pen is interested in doing ecological research that will inform conservation efforts. Pen is also interested in science outreach, having designed and presented interactive chemistry demonstrations to people aged from 9 to 90. He is currently conducting graduate research regarding the possible impacts of the *Deepwater Horizon* oil spill on deep-sea coral ecosystems in the Gulf of Mexico. This is done under the direction of Dr. Charles Fisher at The Pennsylvania State University Department of Biology.

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POPULATION GENETIC ANALYSIS OF *LEIOPATHES GLABERRIMA* IN THE GULF OF MEXICO

Dannise Ruiz-Ramos and Iliana Baums
Pennsylvania State University

To provide baseline information for conservation practices we aim to determine the population structure of the black coral *Leiopathes glaberrima* in the Gulf of Mexico (GOM). In the GOM, *Leiopathes* occurs over a wide depth range and provides habitat for other organisms. For this study, samples were collected from sites VK906, VK826 and GC140 during the *Lophelia* II expeditions (2009–2010).

Two lineages of *Leiopathes* were recovered with mitochondrial markers. The co-occurrence of lineages within sites suggested that geneflow rarely occurs between them. To further investigate the potential presence of cryptic species as indicated by the mitochondrial markers, six newly developed microsatellite loci were applied to 75 samples. Only 65% of the multilocus genotypes were unique; thus, asexual reproduction occurs with some frequency. Bayesian clustering algorithms applied to the microsatellite data resolved four clusters. One cluster was found at all three sites while another cluster was shared between VK826 and VK 906. Neither microsatellite cluster identity nor color of colonies correlated with the two mitochondrial lineages. *L. glabberima* is thus a coherent species in the GOM. Future work on additional samples and microsatellite markers will allow us to describe levels of connectivity among *L. glaberrima* stands in the Gulf of Mexico.

Iliana Baums is Assistant Professor of Molecular Ecology in the Department of Biology at Penn State. She received her Ph.D. from the University of Miami, where she used microsatellite markers to look at clonal population structure and geographic variation in the Caribbean elkhorn coral *Acropora palmata*. She completed a post doctoral at the Hawaii Institute of Marine Biology. Her research involves developing and applying molecular tools to understand the consequences of biogeography, population structure, and mating patterns to the survival and evolution of marine organisms.

Dannise Ruiz is a Ph.D. student in biology at Penn State. She received her Master's degree from the University of Puerto Rico at Mayagüez where she studied genetic variation in fire corals with Dr. Nikolaos Schizas. Dannise is currently working on the population structure in black corals of the genus *Leiopathes*.

Click here to view the slide show that accompanied this presentation.

COMMUNITY PHYLOGENETICS OF OCTOCORALS IN THE DEEP GULF OF MEXICO

Andrea Quattrini, Cheryl Doughty and Erik Cordes
Biology Department, Temple University

Peter Etnoyer
NOAA Center for Coastal Environmental Health and Biomolecular Research
Charleston, South Carolina

Octocorals have been historically well documented in the Gulf of Mexico (GOM), but recent cruises to deepwater habitats in the region yielded additional distribution data, including species previously unreported. Although these data sets are improving, data are still lacking on the phylogenetic diversity and assemblage structure of octocorals throughout the GOM. We set out to test the hypothesis that similar habitat types in different areas of the GOM will contain octocoral assemblages with similar phylogenetic community structure. From 2008–2010, octocorals were collected from sites at depths ranging from 300–2,500 m. The mitochondrial *msh1* and *COI+igr1* genes were amplified and sequenced. At least 40 octocoral taxa were documented, including three genera previously unreported in the GOM: *Paragorgia*, *Corallium*, and *Sibogagorgia*. High phylogenetic diversity was found at the shallowest depths (ca. 300–400 m), and high phylogenetic turnover (phylobetadiversity) occurred between < 850 and > 850 m. In addition, non-random phylogenetic community structure was evident. For example, species were more closely related than expected by chance at the deepest sites surveyed. Understanding both the evolutionary and ecological mechanisms that influence deep-sea coral community assembly is imperative to successfully conserve these species, particularly in the face of global climate change and continued oil exploration.

Andrea M. Quattrini is a Ph.D. candidate in Erik Cordes' lab at Temple University. Andrea holds a B.S. in biology from Millersville University and an M.S. in marine biology from the University of North Carolina–Wilmington. Andrea's broad research interests include how evolutionary and ecological forces shape population, species, and community boundaries of corals and associated fishes in the deep sea. Her dissertation research is focused on the population genetics of *Callogorgia americana* and *Paramuricea biscaya* and the community phylogenetics of octocorals in the deep Gulf of Mexico.

Cheryl Doughty is an undergraduate biology major studying at Temple University. She has been working as a research assistant in the Deep-Sea Marine Ecology lab of Dr. Erik Cordes. The projects she has participated in to date include the Phylogenetics of Octocorals in the deep Gulf of Mexico and the Population Dynamics of the Deep-sea Coral Genus *Paramuricea*.

Dr. Erik Cordes (Temple University) has nearly 20 years' experience with deep-water corals and hydrocarbon seep communities and has worked primarily in the Gulf of Mexico for over 10

years. Dr. Cordes's lab combines ecological and molecular techniques to investigate a wide variety of questions centered on these organisms and their habitats. The work on cold-water corals, funded by a four-year grant from BOEMRE and NOAA OER, includes investigations of the habitat preferences of *Lophelia pertusa* and the genetic connectivity of deep-water gorgonian populations in the Gulf of Mexico. Ongoing studies of cold seeps include the biogeographic and bathymetric patterns in tubeworm- and mussel-associated communities and the influence of tubeworm tube-hosted microbial communities on seep biogeochemistry, particularly the sulfur cycle. Dr. Cordes is also involved in the assessment of the impact of the *Deepwater Horizon* incident on the cold-water coral and natural seep communities of the Gulf of Mexico. Of his 29 publications, 19 are focused on the communities of the deep Gulf of Mexico, and he has participated in 16 research cruises to the Gulf (four as Chief Scientist) using six different RVs, four different ROVs, and three different HOVs (30 dives), as well as the AUV Sentry.

Dr. Peter Etnoyer is project lead for NOAA's Deep-Sea Coral Ecology Laboratory at the National Center for Coastal for Coastal Ocean Science (NCCOS) Center for Coastal Environmental Health and Biomolecular Research (CCEHBR) in Charleston, South Carolina. He holds a Ph.D. in coastal and marine system science from Texas A&M University–Corpus Christi, and a Master's degree in coastal environmental management from Duke University. The patterns and processes underlying biodiversity, and the nature of the relationships between deep-corals, their habitat, and associated species are the primary subjects of study in his laboratory.

Click here to view the slide show that accompanied this presentation.

CORAL ECOSYSTEM DIVERSITY IN THE DEEP GULF OF MEXICO: HOST CORAL-INVERTEBRATE SYMBIONT RELATIONSHIPS AND THE GENETIC CONNECTIVITY OF DEEP-SEA CORAL ECOSYSTEMS

T.M. Shank[1], E. Cordes[2], A. Quattrini[2], W. Cho[1], S. Herrera[1], T. Heyl[1], C. Munro[1], P-Y. Hsing[3], A. Demopolous[4], and C. Fisher[3]

[1]Biology Department, Woods Hole Oceanographic Institution

[2]Biology Department, Temple University

[3]Southeast Ecological Science Center, U.S. Geological Survey

[4]Department of Biology, Pennsylvania State University

Deep-sea corals provide habitat structure for an array of species that have developed diverse symbiotic relationships with relative specificities to their host corals. Growing intensities of fisheries and mineral and oil extraction from seamounts and hydrocarbon-rich continental margins place a premium on understanding the processes controlling coral-rich ecosystems which support biodiversity and where the co-evolution of host-associate relationships may constrain genetic connectivity. We examined more than fifteen long-term observation stations of DSC communities in the deep Gulf of Mexico and additional sites ranging from 10 to 200+ miles from the wellhead in the wake of the *Deepwater Horizon* incident. We documented patterns of associative relationships between particular invertebrates and their host corals via imaging, morphological and molecular systematic/phylogenetic approaches and are assessing levels of associate connectivity across hosts and locations inside and outside the Gulf through faunal and time-series larval trap collections. In addition to digital imagery to examine the identity of these associates and their fidelity, more than 720 coral-associated invertebrates (including shrimp, amphipods, anemones, barnacles, and crabs) were sampled for species and coral-relationship determination. We have identified more than 80 coral-community associated morphospecies from six Phyla living on >18 coral hosts, including octocorals, black corals, and scleractinian corals in the deep Gulf of Mexico. Of these 80 morphospecies, coral symbionts are predominantly crustaceans (27 species) and echinoderms (15 species). Coral-associated species hosted only by dead coral skeleton (e.g., barnacles and polychaetes) were also observed. Genetic identifications have revealed fidelity in some groups to be high in some cases (e.g., specific ophiuroid brittle star species only inhabiting specific species of octocoral), suggesting that these symbionts may be obligate to specific species of corals. Differences in coral associate composition varied markedly with depth and biogeographic location within the Gulf, yet show marked similarities with coral-associate composition and relationships in deepwater coral ecosystems around the world. This presentation describes the patterns and diversity of coral symbiotic relationships in the deep Gulf, potential spill impacts on coral-associate relationships, and the genetic connectivity among associates to understand the vulnerability and resilience of these ecosystems.

Dr. Tim Shank is an Associate Scientist in the Biology Department at the Woods Hole Oceanographic Institution. His research interests focus on understanding the evolution of life in the deep sea and the ecological processes responsible for creating and maintaining biodiversity in the oceans. He combines molecular genetic approaches and ecological field studies to understand the conditions and adaptations that allow various species to migrate, evolve, and thrive along the global mid-ocean ridge, seamount systems, and most recently, in the Gulf of Mexico. His genetic approaches are aimed at understanding the evolutionary processes that drive patterns of diversity and connectivity in coral ecosystems have led to burgeoning insights on the co-evolution and co-dispersal of coral hosts and their invertebrate associates. This research has been driven both by the model system that coral hosts and associates provide for fundamental evolutionary biology and by the need to understand the impacts and sustainability of deep-sea fisheries and increasing mineral and oil exploration activities on these deep-water faunas.

Dr. Erik Cordes (Temple University) has nearly 20 years' experience with deep-water corals and hydrocarbon seep communities and has worked primarily in the Gulf of Mexico for over 10 years. Dr. Cordes's lab combines ecological and molecular techniques to investigate a wide variety of questions centered on these organisms and their habitats. The work on cold-water corals, funded by a four-year grant from BOEMRE and NOAA OER, includes investigations of the habitat preferences of *Lophelia pertusa* and the genetic connectivity of deep-water gorgonian populations in the Gulf of Mexico. Ongoing studies of cold seeps include the biogeographic and bathymetric patterns in tubeworm- and mussel-associated communities and the influence of tubeworm tube-hosted microbial communities on seep biogeochemistry, particularly the sulfur cycle. Dr. Cordes is also involved in the assessment of the impact of the *Deepwater Horizon* incident on the cold-water coral and natural seep communities of the Gulf of Mexico. Of his 29 publications, 19 are focused on the communities of the deep Gulf of Mexico, and he has participated in 16 research cruises to the Gulf (four as Chief Scientist) using six different RVs, four different ROVs, and three different HOVs (30 dives), as well as the AUV Sentry.

Andrea M. Quattrini is a Ph.D. candidate in Erik Cordes' lab at Temple University. Andrea holds a B.S. in biology from Millersville University and an M.S. in marine biology from the University of North Carolina–Wilmington. Andrea's broad research interests include how evolutionary and ecological forces shape population, species, and community boundaries of corals and associated fishes in the deep sea. Her dissertation research is focused on the population genetics of *Callogorgia americana* and *Paramuricea biscaya* and the community phylogenetics of octocorals in the deep Gulf of Mexico.

Dr. Walter Cho is a postdoctoral investigator at the Woods Hole Oceanographic Institution. His research interest is the biodiversity, biogeography, and connectivity of marine fauna. Recently, his research has been focusing on the community structure and population dynamics of invertebrate fauna associated with deep-sea corals.

With an interest in ecology, Pen-Yuan "Pen" Hsing has participated in field research around the world. Whether it is surmounting a cliff to reach an owl's nest in South Africa, running transects in the tropical rainforests of Costa Rica, or measuring leatherback sea turtle nest temperatures in Trinidad, Pen is interested in doing ecological research that will inform conservation efforts. Pen is also interested in science outreach, having designed and presented interactive chemistry demonstrations to people aged from 9 to 90. He is currently conducting graduate research regarding the possible impacts of the *Deepwater Horizon* oil spill on deep-sea coral ecosystems in the Gulf of Mexico. This is done under the direction of Dr. Charles Fisher at The Pennsylvania State University Department of Biology.

Amanda W.J. Demopoulos received her B.S. degree in oceanography from the University of Washington–Seattle (1996) and a Ph.D. in biological oceanography from the University of Hawaii–Manoa (2004). After her post-doctoral fellowship at Scripps Institution of Oceanography (2004–2006), she was hired into her current position as a Research Ecologist with the USGS Southeast Ecological Science Center in Gainesville, Florida. Her research program spans from coastal wetlands to deep-sea environments, where she examines benthic community structure and function, including food webs and impacts of natural and anthropogenic disturbance on benthic ecosystem health. Dr. Demopoulos is a principal investigator within the USGS DISCOVRE project and chief scientist for the USGS Mid-Atlantic Canyons OCS project.

Click here to view the slide show that accompanied this presentation.

LOPHELIA II RIGS, REEFS, AND WRECKS SHIPWRECK COMPONENT: 2009 AND 2010 FIELD SEASON RESULTS

Daniel J. Warren, Robert A. Church, Robert F. Westrick
C & C Technologies, Inc.

Following the 2008 reconnaissance cruise, two additional shipwreck documentation cruises were conducted in 2009 and 2010 as part of the *Lophelia* II Study Shipwreck Component. During these cruises a total of seven shipwreck sites were visited by the research team. This presentation will briefly discuss the findings of these two cruises. The discussion will included a summary of the investigation objectives, the wreck sites visited, and operations undertaken at each site. A review of preliminary findings and current research focus will be included in this presentation.

Daniel J. Warren is a Senior Marine Archaeologist and the Houston Assistant Geosciences Manager at C & C Technologies, Inc. (C & C). He has worked as a professional archaeologist for over 20 years and is trained in both terrestrial and underwater archaeology, as well as material culture analysis. Mr. Warren has worked on shipwreck projects in Bermuda, Australia, and the United States. Since 1998, he has been working at C & C interpreting high-resolution geophysical data for shipwreck investigations, oil and gas surveys, search and recovery operations, and cable route studies in the inland waters of the U.S., the Gulf of Mexico, South America, and Asia. Mr. Warren has worked on numerous oil and gas exploration projects and written over 100 archaeological assessments based on high-resolution geophysical data, diver acquired video data, or ROV video data. In his capacity as a marine archaeologist at C & C, Mr. Warren has spent several hundred hours offshore monitoring diver and ROV investigations of potential archaeological targets for the oil and gas industry. Mr. Warren is one of two C & C archaeologists recognized by the oil and gas industry and the BOEMRE as being among the most experienced deepwater marine archaeologists working in the Gulf of Mexico. Mr. Warren and his colleagues at C & C have worked to expand the multi-disciplinary investigations of deepwater shipwrecks in the Gulf of Mexico. This multi-disciplinary approach for deepwater shipwreck investigations is intended to provide a better understanding of deepwater shipwreck formation and distribution processes. Mr. Warren has authored or co-authored several professional publications and presentations related to deepwater shipwrecks and deepwater archaeological investigation methodology.

Robert A. Church is a Senior Marine Archaeologist at C & C headquarters in Lafayette, Louisiana. He has over 17 years' professional experience in underwater archaeology and historical research. He has served as a marine archaeologist with C & C for the past 12 years. He received his M.A. in maritime history and nautical archaeology from East Carolina University in 2001. Mr. Church has worked on submerged archaeological projects in Florida, North Carolina, Virginia, Maryland, Bermuda, and various locations in the Gulf of Mexico. He has participated as a principle investigator on 10 deepwater expeditions since 2001. He has been the chief scientist on three expeditions, which included the investigation of 11 deepwater shipwrecks. He has conducted field investigations of at least 14 deepwater shipwrecks, which included multiple year investigations of some of the most intriguing deep historic shipwrecks known in the Gulf of Mexico (i.e. *U-166*, *Robert E. Lee*, *Gulf Penn*, the Green Lantern Wreck, the Viosca Knoll Wreck, the Ewing Banks Wreck, the Mardi Gras Wreck, etc). Additionally, he has been involved with the investigation and documentation of numerous chemosynthetic community sites, deepwater unexploded ordnance, and other deepwater targets. While working for C & C, Mr. Church has been the archaeological principle investigator and authored reports on over 200 marine remote sensing surveys.

Robert F. Westrick is a marine archaeologist for C & C, one of the world's leading companies in deep-water geophysical survey. In 2008 and 2009, he was an archaeologist on the Reefs, Rigs, and Wrecks Project. Mr. Westrick holds a Master's degree in maritime history and nautical archaeology from East Carolina University. He is a registered professional archeologist. Westrick has worked on numerous shipwreck projects over the past decade ranging from remote sensing surveys to complete excavation and mapping investigations. In 1997, he completed the first archaeological survey of the U.S.S. *Peterhoff*, a Civil War steamship lost off the coast of North Carolina. *Peterhoff* was the first shipwreck ever to be placed on the National Register Historic Places. Despite that distinction, no prior detailed archaeological survey had ever been conducted on the site. In addition to his work on various Civil War shipwrecks in North Carolina and Virginia, Westrick has worked on projects ranging from 17th-century Spanish merchant ships off Bermuda to 19th-century schooners in Lake Erie.

Click here to view the slide show that accompanied this presentation.

LOPHELIA II: EDUCATION AND OUTREACH

Liz Goehring
Pennsylvania State University

This presentation highlights the multiple education and outreach efforts underway as part of the *Lophelia* II project, including development of a problem-based learning (PBL) curriculum for high school students, NOAA OER website coverage for signature explorations, Past Foundation educational materials on ship wrecks research, and documentary video production distributed through YouTube and other channels. The presentation also discusses additional outreach efforts conducted as a result of the *Deepwater Horizon* Spill.

Liz Goehring has a background in ecology, education, and systems engineering, and is an Education Outreach Specialist at Pennsylvania State University. She has worked with the deep-sea science community for the past 10 years, helping create problem-based curricula on deep-sea science and online tools such as Student-Scientist Forums and Student Experiments at Sea programs for K–12 audiences worldwide. She has also specialized in developing teacher professional development focused on fostering authentic scientific inquiry in the classroom.

Click here to view the slide show that accompanied this presentation.

PAST, CURRENT AND FUTURE DIRECTIONS FOR BOEMRE STUDIES ON DEEP GULF ECOSYSTEMS (AND WHERE DID THE OIL GO?)

Chuck Fisher
Department of Biology
Pennsylvania State University

Charles (Chuck) Fisher is a Professor and Chair of the Graduate Program in Biology at the Pennsylvania State University. He has participated in 57 oceanographic research expeditions, serving as chief scientist on 26 of them. Fisher became involved in research on deep-sea hydrothermal vent ecosystems shortly after their discovery in the late 1970s and in research on the hydrocarbon seeps of the Gulf of Mexico in 1986. He has published over 120 peer-reviewed papers on the biology of hydrothermal vents and cold seeps. He served as the chair of the US NSF Ridge 2000 program until 2005 and is currently the co-chair of the InterRidge Biology working group and a member of the Steering Committee for the Census of Marine Life ChEss (Chemosynthetic Ecosystems) program.

Click here to view the slide show that accompanied this presentation.

SESSION 2C

SPILL RESPONSE TECHNOLOGY

Chair: Darice Breeding, BOEMRE

Co-Chair: Barret Fortier, BOEMRE

THE *DEEPWATER HORIZON*: IMPACT ON DISPERSANT USE POLICIES

James Staves
Environmental Protection Agency Region 6

As the Emergency Preparedness Coordinator for EPA Region 6, Jim Staves is responsible for coordinating the emergency preparedness efforts of EPA with other agencies within, or adjoining the Region 6 area. In his previous position of Director of the Emergency Preparedness Center at the University of Texas at Dallas, he was responsible for developing and leading multi-sector efforts to expand the use of innovative information technologies in emergency management programs. In former positions at EPA Region 6, he was a Federal On-Scene Coordinator, Chief of the Contingency Planning Section, and the alternate EPA Co-chair of the Regional Response Team.

Click here to view the slide show that accompanied this presentation.

ALTERNATIVE RESPONSE TECHNOLOGY (ART)

James L. O'Brien
O'Brien's Response Management, Inc.

During the *Deepwater Horizon* spill event, a dedicated Alternative Response Technology (ART) program was established. The ART program and organization are described and a timeline of key events during the response presented. The ART "triage process" of evaluating technology submittals is reviewed and a list of successful technologies field tested is presented.
The ART program sponsor was the United Area Command (UAC) in New Orleans.

The stated objectives:

- Evaluate use of new, improved and emerging technologies to address operational needs
- Establish a system to gather and categorize new ideas
- Evaluate and rank technologies within specific categories
- Prioritize technologies to address operational needs
- Conduct tests and provide feedback to the UAC
- Coordination with Federal Interagency Alternative Technology Assessment Program (IATAP)

Sources of the ideas included the following:

- ART database (direct submission on the Internet or through the BP call center)
- Operations and field-driven
- "Open House" meetings held at parishes
- Louisiana Business Emergency Operations Center
- Public Information Emergency Response (PIER) System used before deployment of the ART database

A summary and future plans are included in the slideshow presentation.

Jim O'Brien has over 40 years of experience in oil spill and crisis management. He is presently Chairman Emeritus, O'Brien's Response Management, Inc. and has been spill response coordinator, response consultant, and/or technical advisor to petroleum shipping companies, exploration and production companies, and industry cooperatives. He also has provided assistance to industry in numerous training programs and spill cleanup development efforts. He has been involved with significant spill events in the Gulf of Mexico, nationally, and internationally, including the *Deepwater Horizon*, Ixtoc I wellhead incident (Bay of Campeche), Gulf of Arabia war-related spills in Desert Storm and again in the Iraq war, Exxon Valdez, and other major spill events involving oil tankers both in U.S. and international locations.

Click here to view the slide show that accompanied this presentation.

DEEPWATER HORIZON SPILL RESPONSE TECHNOLOGIES

LCDR Octavia Ashburn
U.S. Coast Guard

Lieutenant Commander Octavia Ashburn is a 1995 graduate of the United States Coast Guard Academy. She is currently a port operations analyst at the U.S. Coast Guard Research and Development Center. She has served full tours on three Coast Guard cutters and has spent time on two Navy destroyers and three additional Coast Guard cutters. Her career background is operations, and she has experience in Maritime Law Enforcement, Counternarcotics, Alien Migration Interdiction, Aids to Navigation and Spilled Oil Response. She has a M.S. in organizational management and specializes in guiding Coast Guard units through complex transitions.

Click here to view the slide show that accompanied this presentation.

BUREAU OF OCEAN ENERGY MANAGEMENT, REGULATION AND ENFORCEMENT OIL SPILL RESPONSE RESEARCH AND ITS APPLICATION DURING *DEEPWATER HORIZON*

Joseph Mullin
Program Manager, Oil Spill Response Research
Engineering and Research Branch, BOEMRE

Timely and effective action is critical when responding to an oil spill. Conducting an effective oil spill research program means that the best available technologies are identified, developed, tested, and made available to combat oil spills that may occur in the marine environment. For more than 20 years, the U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly the Minerals Management Service (MMS), has maintained a comprehensive, long-term research program to improve oil spill response technologies.

BOEMRE research projects cover a wide spectrum of oil spill response issues and include laboratory, meso-scale and full-scale experiments, as well as participation in at-sea trials. Current major topic areas include remote sensing and detection, mechanical containment and recovery, chemical treating and dispersants, and operation of Ohmsett—the National Oil Spill Response Test Facility, located in Leonardo, New Jersey. Results of BOEMRE research are directly used as decision support tools by federal and state government agencies in approving specific response techniques. Results from recent research will be presented that include:

- Development of a portable, easy-to-operate, aerial sensor to detect and accurately map the thickness and distribution of an oil slick in coastal and offshore waters in real-time
- Use chemical herders to improve *in situ* burning of oil slicks at sea
- Effectiveness of dispersants on crude oils produces on the U.S. Outer Continental Shelf
- Ability to effectively recover oil following dispersant application
- New instrumentation for monitoring the efficacy of dispersant operations
- New American Society of Testing and Materials (ASTM) skimmer test standards

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Joseph Mullin has been the Program Manager for the Bureau of Ocean Energy Management, Regulation and Enforcement's (formerly MMS's) Nationwide Oil Spill Response Research (OSRR) Program for 20 years. He is responsible for development of research priorities for oil spill response and for the management of contractual research. Joe is also responsible for the operation and management of Ohmsett—the National Oil Spill Response Research and Renewable Energy Test Facility, located in Leonardo, New Jersey. Under Mr. Mullin's direction, BOEMRE's oil spill response research program has successfully initiated, coordinated and managed more than 150 research projects and technical assessment studies and he has authored or co-authored 145 scientific papers, technical articles and peer-reviewed publications.

Click here to view the slide show that accompanied this presentation.

SESSION 2D

MARINE ARCHAEOLOGY — MODELING OF SURVIVING PREHISTORIC LANDFORMS ON THE OCS

Chair: Brian Jordan, BOEMRE

Co-Chair: David Ball, BOEMRE

ARCHAEOLOGICAL APPROACHES TO IDENTIFYING SUBMERGED CULTURAL LANDSCAPES AND ANCIENT NATIVE AMERICAN ARCHAEOLOGICAL SITES IN SOUTHERN NEW ENGLAND

David S. Robinson
Fathom Research, LLC

Click here to view the slide show that accompanied this presentation.

PALEOLANDFORMS AND PREHISTORIC SITE POTENTIAL ON THE MID-ATLANTIC OCS

Daria Merwin
Stony Brook University

Predictive modeling and reconstruction of paleolandforms that are now submerged on the continental shelves of the U.S. and elsewhere around the world may help guide us to places where we are most likely to find inundated prehistoric sites that have survived sea level rise. While delineating areas of high sensitivity for the presence of archaeological sites may maximize our chances of discovery, I suggest that for most areas of the continental shelf in the Mid-Atlantic which could have been occupied in the past, there is some potential for prehistoric deposits unless proven otherwise. In this paper, I present a case study from the New York Bight, where an assemblage of more than two hundred lithic artifacts (from possibly as early as 10,000 B.P. through as late as 4000 B.P.) known as the Corcione collection was accidentally removed from its underwater context by dredging. The Corcione case study suggests that broad areas of the continental shelf beyond those with obviously high sensitivity may yield important archaeological data. Thus, while it is important to recognize that different portions of the continental shelf will have variable likelihoods for the presence of prehistoric deposits, it may be prudent to err on the side of over-estimating archaeological site sensitivity, with the exception of those areas with obviously low or no potential, such as areas where the water depths are sufficiently deep that the shelf in that location was not exposed when people arrived in the area, or where prior thorough disturbance can be well documented.

Daria Merwin received her M.A. degree from the Nautical Archaeology Program at Texas A&M University and her Ph.D. in anthropology (archaeology) from Stony Brook University. Her research focuses on early Native American sites, and specifically, how underwater archaeology of submerged landscapes can contribute to our understanding of topics such as the origins of aquatic adaptations, and continuity in subsistence and settlement patterns despite changing environmental conditions over the course of the Holocene. Daria directed field work at sites in the Atlantic Ocean off Sandy Hook, New Jersey, and in Croton Bay, New York, which resulted in the discovery of submerged prehistoric artifacts. She is currently a Research Assistant Professor at Stony Brook University.

Click here to view the slide show that accompanied this presentation.

MODELING OF SURVIVING PREHISTORIC LANDFORMS ON THE FLORIDA ATLANTIC OCS

Michael A. Arbuthnot
Southeastern Archaeological Research Inc. (SEARCH)

Abstract

Research was conducted in 2010 for a BOEMRE-sponsored study as part of the Prehistoric Site Potential and Historic Shipwrecks on the Atlantic Outer Continental Shelf project. One objective of the study was to evaluate current theories on prehistoric settlement patterns, paleoshoreline positions, relative sea level rise, and regional geology in order to identify potential areas on the Atlantic OCS where submerged prehistoric sites might be located. SEARCH, Inc. developed the Florida Atlantic OCS component of the study.

The intent of this presentation is to explain relevant past and present geologic and physiographic changes within the study area as global sea levels rose since the LGM, ca. 20,000 B.P. Understanding the evolution of the shelf and coastal geomorphic features provides insight into the potential preservation and destruction of submerged prehistoric sites, and provides a model for determining high, medium, and low site potential on Florida's continental shelves.

Slide 1: Intro: Modeling of Surviving Prehistoric Landforms on the Florida Atlantic OCS

- Research was conducted in 2010 for a BOEMRE-sponsored study as part of "Prehistoric Site Potential and Historic Shipwrecks on the Atlantic Outer Continental Shelf" project.
- One objective of the study was to evaluate current theories on prehistoric settlement patterns, paleoshoreline positions, relative sea level rise, and regional geology in order to identify potential areas on the Atlantic OCS where submerged prehistoric sites might be located.
- SEARCH developed the Florida Atlantic OCS component of the project.

Slide 2: Study Area and Intent

- The congressional mandate exists for the protection and management for cultural resources on the Outer Continental Shelf (OCS). This mandate is set forth in the National Environmental Policy Act of and the Archaeological and Historic Preservation Act of 1974. The National Historic Preservation Act requires federal agencies to protect historic and cultural resources which include prehistoric sites that have become submerged due to the global and local rise in sea level.
- As a federal agency, BOEMRE must protect the significant archaeological and historic sites that may be impacted by its activities.
- In keeping with its mandate to protect archaeological and historic cultural resources, BOEMRE commissioned this study to review its current practices and procedures.
- The study area is depicted here.

- The intent of this presentation is to explain relevant past and present geologic and physiographic changes within the study area as global sea levels rose since the LGM, ca. 20,000 B.P.
- Understanding the evolution of the shelf and coastal geomorphic features provides insight into the potential preservation and destruction of submerged prehistoric sites, and proves a model for determining high, medium, and low site potential on Florida's continental shelves.

Slide 3: The Florida Platform

- Continental shelves around the world are remarkably dynamic; thus recreating past submerged landscapes has been an adopted goal of archaeological, geological, and geomorphological researchers.
- The Florida Platform extends southward from the North American continent and separates the Atlantic Ocean from the Gulf of Mexico. Since its formation, it has been alternately flooded by the shallow seas and salt lakes or has been sub-aerially exposed.
- The Florida peninsula represents the exposed portion of the platform, and the remainder extends offshore well into the Gulf of Mexico and, for a short distance, into the Atlantic Ocean.

Slide 4: Florida's Continental Shelf

- Contemporary depths of the ocean floor around Florida are shown. The tectonic stability, porous limestone bedrock, and thin sediment cover of the Florida Platform during the last 15,000 years provide an ideal physical environment for the reconstruction of paleoshorelines.
- As early as the 1960s, researchers speculated about the possibility that prehistoric peoples inhabited the now-inundated Atlantic Continental Shelf of Florida.
- The modern Florida Atlantic Continental Shelf is a wave-dominated, low gradient feature with a well-defined shelf/slope break.
- The modern sedimentary cover is dominated by quartz within the northern portion, and is more carbonate-enriched to the south, while the inner shelf topography is characterized by shoreface sand ridges on the north and relict reefs on the south.
- The shelf width throughout the study area varies greatly from 115 km off Jacksonville to 2 km off southern Palm Beach County.

Slide 5: Anastasia Formation—prominent geological formation

- The Anastasia Formation is a multi-cyclic deposit formed during former transgressions of the sea.
- At the time the Anastasia was deposited, 130,000–100,000 B.P., the earth was experiencing an interglacial, and sea level was approximately 6 m higher than that of today.

- From Jacksonville to West Palm Beach, lithified beach deposits of the Anastasia Formation are sporadically exposed. Major outcrops of the Anastasia Formation occur on the east coast of Florida from St. Augustine to Ormond Beach, Cocoa to Eau Gallie, and Stuart to Boca Raton.
- The outcrops that still remain form offshore reefs consisting of bedrock ledges with varying amounts of living and dead coral, and are separated by intervals of barren, sandy bottom.
- Within the North/Central Florida Shelf, Holocene cover is generally thin to absent, and is seldom thicker than 5 m, except beneath the linear or cape associated shoals such as Cape Canaveral.
- Peats obtained by vibra-coring strongly suggest that back-barrier environments are preserved within the shelf stratigraphic section in this area. Radiocarbon dates from peats show Holocene and Late Pleistocene ages, which would be contemporaneous with early populations if they existed here. For this reason, there is a high potential for preserved sites or artifacts in the Cape Canaveral area (see star).

Slide 6: Southern Florida Shelf

- The Southern Florida Shelf north of the Keys consists of the portion of the shelf extending from Palm Beach County to Key West. It is a narrow section consisting of four shelf environments: sand flats and karst; sand flats and coral reefs; sand flats, hardgrounds, and coral reefs; and tidal sand flats and ridges, hardgrounds, and coral reefs (Finkl and Andrews 2008)
- .*In-situ* carbonate skeletal sands have accumulated up to 5 m in the topographic lows between the reefs. These areas presumably have high preservation potential for cultural resources, as little sediment exchange occurs between the mixed terrigenous/carbonate sands of the beach zone and the offshore carbonate sands.
- The potential for preservation of sites on this subaerially exposed pre-Holocene surface would be high. As the seaward reefs build up, the back reef areas become flooded by low-energy lagoonal waters. Further, carbonate-producing organisms generate sediment, which would slowly bury man-made artifacts or sites. Since most wave energy is expended on the shelf edge reef, it would be unlikely that the lagoonal sedimentary sequence would be disturbed to any significant depth by high energy events.

Slide 7: Florida's Atlantic Submerged Prehistoric Sites

- Determining a proper sea level curve is difficult for any region.
- In a previous study of the current project area, Science Applications, Inc. (1981) developed a regional sea level curve specific to the Atlantic Coast, south of Cape Hatteras to determine the exact position of sea level at any time during the last 20,000 years AND approximately how long portions of the OCS were exposed and potentially inhabitable.
- During the brief Clovis florescence from 13,100 to 12,800 calendar years before present, sea level rose nearly 25 m, from roughly 75–50 m, which has profound implications to

land use, resource distribution, and resource exploitation by Early Paleoindians (Balsillie and Donohue 2004).

- The figure illustrates the changing coastline of Florida over the past 10,000 years and depicts coastal archaeological sites.
- The rate of sea level rise is a major factor determining the severity of erosion during shoreface retreat, and as a consequence the preservation potential of Late Quaternary sediments and any contained sites (Belknap and Kraft 1981).
- More important archaeologically are those preserved terrestrial or fresh water features indicative of the actual Pleistocene landscape inhabited by the early human arrivals. Such features can include buried river and stream channels, karst features and more developed sinkholes, inplace soils, peats, tree stumps, higher elevation rock outcrops, and other similar landform features.
- More important than sea level rise in the potential for site preservation is the configuration of the topography on the Continental Shelf prior to transgression (Belknap and Kraft 1985). If a site is located and later buried in a topographic position that will not be eroded during transgression, it will be preserved under the ravinement surface.

Slide 8: Prehistoric Settlement Patterns

- Native American land use is predicated on such factors as topography, access to water, soil drainage, and resource availability. Specifically, elevated and well-drained landforms were often preferred for habitation sites. Availability of raw materials, such as stone for the manufacture of tools, has influenced Native American settlement, as has the proximity and direct access to water.
- Water—a BIG draw. Within Florida, there are numerous types of water sources, including streams, rivers, wetlands, ponds, lakes, springs, and oceans, and these sources proved important as a drinking source for humans and the terrestrial animals they hunted, as a source of various edible aquatic species, as well as for water travel and bathing.
- Today, Florida's coasts support the state's most densely populated areas, and Native Americans also aggregated along the shore.
- The image on the left shows all terrestrial archaeological sites with Native American artifacts within one mile of the present coastline, as well as offshore submerged sites (n=1,014).
- The image on the right illustrates inundated or partially inundated sites in the Atlantic and one mile inland (n=68).
- Because the inundated portion of the shelf is an extension of the Coastal Plain, it is asserted that settlement patterning along the present terrestrial coastline should be mirrored in submerged settings of the Coastal Plain.
- Unlike the northeast Gulf of Mexico, there are no major paleochannels extending onto the Florida Continental Shelf; however, two offshore springs have been mapped on this side of the state. The two Atlantic Coast submarine springs include the Crescent Beach Spring, which is a short distance off the coast of southern St. Johns County, and Red Snapper Sink, which is about 30 km off the coast, east of the boundaries of St. Johns and Flagler counties (Rosenau et al. 1977).

- Both of these areas represent high-probability locations for encountering submerged cultural resources.

Slide 9: Geological Considerations of Sea Level Rise

- Before 7000 B.P., the rate of sea level rise was too great for the prolonged stabilization of barrier islands. The stabilization of barrier islands is important because the lower topographic areas behind these islands never infill with marsh, but instead develop into open-water lagoons. Marshes in this environment are restricted to low-energy, narrow fringes along the lagoon/estuarine shoreline where they are protected from wave erosion (SAI 1981). This environment produces a highly productive backbarrier and lagoonal flats with substrates beneficial to mollusks, sea grasses, mangroves, fish, and numerous other species. More importantly, this area would have provided an attractive location for habitation.
- The low energy level combined with the sediment trapping and sediment stabilizing effects of salt grass and mangroves would allow for the subsequent preservation of prehistoric sites and their protective estuarine muds. These sites and estuarine muds could lie buried beneath the active Holocene sands on the shelf during continued sea level rise and landward barrier island movement; recovery of peat during coring on the Continental Shelf could indicate potential preservation.
- Geological considerations are important to the understanding of site preservation and/or destruction. Factors such as wave and current action are paramount to the preservation of submerged resources. Recognition of such off-shore geological features as springs and sinks can aid in the detection of submerged sites as well.

Slide 10: Submerged Resources Sensitivity Zones

- Generally speaking, most of the Florida Atlantic Continental Shelf is low and sloping, and therefore would have been dominated by erosional transgression—particularly in the North/Central Florida Shelf. Such conditions would afford a low potential to preserve archaeological sites that may have existed.
- However, there are local settings within this region that would have experienced a depositional transgression, such as cape-associated shoals, nearshore linear shoals, the mainland side of lagoons, and along the banks of estuaries (SAI 1981:I-57, I-59).
- The carbonate-dominated Southern Florida Shelf also exhibits preservation potential for underlying Pleistocene substrate due to its physically hard character and reef development, resulting in a low energy wave environment. Therefore, sites may have survived in low energy environments such as the marshes of a delta or lagoon, or tidal flats fronting the ocean, since such sites often subside into the mud and become buried (Gagliano et al. 1982, Gagliano 1984).
- Three sensitivity (probability) zones have been defined for identifying submerged prehistoric sites on the Florida Atlantic Continental Shelf. These zones include: (1) a high sensitivity area where archaeological sites are most likely to occur; (2) a medium

sensitivity area where sites are less likely to occur; and (3) a low sensitivity area where sites are unlikely to occur.

Zone 1 – The High Potential Sensitivity Zone: This zone includes the area that extends from the outer edge of the shoreline as it was exposed at 8000 B.P. to the present shoreline. It dates from the Early to Middle Archaic periods. This zone is found at depths of 10 m and less. The present archaeological record shows a higher incidence of deposits of this time period along the coastal strand than earlier sites dating to the Paleoindian period. This area does not extend very far from the present shoreline and exhibits a high probability for yielding deposits from seasonal camps dating to the earlier part of the Archaic period. Included within Zone 1 are areas around the two known Atlantic Coast submerged spring sites (Crescent Beach Spring and Red Snapper Sink).

Zone 2 – The Medium Potential Sensitivity Zone: This zone includes the area between the 8000–12000 B.P. shorelines. Sites affiliated with Zone 2 would date to the Pleistocene and Early Holocene. This stretch of the Continental Shelf was last exposed during the Paleoindian period, and there is very little archaeological evidence of occupation along the Atlantic Coast during this period based on terrestrial data. During this period, most Native American settlements in Florida were tethered to karstic areas where springs and sinks were present and where raw material for use in stone tool production was prevalent. Although two sinks are known to be submerged in the Atlantic Ocean off the coast of southern St. Johns and northern Flagler counties, these two water holes lacked the silicified Tertiary-age limestone that would have been sought as a raw material for tool production. Thus the lack of locally available cryptocrystalline lithic raw material might have deterred prolonged Atlantic Coast habitation during this early period in Florida prehistory; although the presence of minimally used transitory camps within Zone 2 remains a distinct possibility. Further substantiating the reduced potential for offshore\ Paleoindian period sites along Florida's east coast is the minimal number of Paleoindian projectile points reported for the 12 Florida counties that front the Atlantic Ocean. Specifically, only nine Paleoindian points have been reported from these 12 counties (PDBA 2009), and this sparse number of points suggests that Paleoindian land migrations passing through these present coastal counties were minimal. However, the use of small watercraft by early Native Americans and the potential for long distance coastal migrations have been raised by many archaeologists (e.g., Anderson and Gillam 2000; Faught 2008); thus, it remains possible that traversing the present Atlantic Coast was not necessary to gain access to now-submerged offshore areas.

In addition to examining the potential for submerged Paleoindian deposits within Zone 2, later sites must also be considered. More recent deposits dating ca. 10,000–8000 B.P. represent another possibility for offshore submerged resources in Zone 2 (as well as in Zone 1). As Zone 2 is largely characterized as the area of exposed shoreline dating from 8000–12000 B.P., a time when Florida's Atlantic Coast is assumed to have been minimally populated, it was only shortly after this period that the first substantial occupation of Florida's east coast is documented. Namely, the Windover Pond Site, a mortuary pond in Brevard County, dates to about 7400 B.P. Excavations from this unique site portray a sedentary society that apparently had a restricted mobility range and ceremonious mortuary practices. Although this site post-dates 8000 B.P., other such charnel ponds from earlier periods might exist beneath the ocean's waters. Depths for this zone are from 10–40 m.

Zone 3 – The Low Potential Sensitivity Zone: This zone extends from the 12000 B.P. to the 16000 B.P. shorelines, and the probability of archaeological sites occurring in this zone is considered very low. Any cultural material identified during this period, however, would be considered pre-Paleoindian and of significant value to the archaeological community, based on their presumed antiquity and their ability to shed significant insight on the location and timing of early migration routes. Depths greater than 40 m are within this zone.

Slide 11: Past Underwater Archaeological Efforts

- Underwater archaeological investigations along Florida's Gulf Coast have successfully yielded <u>early</u> submerged cultural deposits. To the contrary, only one offshore submerged archaeological site has been identified on Florida's Atlantic Coast. This site has an intact Early Archaic component and Pleistocene-era megafauna, and is referred to as the Douglas Beach Site (8SL17).
- The site was found 200 m off the coast in shallow waters (2–6 m in depth) approximately 6 km south of Fort Pierce Inlet (Murphy 1990).
- The site was associated with a peat deposit underlain by gray-green clay, and the occurrence of this underlying clay deposit might signify the type of sediments where other submerged sites exist.
- Late Archaic components have been identified at the Douglas Beach Midden, where, in addition to its Early Archaic component, the site yielded a Newnan point and sharpened wooden stakes that dated to Late Archaic (4,630 +/- 100 years) at about 7 meters depth (Cockrell and Murphy 1978; Pepe 2000).
- Last year an avocational collector recovered a Paleoindian Clovis projectile point from the site.
- According to Dunbar, Douglas Beach is similar to the so-called Melbourne bone bed. The only trouble is that the Melbourne bone bed is not a unified temporal unit and fossil different sites may range from Sangamon to late Pleistocene age. Some fossil sites are likely much too old to have a Paleoindian association, yet others are young enough for a potential association.
- Moreover, the Apollo Beach (Warren 1968) and Venice Beach sites (Koski 1989) both yielded water worn ceramics, in addition to shell tools and chipped stone artifacts.
- The bottom line is that, although the Florida Atlantic coast has yielded much, it has produced artifacts and so we know it has potential.

Slide 12: Past Underwater Archaeological Efforts

- Our objective in this study was to evaluate the potential for encountering intact cultural deposits in the offshore areas that comprise the Florida Atlantic Outer Continental Shelf and to offer a mapped reference that divides the acreage into areas of high, moderate, and low archaeological potential.
- The application of this model is intended to help assure the avoidance or management of such submerged resources.
- As mentioned, the potential for submerged cultural deposits is higher closer to the present shoreline and is significantly reduced within the lower elevated areas further from the present shoreline.
- It is recommended that …
  - All available data, including seismic and core data that have been previously collected from any lease parcel in question be reviewed. This information can provide the geological history and its archaeological potential of the study area prior to fieldwork.
  - High-resolution shallow seismic profilers are the primary instruments used in locating relict landforms with a high probability for associated prehistoric sites on the Continental Shelf.
  - The systematic analysis of core sediment samples can provide a basis for distinguishing cultural deposits from natural deposits, or paleosediments.
  - If high-probability areas are identified, additional (or initial) detailed seismic profiling and coring would be necessary to locate preserved sites in the high-probability areas.
  - In addition, the relative shallow nature of the high- and medium-probability zones within the study area would allow for diver investigation.
- It is recommended that prior to future work along Florida's Atlantic Continental Shelf, the sensitivity model be reviewed. If proposed work requires impacting the ocean's base within the high or medium sensitivity zones, it is recommended that a maritime archaeologist assess the area through coring or a means most suited to the recovery of cultural resources, should they exist.
- The intensity of the testing should increase within areas that exhibit the greatest potential for containing intact deposits, such as around submerged springs, at locations of comparatively higher elevation, at areas with intact peat deposits, at areas where gray-green clay has been identified (such as at the submerged site of 8SL17 and South Alabama riverine settings where such sediments have been documented in association with Pleistocene megafauna).

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THE INUNDATED LANDSCAPE FROM FLORIDA'S WEST COAST TO THE LGM SHORELINE: RECENT INVESTIGATION OF BURIED FEATURES AND POTENTIAL EARLY HUMAN SITE LOCATIONS

J.M. Adovasio and C. Andrew Hemmings
Mercyhurst Archaeological Institute, Mercyhurst College

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RECONSTRUCTED LANDSCAPES: PRELIMINARY RESULTS FROM THE NORTHWESTERN GULF OF MEXICO

Patrick Hesp and Amanda Evans
Geography and Anthropology, LSU

Brooks Ellwood, Sophie Warny, Graziela da Silva, and Barun sen Gupta
Geology and Geophysics, LSU

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MODELING PREHISTORIC LANDSCAPES ALONG THE PACIFIC COASTLINE: TWO CASE STUDIES FROM OREGON AND BAJA CALIFORNIA SUR

Loren G. Davis
Oregon State University, Department of Anthropology

Archaeological assessments on the Pacific Outer Continental Shelf (POCS) of western North America must begin with a clear understanding of late Pleistocene to middle Holocene-aged paleolandscapes now submerged beneath post-glacial transgressive sea levels. Fundamentally, best approaches to paleocoastal landscape reconstruction include high-resolution bathymetric data coupled with relative sea level curves. In contrast with the Atlantic and Gulf of Mexico regions, efforts to reconstruct paleolandscapes on the POCS must integrate the cumulative effects that the Cascadia Subduction Zone and other near shore neotectonic systems had on relative sea level at local and regional scales. With an appropriate paleolandscape model in place, efforts to predict the distribution of submerged archaeological sites on the POCS can be facilitated through the construction of a Geographic Information Systems model that displays the potential distribution of archaeological sites through time on a changing POCS coastal landscape. Two case studies are presented that highlight elements of paleolandscape reconstruction and underwater archaeology practiced in pursuit of finding early submerged sites.

Loren Davis is an Associate Professor of Anthropology at Oregon State University and maintains a professional consulting practice—Davis Geoarchaeological Research. He received his Ph.D. in anthropological archaeology and Quaternary geology in 2001 from the University of Alberta. Davis has directed numerous archaeological surveys and excavations throughout western North America and is Vice Chair of the Geological Society of America's Archaeological Geology Division and a past Co-Organizer of the Society for American Archaeology's Geoarchaeology Interest Group. Davis has authored numerous peer-reviewed publications on archaeological and geoarchaeological topics of western North America, 22 of which focus specifically on the early prehistory and geoarchaeology of the modern Pacific coast and POCS. These publications address issues of paleolandscape reconstruction, paleoceanographic reconstructions, human-environmental interactions through time, prehistoric lithic technology and settlement patterns, the geoarchaeology of coastal paleoenvironments since the last glacial period, and GIS-based paleolandscape modeling.

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SESSION 2E

DEEP-SEA CORALS — *LOPHELIA* II: USGS

Chair: Bill Shedd, BOEMRE

Co-Chair: James Sinclair, BOEMRE

LOPHELIA II: OVERVIEW AND PROGRESS

Steve W. Ross
University of North Carolina–Wilmington

Lophelia I investigations in the Gulf of Mexico (GOM) helped resolve some basic questions about habitat distributions, species occurrence and the general biology of deep water (aphotic) coral and hardground communities on the continental slope of the northern GOM. For example, we know the kinds and relative abundances of fishes and larger invertebrates that co-occur with deep coral reefs. We know that GOM *Lophelia* are genetically somewhat isolated from *Lophelia* in the the rest of the Atlantic and that *Lophelia*-associated bacterial communities differ among sites. Water depth, water temperature, substrata, currents, and food availability may play important roles in the ecology of these systems. Because there remained much to learn about the fundamental processes that structure, link, and constrain these uncommon deep-water habitats, USGS began a renewed partnership (*Lophelia* II) with BOEMRE, NOAA, and a BOEMRE contractor to expand studies on deep-sea coral and reef habitats in the GOM. Starting in 2008 and ending in 2011, we used a combination of 1) focused studies and *in situ* experiments at a few sites, and 2) limited exploration and description of additional sites that included the eastern GOM. Detailed objectives in each of the USGS team's topical study areas follow.

Habitat Mapping and Discovery

The overall goal was to map, in greater detail, existing deep-sea coral areas in the GOM and to discover new areas of deep corals. Objectives: 1) conduct ship-based multibeam surveys of slope depths containing known corals and areas where corals were expected, 2) construct detailed maps from multibeam data to guide other sampling.

Physical Oceanography and Ecology of the Habitat

The overall goals of this component were to describe short-term (hours-days) and longer term (weeks-months) variability of benthic physical oceanographic parameters on deep-coral habitats using highly technical benthic landers. Landers also provided instruments for use in various biological/ecological studies. Objectives: 1) describe water column and benthic currents around a deep-coral habitat, 2) describe variability in basic benthic water chemistry, 3) collect data on particle flux and food value of particle rain, 4) conduct long-term observations of habitat and fauna, 5) examine invertebrate settlement and microbial recruitment via settling plate experiments, 6) examine aragonite saturation states in relation to coral distributions.

Trophodynamics

The overall goals were to describe the benthic trophic web, construct an energy flow model, and evaluate impacts from potential changes in food supply on and around deep-coral habitats in several GOM locations. Objectives: 1) determine basic feeding patterns of major faunal groups using deep-reef and near-by habitats, 2) determine food sources for deep-reef communities, 3) assess adequacy of the food supply to major faunal groups, 4) assess the impact of seeps on deep-coral trophodynamics, 5) develop a carbon budget for selected deep-coral systems, 6) determine impact of habitat or micro-habitat characteristics on trophic patterns, 7) determine extent of trophic isolation.

Coral Biology

The goal was to improve knowledge about the basic characteristics of deep-sea corals, especially *L. pertusa*. Objectives: 1) examine reproductive condition and seasonality of several coral species, 2) conduct respiration physiology experiments on selected coral species, 3) examine coral growth and mortality where possible, 4) collect corals to hold in cold water facilities for future experiments.

Benthic Ecology

The overall goal was to gain improved understanding of deep reef habitat usage and associations through descriptions of deep-reef and off-reef (nearby) fauna and related ecosystem characteristics. Objectives: 1) identify the macrofauna observed on and around the study sites and assess habitat usage, 2) assess levels of endemism at deep-reef habitats, 3) examine patterns of species diversity and geographic distribution of the invertebrate and fish fauna between sites and make comparisons with similar habitats in other locations, 4) assess community structure and basic ecology of the invertebrate and fish fauna.

Genetics – Population Structure

Objectives: 1) quantify local and regional patterns of genetic variation in *Lophelia* via microsatellite markers, including assessments of genetic connectivity between natural reefs and manmade structures; further examine the relative contributions of clonal (asexual) and sexual reproduction and inferences regarding larval dispersal patterns, 2) document biodiversity of scleractinian corals using informative nuclear and mitochondrial DNA markers and appropriate phylogenetic analyses, 3) characterize connectivity between *Lophelia*-associated mobile fauna (selected invertebrates and fishes), 4) interpret genetics results in relation to abiotic variables and patterns of microbial diversity.

Microbiology

Objectives: 1) identify and characterize microbial communities associated with live *L. pertusa* at multiple sites in the GOM, 2) compare the microbial communities associated with live and dead *Lophelia* and surrounding sediments, 3) determine if *Lophelia*-associated mobile fauna are vectors, transporting specific bacteria between coral colonies, 4) identify and characterize the microbial communities associated with other deep-sea coral species (e.g., *Madrepora*, *Enallopsammia*) in conjunction with the population genetics work.

Geochemistry (Paleoecology)

Objectives: 1) age selected black and bamboo coral species, 2) using chemical proxies in coral skeletons, reconstruct oceanographic and ecological histories of deep-coral habitats that go back hundreds to thousands of years.

This project completed three major cruises in the GOM using the NOAA ship *Nancy Foster* (October 5–23, 2008) in conjunction with a Saab Seaeye Falcon DR ROV, the R/V *Seward Johnson* (September 14–25, 2009) with the manned submersible *Johnson-Sea-Link II*, and the R/V *Cape Hatteras* (September 30– October 3, 2010) with the ROV *Kraken II*. See Table 2E.1 for a summary of the stations sampled during the three cruises. Also, some of our team gathered additional data during outside funded cruises of the M/V *Arctic Sunrise* with a manned submersible (dual DeepWorker), provided by Greenpeace International and the Waitt Institute (October 2010) and a cruise using the NOAA vessel *Ronald H. Brown* with the *Jason II* ROV (November 2010). Some scientists on the USGS team participated on the BOEMRE contractor cruises, and some of the contractor scientists also participated in USGS cruises. The major sites visited are illustrated in Figure 2E.1. The cruises and project were documented on the USGS DISCOVRE web site (see http://fl.biology.usgs.gov/DISCOVRE/index.html).

Table 2E.1

Three deep-sea coral cruises accomplished during the *Lophelia* II (DISCOVRE) project in the Gulf of Mexico. These cruises were supported by the U.S. Geological Survey and NOAA. ROV/HOV = remote operated vehicle/human occupied vehicle, MB = multibeam sonar in km^2 mapped, CTD = Seabird SBE 19+ data logger, OT = 3.2 m otter trawl, TT = midwater Tucker trawl or MOCNESS net, PN = plankton net, cores = box core or multicore.

					Gear/Stations							
Vessel	**Dates**	**UW Vehicle**	**ROV/HOV**	**Lander**	**MB**	**CTD**	**OT**	**TT**	**PN**	**Trap**	**Cores**	**Other**
Nancy Foster												
Leg I	5–13 Oct 08	Saab Seaeye Falcon DR	6	4		32	16	16	6	4		5
Leg II	19–23 Oct 08				222	6						
Seward Johnson	14–25 Sep 09	JSL-II	15			11		22	9	2	20	19
Cape Hatteras	30 Sep– 3 Oct 10	Kraken-II	11			35	5	32	19	4	5	10
TOTALS			**32**	**4**	**222**	**84**	**21**	**70**	**34**	**10**	**25**	**34**

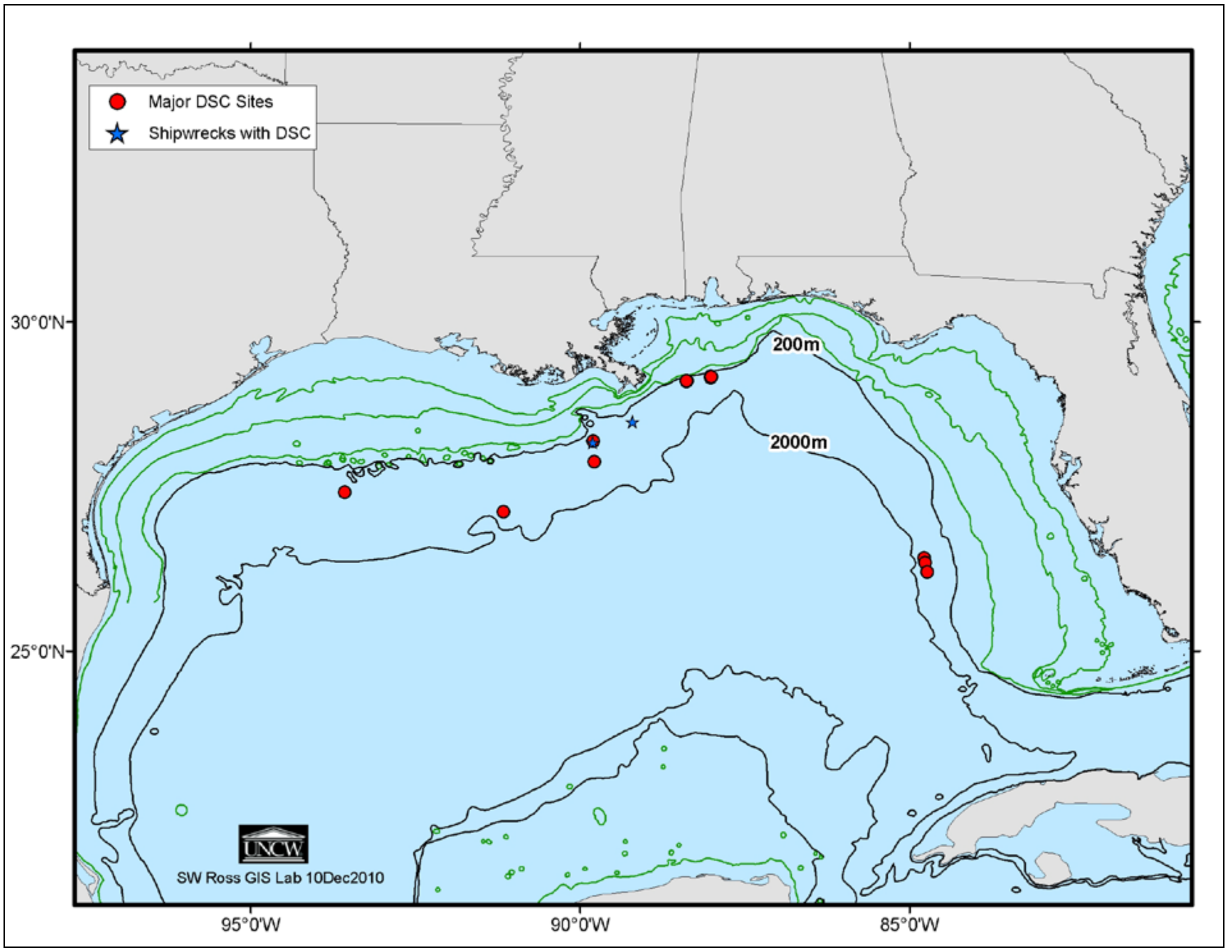

Figure 2E.1. Major natural (red dots) and artificial (blue stars) deep-sea coral study sites occupied by the USGS/UNCW Lophelia-II (DISCOVRE) research team, 2008–2010.

Overall, 32 submersible and ROV dives were made on GOM deep coral sites. Two heavily instrumented benthic landers were provided to the project by Dutch collaborators (Netherlands Inst. of Sea Research), and these were used in a short five-day deployment (see Davies et al. 2010) and a one year deployment (data being analyzed) on Viosca Knoll 826. A third benthic lander was deployed in October 2010 at Viosca Knoll 862/906 for one year (to be retrieved October 2011). A large section (222 km^2) of the West Florida slope was mapped using multibeam sonar, producing invaluable new maps of extensive coral and rock habitats. Two hundred seventy eight additional stations were sampled with a variety of gear during the three cruises (Table 2E.1). This massive database is currently being analyzed by the project scientists, their technicians, and students. To date, 13 peer-reviewed publications have resulted from the *Lophelia* I and II research of this team and many more will follow in coming years.

Preliminary observations resulting from these studies:

- Deep-sea corals on the West Florida slope may exceed those of anywhere else in the GOM.
- Some fish and invertebrate species appear to be dependent on deep reef habitat similar to such habitat use on shallow reefs.
- Many new faunal records and species new to science were discovered in association with deep reef habitats.
- Black and bamboo corals can be used as proxies providing an environmental history going back hundreds to thousands of years.
- Ocean physics is dynamic and variable around deep reef habitats and probably has great influence on coral ecosystem productivity and faunal recruitment.
- GOM populations of *L. pertusa* are somewhat genetically isolated from those in the Atlantic Ocean.
- Coral microbial communities are diverse and may play important roles in the ecology of these ecosystems.
- Commercially and recreationally important species use these deep reef habitats.
- These habitats are fragile and may be threatened by a variety of anthropogenic impacts.

Reference

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LOPHELIA II: DEEP REEF COMMUNITIES AND HABITATS OF THE WEST FLORIDA SLOPE

Steve W. Ross
University of North Carolina–Wilmington

Compared with the northeastern Atlantic Ocean or off the southeastern United States, deep-sea coral (DSC) habitats in the Gulf of Mexico (GOM) appear to be more scattered and perhaps less abundant. In contrast with other regions of the Atlantic, there appear to be relatively few bioherms (coral built mounds) in the GOM, and most deep-sea corals are attached to existing hard substrata, often authigenically formed carbonate blocks. In general, the area in the GOM thought to exhibit the best development of DSC habitat is within oil and gas lease blocks Viosca Knoll 826 and Viosca Knoll 862/906, which are about 37 km apart. Generally, Viosca Knoll DSC habitats are a mixture of bioherm features apparently formed by *Lophelia pertusa* and carbonate blocks colonized by DSC, interspersed with shell hash, coral rubble and soft sediments. Various aspects of the ecology and biology of communities on and around the Viosca Knoll coral banks have been reported, and many more papers are in preparation.

This talk provides a general description of newly discovered, extensive DSC habitats in the eastern GOM. Surficial geology and DSC habitat have been described for a small part of the West Florida slope (WFS), where numerous small topographic highs with mostly dead stands of *L. pertusa* were reported. Recent multibeam sonar surveys of the WFS and subsequent submersible and ROV dives have revealed widespread living coral colonies capping large ridges and bioherms. Considering the amount of topographic structure apparent, this area may now rank as having the most extensive coverage of live DSC in the GOM.

Data were collected on the WFS during five research cruises sponsored by USGS, NOAA, and NURC-UNCW. A large region (about 222 km^2) off the West coast of Florida was surveyed with multibeam sonar using the NOAA vessel *Nancy Foster* (October 20–22, 2008). These multibeam data were supplemented by a single track line of multibeam sonar data collected by the *Lost Coast Explorer* (November 2010) to the south of the *Nancy Foster* survey. These maps were used to guide submersible, ROV and other sampling (Figure 2E.2). Three JSL dives and six ROV dives resulted in 54.92 hours of bottom observations and video recordings on the WFS. Reef (coral and/or rock) and soft sediment habitats were observed in every dive; however, reef habitat was the primary target of these investigations. Visual observations along the dive tracks revealed that the long north-south trending scarp was composed entirely of large rocky ledges and boulders with varying degrees of attached, sessile invertebrates. These ledges supported a high diversity of fauna but were less heavily populated than the mounds and ridges offshore (west) of the scarp. To the west of this scarp, complex bottom topography was exhibited at various places and was composed of large carbonate blocks intermixed with *L. pertusa* formed bioherms. The mounds and ridges were usually topped with extensive stands of living *L. pertusa* and other attached sessile fauna. Golden crabs and a variety of other animals colonized these

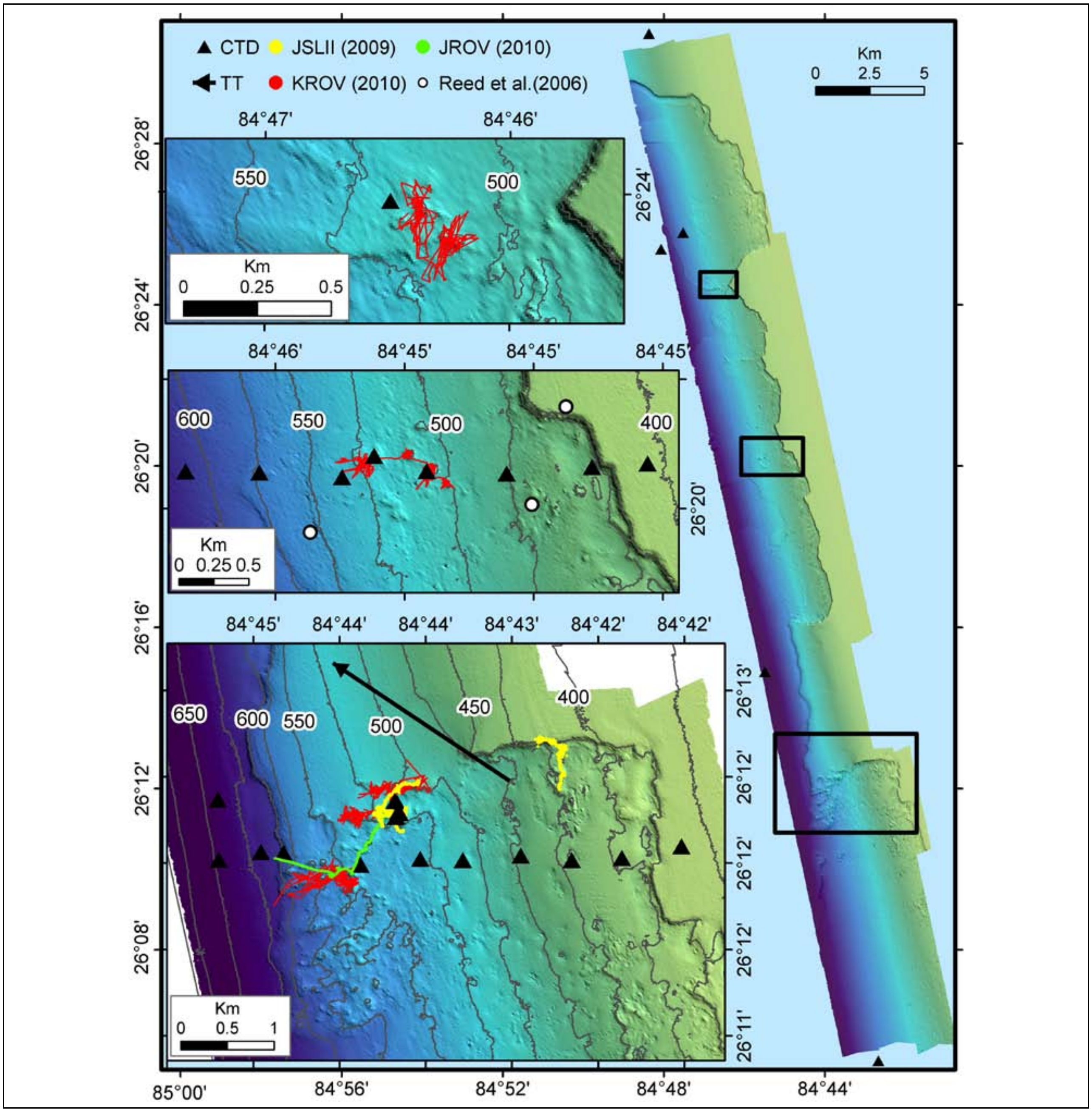

Figure 2E.2. Areas of intensive survey on the West Florida slope. Depth contours are in meters and resulted from *Nancy Foster* multibeam sonar surveys. Johnson-Sea-Link (JSLII), Kraken ROV (KROV), and Jason ROV (JROV) bottom dive tracks are illustrated. T TT=Tucker trawl tow. Reed et al. (2006) refers to previous study sites.

bioherms. In places, we observed lost fishing gear, but otherwise these ecosystems appeared to be healthy and thriving.

Eight general habitat types on the WFS were documented by video analysis. Benthic habitats with more that 50% of live *L. pertusa* cover composed about 25% of the area observed and were characteristic of the tops of ridges and mounds. Complex reef structures composed of mostly dead (>50% dead) *L. pertusa* comprised the largest habitat category (31% of area observed). Rubble covered low profile habitat (14%) and high profile rocky ledges (12%) were also commonly observed habitats. At least 71 taxa of invertebrates and 49 taxa of fishes were observed and/or collected on or near these WFS reefs. Most of these species appeared to be closely associated with deep-reef habitat.

Reference

Reed, J.K., D.C. Weaver and S.A. Pomponi. 2006. Habitat and fauna of deep-water *Lophelia pertusa* coral reefs off the southeastern U.S.: Blake Plateau, Straits of Florida, and Gulf of Mexico. Bulletin of Marine Science 78:343–375.

Steve W. Ross, Ph.D., is a research professor at the University of North Carolina at Wilmington, Center for Marine Science. He has spent most of his career involved in marine science of the southeast region. He was the Research Coordinator for the North Carolina Coastal Reserve Program for 13 years and has led offshore studies for the U.S. Geological Survey. His specialization is ichthyology, particularly ecology and life history studies. He has conducted diverse projects from estuaries to offshore waters and has been chief scientist on many cruises. The current work of Dr. Ross and his team involves fish communities of unique deepwater habitats. In particular, they are examining energy flow (trophodynamics) and relationships of animals to various habitats. Dr. Ross is involved with European scientists in conducting deep-sea trans-Atlantic ecosystem studies. One goal of this research is to provide information for these poorly known areas that will facilitate management and protection of productive and vulnerable habitats.

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LOPHELIA II: *LOPHELIA* REPRODUCTIVE BIOLOGY

Sandra Brooke
Oregon Institute of Marine Biology

Background

This is a supplemental project to the U.S. Geological Survey (USGS) study on deepwater corals in the Gulf of Mexico (GOM). The USGS study matches the MMS-(now BOEMRE-) funded project entitled "Continued Investigation of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral," also known as *Lophelia* II. The objective of this supplemental component is to investigate the reproductive biology of deep water corals, focusing primarily on *Lophelia pertusa* in the GOM. Other deep water sessile invertebrates, mostly Cnidaria, will also be examined for reproductive condition. Many samples have been collected for this study but have not been fully processed. Analysis of existing and new samples in this study component will result in the most comprehensive view of reproductive biology of *L. pertusa* (and other corals) in the western Atlantic. Such data, missing from *Lophelia* II studies, is highly collaborative and supportive of other study components. Understanding the reproductive biology of sessile, habitat forming species ties closely to the extensive genetics project and will help explain observed population patterns. A variety of factors may trigger coral gametogenesis (gamete production), spawning or influence growth and energy storage patterns. Data collected from one-year deployments of benthic landers, supplemented by other sampling, will provide correlative environmental data (e.g., food delivery, temperature, currents) for timing of reproductive events. This research complements an ongoing study on reproductive ecology of *L. pertusa* from Norwegian fjords, where gametogenic cycles are offset from the western Atlantic by several months. Matching physical oceanography with biological data on the same species from separate regions provides a powerful natural experiment which will help clarify some of the underlying processes that drive these ecosystems. If feasible, these studies will also examine larval biology and settlement behavior, primarily for *L. pertusa*, which will further address dispersal potential and recruitment dynamics. This study component will assist the UNCW study in evaluating coral habitat and associations of selected invertebrates. The final component of this work will include preliminary investigation into how variation in food supply (measured by the Landers) influences coral energy (lipid) content and reproductive output (fecundity) at different locations in the GOM. Basic life history data for the dominant benthic species will allow us to interpret information on population structure from genetic studies.

Objectives

The overall goals of this study component are to provide comprehensive information on the reproductive biology of dominant deep water, habitat forming corals in the GOM and to coordinate these results with other study components. Comparisons with matching data from the eastern and western Atlantic will provide context for the GOM samples. Specific objectives: 1) add to existing database on reproductive status of *L. pertusa* and complete description of the gametogenic cycle, 2) assess reproductive status of other dominant cnidarians (including *Leiopathes* spp., *Keratoisis* spp., *Callogorgia a. delta*) to determine if reproductive cycles are synchronous across various taxa, 3) correlate physical oceanographic data (temperature, currents, food supply) with gametogenesis in *L. pertusa* (and other species if data are sufficient), 4) correlate food supply to the benthos with lipid content and reproductive output.

Methods

During 2009 and 2010 cruises, approximately 150 samples of *Lophelia* (120), *Madrepora* (34), black corals (12) and gorgonians (15) were collected to document coral reproduction in the GOM. Live corals were also collected and are being held at the UNCW and OIMB labs. Deep-sea coral sampling ranged from the northern GOM to the West Florida Slope (300–800 m). Samples of *L. pertusa* and other species were fixed in 10% formalin for standard histological processing, and frozen for energetic analysis. Onset of gametogenesis, oocyte diameter, size frequency distribution and spawning period will be assessed from the histology analysis. Frozen samples were also fixed briefly (8 hours) and decalcified. A standard chloroform/methanol extraction process will be used to determine lipid content. Fecundity (reproductive output) will be assessed by micro-dissection of mature females.

Significance

In light of the movement toward deeper waters by fishing and energy industries, increased knowledge of how these systems function is critical; understanding reproductive cycles and recruitment dynamics will provide insight into recovery rates after damage (natural or anthropogenic), and will assist sound management decisions. Environmental degradation and vicarious events such as oil spills do not always cause mortality, but may have more subtle sub-lethal effects. For example, reductions in reproductive output or energy levels are possible side effects of chronic or acute stress. These studies will provide baseline ecological information about dominant structure-forming species.

Sandra Brooke, Ph.D., is Director of Coral Conservation at the Oregon Institute of Marine Biology/Marine Conservation Biology Institute. She also holds adjunct positions at the University of Oregon and University of North Carolina, Wilmington. She received her M.A in marine biology from VIMS and her Ph.D. (2002) from the University of Southampton, UK. She has worked on chemosynthetic vent and seep ecosystems as well as bathyal soft-sediment and hard-bottom habitats. She has also worked extensively on shallow coral reefs in the Caribbean and south Florida. Her research interests include coral biology and ecology with a focus on reproductive ecology and on several deepwater coral projects in the Aleutian Islands, Norwegian Fjords, South Atlantic Bight, and Gulf of Mexico, including post oil-spill assessment. Her future research projects include a multidisciplinary study of the Mid-Atlantic Canyons and a collaborative project with Norwegian academic institutes on deep corals and sponges.

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SEDIMENT MACROFAUNAL COMMUNITY STRUCTURE ASSOCIATED WITH DEEP-SEA HARD BOTTOMS IN THE GULF OF MEXICO

Amanda W.J. Demopoulos and Jennifer McClain-Counts
Southeast Ecological Science Center
US Geological Survey, Gainesville, Florida

Deep-sea hard-bottom environments are structurally complex and the associated habitat heterogeneity is a major structuring force in biological assemblages, often promoting local and regional biodiversity. While these systems may harbor significant levels of biodiversity, details of their community structure and function remain a mystery, both in natural environments and artificial substrates (e.g., shipwrecks). Better understanding of their diversity and connectivity will lead to development of effective adaptive management and conservation strategies for these vulnerable ecosystems. By comparing natural and artificial substrates, this study seeks to understand how shipwrecks may function as artificial reefs and address the question of ecosystem connectivity over larger spatial scales.

The information presented here represents an ongoing study of the benthic ecology of deep-coral ecosystems in the Gulf of Mexico. Study areas were located in the northern Gulf of Mexico on the continental slope off Louisiana, Mississippi, and Alabama. Specific coral locations represented two geological mound features identified as BOEMRE Lease Blocks Viosca Knoll 826 and Viosca Knoll 906 and three shipwrecks: Ewing, Gulfpenn, and the Viosca Knoll. Collections were made during two ROV and submersible cruises in 2009. *In situ*, quantitative samples of macrobenthic (> 300 µm) communities and their environment were collected using specialized sampling gear enabling minimal sample loss. In addition, background samples were collected at each of these sites in order to facilitate comparisons with off-reef sites. Macrofauna from these collections were sorted and identified in order to quantify infaunal densities and diversity. Benthic community structure and function, including densities, diversity, and functional groups were examined in natural and artificial (shipwrecks) coral communities and adjacent off-coral mound environments, including soft sediments in the Gulf of Mexico. Sediment cores were collected to assess species diversity, composition, and numerical abundance of sediment macrofauna residing in deep-coral ecosystems. Sediment collections from deep-coral habitats revealed a predominance of polychaete annelids, amphipod and tanaid crustaceans, and bivalves. Polychaetes represented a broad range of functional groups, including suspension feeders, deposit feeders, and predatory forms. Discrete polychaete assemblages were observed residing within the corals and differed from communities present in adjacent and background soft sediments. In conclusion, benthos residing in hard-bottom environments in the Gulf of Mexico represents complex communities both in terms of biodiversity and community structure.

Amanda W.J. Demopoulos received her B.S. degree in oceanography from the University of Washington–Seattle (1996) and a Ph.D. in biological oceanography from the University of Hawaii–Manoa (2004). After her post-doctoral fellowship at Scripps Institution of Oceanography

(2004–2006), she was hired into her current position as a Research Ecologist with the USGS Southeast Ecological Science Center in Gainesville, Florida. Her research program spans from coastal wetlands to deep-sea environments, where she examines benthic community structure and function, including food webs and impacts of natural and anthropogenic disturbance on benthic ecosystem health. Dr. Demopoulos is a principal investigator within the USGS DISCOVRE project and chief scientist for the USGS Mid-Atlantic Canyons OCS project.

Jennifer McClain-Counts received her B.S. degree in marine biology (2006) and her M.S. in marine science (2010) from the University of North Carolina–Wilmington. She is a laboratory manager and biological technician for Dr. Amanda Demopoulos with the USGS Southeast Ecological Science Center in Gainesville, Florida. Her research has focused on deep-sea environments and includes examining the trophic and community structure of midwater and benthic fauna and the behavior and habitat preferences of a squat lobster.

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GENETIC CONNECTIVITY AMONG *LOPHELIA PERTUSA* REEFS IN THE GULF OF MEXICO

Cheryl L. Morrison
U.S. Geological Survey

In the Gulf of Mexico (GOM), the cold-water coral *Lophelia pertusa* forms extensive reefs at relict cold seep sites where authigenic carbonates often serve as a substrate for larval settlement. Knowledge of the degree to which populations are connected through larval dispersal is imperative to effective management and mitigation efforts, yet little is known about larval dispersal ability or population connectivity in *L. pertusa*. To assess the spatial scale and pattern of genetic connectivity among eight *L. pertusa* reef localities in the GOM, approximately 230 *L. pertusa* individuals were assayed using eight microsatellite DNA markers. Sampling sites spanned nearly 900 kilometers and included colonies inhabiting two Mississippi Canyon shipwrecks, the *Gulfpenn* and *Gulf Oil*. Population genetic analyses revealed weak genetic structuring, indicative of high connectivity among GOM reef localities. The Viosca Knoll 862 site was the most genetically distinctive of the surveyed GOM reef localities. Additionally, multi-locus genotypes from 200 *L. pertusa* sampled from seven deep reef sites off the southeastern U.S. (SEUS) coast in the western Atlantic Ocean were included in the present analysis to estimate gene flow between neighboring ocean basins. In concordance with previous results (Morrison et al. 2011), dispersal between *L. pertusa* populations in the Gulf of Mexico and the western North Atlantic Ocean appears restricted. The *L. pertusa* locality in closest proximity to the SEUS, the West Florida Slope, grouped with GOM localities. Increased sample sizes attained through this project for the Viosca Knoll sites will allow for statistical testing of fine-scale non-random mating indicated by heterozygote deficits.

The *Deepwater Horizon* oil spill (April–July 2010) occurred in close proximity to some of our *Lophelia pertusa* study sites in the Gulf of Mexico. Although post-spill visual examination of the corals by remotely operated vehicles (ROVs) did not indicate mass mortality, experiences from past oil spills and laboratory experiments suggest that corals may be negatively impacted by direct exposure to crude oil and xenobiotics such as dispersants. An early response to environmental stressors includes the alteration of gene expression and the synthesis of proteins that drive homeostatic physiology. Sub-lethal, chronic effects may include shifts away from normal homeostasis at the molecular and cellular levels that are difficult to observe, yet may be indicative of pathophysiological effects. Through examination of transcriptomes, or the set of all RNA molecules present at a particular time, identification of genes (or gene systems) that are actively expressed can be interrogated. Currently, we are assembling and annotating transcriptomes from 454 next-generation sequence data for two deep-sea corals, *Lophelia pertusa* and *Madrepora oculata*. Through this research we will identify candidate biomarker genes that will facilitate the development of improved diagnostics for monitoring coral health through the complex recovery process.

Reference

Morrison, C.L., S.W. Ross, M.S. Nizinski, S. Brooke, R.G. Waller, R.L. Johnson, and T.L. King. 2011. Genetic discontinuity among regional populations of *Lophelia pertusa* in the North Atlantic Ocean. Conservation Genetics 12(3):713–729, doi: 10.1007/s10592-010-0178-5.

Cheryl Morrison received her B.S. degree in marine biology from UNC-Wilmington (1991) and a Ph.D. in biology from Florida State University (1997). Currently, she is a research geneticist for the USGS Leetown Science Center, Aquatic Ecology Branch, in Kearneysville, West Virginia. Her research interests include the application of genetic analyses to estimate spatial patterns of gene flow and dispersal, ultimately contributing towards informed management of biodiversity. Dr. Morrison is a part of the USGS DISCOVRE team (Diversity, Systematics and Connectivity of Vulnerable Reef Ecosystems) and has been working in the Gulf of Mexico since 2004.

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LOPHELIA II: COLD-WATER CORAL MICROBIOLOGY

Christina A. Kellogg and Michael A. Gray
U.S. Geological Survey

Julia P. Galkiewicz and Sarah H. Stellick
University of South Florida

Our USGS laboratory has been studying the microbial ecology of cold-water corals since 2004. Like humans, corals maintain an associated microbial population that is an intrinsic part of their biology. Characterizing these microbes and their functions is an important aspect of understanding coral health. Moreover, the coral's associated microbes, including bacteria, archaea, fungi, protists, and viruses (i.e., the microbiome) are its first line of adaptation to change. The microbiome can be altered in response to environmental pressures (or stresses or stimuli) on the order of hours to days, compared to decades or centuries for genetic adaptations to manifest in the coral animal.

Our current work builds upon information obtained during the *Lophelia* I study, including the first survey of cultured bacteria from *Lophelia pertusa*, which revealed many similarities to bacteria previously cultured from shallow-water scleractinian corals. Additionally, molecular data revealed that *Lophelia* maintains species-specific bacterial symbionts and that the loss of these symbionts may signal heat stress.

During research cruises in 2008–2010, we collected additional samples of *Lophelia* for both culture-based and molecular work. Employing a variety of new culture media resulted in the discovery and characterization of several fungi, both yeasts and filamentous forms. This is the first time eukaryotic members of the *Lophelia* microbiome have been identified and the first time these fungal genera have been found in a deep-sea coral.

Having obtained *Lophelia* samples from off the southeastern coast of the United States, the west Florida slope, Viosca Knoll, and two shipwrecks in the northern Gulf of Mexico, we are positioned to complete the first biogeographic survey of *Lophelia*-associated bacterial communities. The results can then be compared to data from Norwegian fjords to better estimate the variability across the Atlantic Ocean basin. DNA extractions from both Atlantic and Gulf samples are being prepared for next-generation sequencing to give us a first look at the *Lophelia* metagenome (the sum of all microbial associate genes). This will add to the species-diversity information we have collected previously and will also allow analysis of functional genes, providing insight into the metabolic services these microbes are performing for the coral.

Microbes are ecosystem architects. It has been shown in shallow-water systems that bacterial biofilms on surfaces affect the settlement and metamorphosis of marine invertebrates, including corals, sea urchins, and starfish. We constructed settling-plate arrays using blocks of coral limestone and inoculated some of the arrays with bacteria previously cultured from *Lophelia*.

These arrays were suspended on a benthic lander that was deployed in 419 m of water in the Gulf of Mexico in early October 2010, the season for *Lophelia* spawning and larval recruitment in the Gulf. The objective is to determine if any of the biofilms, created by soaking the arrays in various laboratory-grown bacterial cultures, increase settlement compared to a control array that was saturated in sterile broth. This would be a first step toward determining why *Lophelia* is present in some hard-bottom habitats in the Gulf but not in others.

Christina A. Kellogg received her Ph.D. in marine microbiology from the University of South Florida for her work on the genetic diversity of environmental viruses. She did postdoctoral research on an NIH-funded fellowship at the Georgetown University Medical Center, using molecular methods to identify novel drug targets in pathogenic fungi. She also interned for several months at Human Genome Sciences, processing microarrays and using bioinformatics software to mine the data. She joined the U.S. Geological Survey as one of the first Mendenhall Fellows, characterizing the microbial communities in African dust, beach sediments, sea grass beds and coral reefs. Currently, Chris leads the marine microbiology laboratory at the USGS St. Petersburg Science Center, conducting research that applies molecular techniques and classical microbiology to study the marine environment, tropical corals and deep-sea corals.

Michael A. Gray graduated from Eckerd College with a B.S. in biology in 1998. He received his M.S. from the University of South Florida College of Marine Science in marine microbiology in 2004. He has worked at the USGS since then as an environmental microbiologist and is currently engaged in both deep- and shallow-water coral microbiology projects.

Julia P. Galkiewicz is a Ph.D. candidate at the University of South Florida, working in the marine microbiology lab at the USGS. Her projects include working on the microbial diversity and function associated with the cold-water coral *Lophelia pertusa*. Julie's research interests focus on the functional roles that different microbes may have in symbiosis with corals.

Sarah H. Stellick graduated from the University of South Florida in 2010. She currently works in the marine microbiology lab at the USGS where she is researching the presence of sulfate-reducing bacteria on healthy corals. She also assists with various other projects involving deep- and shallow-water corals.

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TAXONOMY, DIVERSITY, AND ECOLOGY OF MEGAFAUNAL INVERTEBRATE ASSEMBLAGES ASSOCIATED WITH DEEP-SEA CORAL HABITATS IN THE GULF OF MEXICO

Martha S. Nizinski
NOAA, National Marine Fisheries Service National Systematics Laboratory
Smithsonian Institution, Washington, D.C.

Recent surveys using submersibles, ROVs, and trawls have collected a diverse assemblage of megafaunal invertebrates associated with, and occurring adjacent to and over, deep-coral habitats in the north-central and north-eastern regions of the Gulf of Mexico. These collections provide the basis for a variety of objectives including discovery of diversity, determining species composition of faunal assemblages, phylogenetic relationships, species associations, and habitat utilization. Accurate identifications are fundamental and critical to this investigation and provide the first step towards our understanding of richness, diversity, and ecology of corals and their associated fauna, as well as community structure and function at these deep coral habitats. Approximately 3,500 individuals, representing eight phyla, have been collected over the course of the project. Morphological examination of invertebrate material collected has revealed several species new to science, provided information necessary for re-descriptions of species with vague or inadequate descriptions, and has increased our understanding of intra- and inter-specific variation. A species accumulation curve, based on all taxa collected at Viosca Knoll, the most frequently sampled study area, is still ascending indicating that we are not close to knowing the total diversity of the megafaunal assemblage associated with these habitats. For some major taxa, such as the Crustacea, the species accumulation curve, also based on Viosca Knoll samples, appears to be reaching an asymptote, which indicates that we have a better understanding of the diversity represented among this group of invertebrates. Based on identified material, some species thought to be rare may actually be more common in the Gulf than was previously thought. Reported occurrences for other species collected in this study are new records for the Gulf of Mexico, while capture records for others provide information to redefine geographic and bathymetric distributions for these species. Among groups studied in detail, endemic species are minimal in number; however, some regional differences in faunal compositions are suggested. Ecologically, the invertebrate megafaunal assemblages occurring in off-reef areas differ significantly from the assemblages observed associated more closely with coral habitat. Continued analyses of data derived from video footage taken of deep-coral habitat and its associated fauna should test this hypothesis.

Martha Nizinski is a zoologist for NOAA/NMFS National Systematics Laboratory, National Museum of Natural History, Washington, D.C. Dr. Nizinski earned a B.S. in biology at West Virginia Wesleyan College, a M.S. in zoology at University of Maryland, and her Ph.D. in marine science at the Virginia Institute of Marine Science, School of Marine Science, College of William and Mary. She has been employed by the Systematics Laboratory since 1987, first as a technician, then as a zoologist. After completion of her doctoral degree in 1998, Dr. Nizinski began her research program studying the biodiversity, biogeography, taxonomy, and systematics of marine invertebrates, particularly decapod crustaceans. Her current research interests include taxonomy and systematics of galatheoid crabs; biodiversity, biogeography, population genetics and community structure of decapod crustaceans; biodiversity and community structure of invertebrate fauna associated with deep-water coral reefs and cold seeps.

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LOPHELIA II: GROWTH RATE AND AGE DISTRIBUTION OF DEEP-SEA BLACK CORALS IN THE GULF OF MEXICO

Nancy G. Prouty
USGS Pacific Coastal and Marine Science Center

E. Brendan Roark
Texas A&M

Noreen Buster and Chuck Holmes
USGS–St. Petersburg

Alan Koenig
USGS–Denver

Steve W. Ross
University of North Carolina–Wilmington

Black corals (order Antipatharia) are important long-lived, habitat-forming, sessile, benthic, suspension feeders that are found in all oceans and are usually found in water depths greater than 30 m. Deep-water black corals are some of the slowest growing, longest lived deep-sea corals known. Previous age dating of a limited number of black coral samples in the Gulf of Mexico has focused on extrapolated ages and growth rates based on skeletal ^{210}Pb dating. Our results greatly expand the age and growth rate data of black corals from the Gulf of Mexico. Radiocarbon analysis of the oldest *Leiopathes* sp. specimen from the upper De Soto Slope at 300 m water depth, indicate that these animals have been growing continuously for at least the last two millennia, with growth rates ranging from 8 to 22 μm yr^{-1}. Visual growth-ring counts based on SEM images were in good agreement with the ^{14}C-derived ages, suggestive of annual ring formation. The presence of bomb-derived ^{14}C in the outermost samples confirms sinking particulate organic matter (POM) as the dominant carbon source and suggests a link between the deep-sea and surface ocean. There was a high degree of reproducibility found between multiple discs cut from the base of each specimen, as well as within duplicate subsamples. Robust ^{14}C-derived chronologies and known surface ocean ^{14}C reservoir age constraints in the Gulf of Mexico provided reliable calendar ages with future application to the development of proxy records.

Nancy Grumet Prouty, USGS Pacific Coastal and Marine Science Center, completed her Ph.D. at Stanford University in the Oceans Programs in 2004 after earning a M.S. at the University of New Hampshire. Her scientific background includes atmospheric chemistry, oceanography, and climate change. Her training includes a postdoctoral position at the Cooperative Institute for Climate and Ocean Research (CICOR), a NOAA Cooperative Institute at the Woods Hole Oceanographic Institution (WHOI). She joined the U.S. Geological Survey in 2006 as a

Mendenhall Fellow as part of the Ridge-to-Reef studies in Hawaii. She is now working as a research oceanographer as part of the Coral Reef Project, and is a member of the Diversity, Systematics, and Connectivity of Vulnerable Reef Ecosystems (DISCOVRE) team.

E. Brendan Roark is a paleoceanographer with Texas A&M University whose research emphasis is in stable isotope biogeochemistry, trace metal analyses, and geochronology using radiocarbon and U/Th dating methods to study climate variability over the last 50,000 years. He has been doing research on proxy development and age and growth rates studies in deep-sea corals for more than seven years as part of his dissertation, post-doctoral and current research initiatives. Additionally, Dr. Roark has participated in four submersible and ROV research cruises in the Pacific Ocean, including 11 submersible dives to study and collect deep-sea corals.

Noreen Buster is a geologist at the US Geological Survey, St. Petersburg Coastal and Marine Science Center, located in St. Petersburg, Florida. Noreen studied coral micro-structure using scanning electron microscopy, including trace element analysis of skeletal features. Her current research focuses on analysis of historical coastal change (topographic and bathymetric) and present-day geophysical studies of the near shore environment.

Chuck Holmes is a retired geologist with the USGS Center for Coastal and Watershed Studies in St. Petersburg, Florida. He has participated in a number of USGS studies, including The Effects of Globally Transported African and Asian Dust on Coral Reef and Human Health, Historical Trends in Epiphytal Ostracodes from Florida Bay: Implications for Seagrass and Macro-benthic Algal Variability, The South Florida Ecosystem Restoration Project, Short-Lived Isotope Chronological Knowledge concerning Gulf of Mexico Estuaries, and the Buttonwood Embankment project.

Dr. Alan Koenig is a research geologist with the USGS Central Mineral and Environmental Resources Science Center. Dr. Koenig specializes in deciphering the chemistry hidden within rocks, minerals, metals, bones, teeth and other things using analytical chemistry and instrumentation development, trace element analyses, mineral and materials characterization. In particular he is involved in laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS).

Steve W. Ross, Ph.D., is a research professor at the University of North Carolina at Wilmington, Center for Marine Science. He has spent most of his career involved in marine science of the southeast region. He was the Research Coordinator for the North Carolina Coastal Reserve Program for 13 years and has led offshore studies for the U.S. Geological Survey. His specialization is ichthyology, particularly ecology and life history studies. He has conducted diverse projects from estuaries to offshore waters and has been chief scientist on many cruises. The current work of Dr. Ross and his team involves fish communities of unique deepwater habitats. In particular, they are examining energy flow (trophodynamics) and relationships of animals to various habitats. Dr. Ross is involved with European scientists in conducting deep-sea trans-Atlantic ecosystem studies. One ultimate goal of this research is to provide information for these poorly known areas that will facilitate management and protection of productive and vulnerable habitats.

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ATLANTIC DEEPWATER CANYONS: NEW STUDY INTRODUCTION

Sandra Brooke
Oregon Institute of Marine Biology

Steve W. Ross
University of North Carolina at Wilmington

In response to Request for Proposal M10PS00206 "Atlantic Deepwater Canyons," CSA International, Inc. (CSA) and academic partners submitted a proposal to the Minerals Management Service (now BOEMRE). CSA and partners were awarded this four year interagency project which is sponsored by the National Oceanographic Partnership Program (NOPP) involving BOEMRE, NOAA Office of Ocean Exploration and Research (OER), and the U.S. Geological Survey (USGS). The study will focus on the exploration and characterization of canyon ecosystems and shipwreck sites off Virginia and Maryland, with emphasis on deep-sea corals (DSC) and other hard-bottom communities. These studies are expected to result in the discovery of ecologically important canyon habitats (e.g., corals, cold seeps) and identification of historically important shipwreck sites.

Mid-Atlantic submarine canyons have enhanced currents, high organic input, and localized exposed hard substrata (steep walls, emergent hard-bottom, talus fields). DSC habitats are generally associated with such environmental conditions; therefore, hard substrata within the canyons are expected to support these sessile benthic organisms and associated communities. The larger and more complex of the benthic fauna (corals and sponges) also provide habitat and food for other species. The shelf and slope adjacent to the canyons is generally soft-bottom, with the exception of artificial hard-substrate provided by human artifacts and are expected to be more depauperate in benthic fauna, since the organic deposition is generally lower than within the canyon axis.

This study will describe the distribution, biology and ecology of hard- and soft-bottom communities inside and outside the target canyons. Shipwreck sites within and adjacent to the canyons will also be assessed for historical value and biological community development. Priority canyons are Norfolk Canyon, Washington Canyon, Accomac Canyon, and Baltimore Canyon (Figure 2E.3). The results of this project will allow BOEMRE to develop the appropriate Notice to Lessors (NTLs) necessary to prevent damage to sensitive habitats and will highlight the value of these deepwater ecosystems and their contributions to offshore ecology and historical understanding.

Natural Substrata Objectives

- Characterize biological communities and their habitat associations
- Describe the distribution and diversity of canyon natural hard-bottom communities

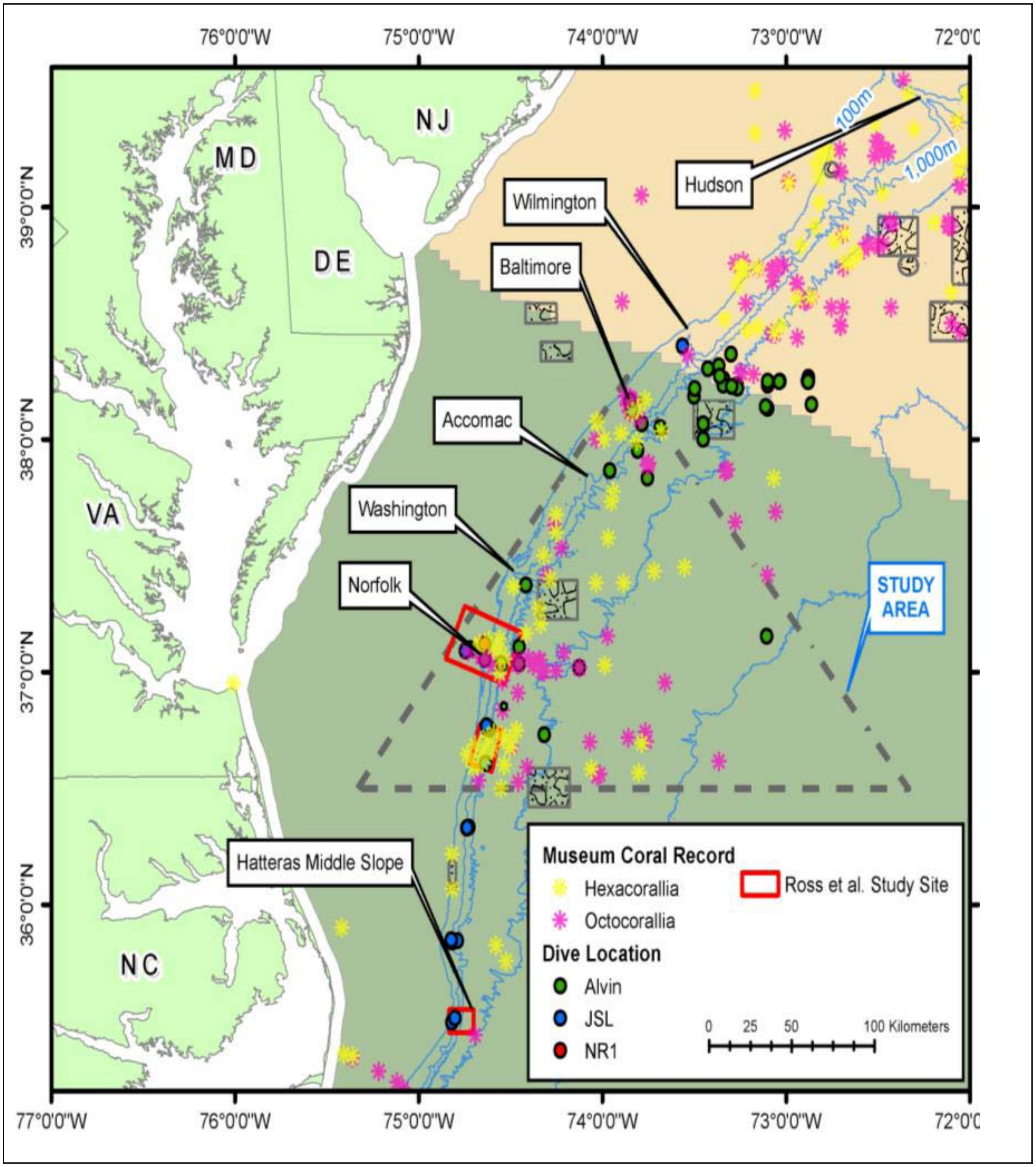

Figure 2E.3. Map of the Mid-Atlantic Bight showing the target canyons, coral locations and submersible dives within the project study site.

- Develop predictive models to correlate environmental data with potential presence of DSC
- Evaluate and rank sensitivity of biological communities to anthropogenic impacts

- Understand connectivity between canyons
- Investigate life history strategies and other biological aspects of key canyon species
- Understand the environmental setting of the target area with long-term, high-resolution data

Historical Shipwreck Objectives

- Locate valuable prehistoric habitation sites
- Locate and document new shipwrecks within the study area
- Determine eligibility to the National Register of Historic places and prepare a National Register nomination, if appropriate
- Assess the physical stability of shipwrecks
- Determine the biological effects of deep shipwrecks as artificial reefs
- Describe and access spatial heterogeneity of fouling community, fishes, and invertebrates associated with wrecks

The following hypotheses will help guide the biological components of this study:

- *Hypothesis 1*: Submarine canyons promote the development of sessile megabenthic communities, especially DSC, by providing more suitable substrata, enhanced flow, and higher input of organic material than non-canyon slope habitats;
- *Hypothesis 2*: Structurally complex habitats (including corals) enhance richness of associated megafauna over unstructured (soft-sediment) habitats;
- *Hypothesis 3*: The dominant fauna of the mid-Atlantic canyons are well connected genetically and trophically.

During the first year of the project NOAA, will provide a vessel to conduct multi-beam sonar surveys of the major canyons and selected archaeological sites. This will be followed by two cruises (one per year) using a large NOAA vessel and a science class ROV, for collection of field data. These primary cruises may be augmented through collaborations with the Monitor National Marine Sanctuary. The final year of the project will conclude data analysis and reporting.

Sandra Brooke, Ph.D., is Director of Coral Conservation at the Oregon Institute of Marine Biology/Marine Conservation Biology Institute. She also holds adjunct positions at the University of Oregon and University of North Carolina, Wilmington. She received her M.A in marine biology from VIMS and her Ph.D. (2002) from the University of Southampton, U.K. She has worked on chemosynthetic vent and seep ecosystems as well as bathyal soft-sediment and hard-bottom habitats. She has also worked extensively on shallow coral reefs in the Caribbean and south Florida. Her research interests include coral biology and ecology with a focus on reproductive ecology and on several deepwater coral projects in the Aleutian Islands, Norwegian Fjords, South Atlantic Bight and Gulf of Mexico, including post oil-spill assessment. Her future research projects include a multidisciplinary study of the Mid-Atlantic Canyons and a collaborative project with Norwegian academic institutes on deep corals and sponges.

Steve W. Ross, Ph.D., is a research professor at the University of North Carolina at Wilmington, Center for Marine Science. He has spent most of his career involved in marine science of the southeast region. He was the Research Coordinator for the North Carolina Coastal Reserve Program for 13 years and has led offshore studies for the U.S. Geological Survey. His specialization is ichthyology, particularly ecology and life history studies. He has conducted diverse projects from estuaries to offshore waters and has been chief scientist on many cruises. The current work of Dr. Ross and his team involves fish communities of unique deepwater habitats. In particular, they are examining energy flow (trophodynamics) and relationships of animals to various habitats. Dr. Ross is involved with European scientists in conducting deep-sea trans-Atlantic ecosystem studies. One ultimate goal of this research is to provide information for these poorly known areas that will facilitate management and protection of productive and vulnerable habitats.

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SESSION 2F

PROTECTED SPECIES RESEARCH

Chair: Deborah Epperson, BOEMRE

Co-Chair: Tre Glenn, BOEMRE

SPERM WHALE PREY STUDIES IN THE GULF OF MEXICO

Lance P. Garrison and Anthony Martinez
Southeast Fisheries Science Center
National Marine Fisheries Service, Miami, Florida

Keith D. Mullin
Southeast Fisheries Science Center
National Marine Fisheries Service, Pascagoula, Mississippi

Sperm whales in the Gulf of Mexico inhabit high productivity regions along the shelf break and inner continental slope. Mesoscale physical features locally increase primary and secondary production and thereby support regions of high prey availability. While these processes have been previously studied, there has yet to be a direct study of sperm whale prey resources. Studies of stomach contents suggest that mesopelagic histioteuthid squids are an important component of sperm whale diets, but their availability and distribution has not been examined. Large vessel surveys were conducted during summer 2009 and spring 2010 to quantify the prey community of sperm whales to accomplish the following objectives: 1) Characterize the spatial distribution of sperm whales and other marine mammals within the survey area, 2) Quantify the relative biomass and taxonomic composition of potential prey using scientific echosounder data and mid-water trawl sampling at fixed stations, 3) Identify trophic linkages between sperm whales and mesopelagic species through collection and analysis of tissue samples from potential prey taxa and stable isotope analysis, and 4) Collect hyrdographic profile data to characterize the oceanographic habitat of both sperm whales and their potential prey. During the 2010 survey, forty midwater trawl stations were sampled with sample depths typically ranging between 600–800 m. The samples collected included at least 57 distinct species of squids including representatives of histioteuthids and other families that are likely sperm whale prey. Specimens of each identified squid species were collected and processed for genetic barcoding for use in identification of partial samples and/or from sperm whale scat samples. Tissue samples were collected from 1,241 specimens from the trawls from a diversity of squid and fish species were collected for stable isotope analysis to evaluate the trophic relationships within the mesopelagic food web that supports sperm whales. Scientific echosounder data at frequencies of 38 kHz and 120 kHz were collected throughout the survey to characterize the vertical and horizontal distribution of deep scattering layers in the survey area. These data will be collectively analyzed to evaluate the correlations between trawl catch composition, secondary production, physical oceanographic structure, and sperm whale spatial distribution. These studies will characterize the dynamic oceanographic features and trophic resources of the northern Gulf of Mexico that support the resident sperm whale population.

Dr. Lance Garrison is a Research Biologist at the National Marine Fisheries Service, Southeast Fisheries Science Center in Miami, Florida. He is the lead of the Marine Mammal Assessment

unit within the SEFSC's Protected Species and Biodiversity Division. Dr. Garrison has broad expertise in quantitative ecology, stock assessment, trophic ecology, and population dynamics.

Anthony Martinez is a systems operations analyst at the National Marine Fisheries Service, Southeast Fisheries Science Center in Miami, Florida. He has served as the lead on numerous large-vessel and aerial surveys to assess the population abundance and spatial distribution of marine mammals in the Atlantic Ocean, Gulf of Mexico, Caribbean, and Pacific. His range of expertise includes passive acoustic monitoring technologies, telemetry tag deployment, visual line-transect surveys, and collection of biopsy tissue samples from wild marine mammals.

Dr. Keith D. Mullin is a Research Fishery Biologist at the National Marine Fisheries Service, Southeast Fisheries Science Center in Pascagoula, Mississippi. He received his Ph.D. in zoology from Mississippi State University. Dr. Mullin is the SEFSC Marine Mammal Program coordinator and has been working on population assessments of marine mammals in the Gulf of Mexico for over 25 years. He has expertise in marine mammal ecology and population dynamics including assessments using vessel and aerial line-transect surveys and distance analysis.

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ATLANTIC MARINE ASSESSMENT PROGRAM FOR PROTECTED SPECIES (AMAPPS)

Lance P. Garrison
National Marine Fisheries Service
Northeast and Southeast Fisheries Science Centers

The Atlantic Marine Assessment Program for Protected Species (AMAPPS) is a comprehensive, multi-year effort to collect data required to estimate abundance and develop seasonally specific, localized density estimates for marine mammals, sea turtles, and seabirds. The program coordinates data collection and analysis efforts by the NMFS Northeast and Southeast Fisheries Science Centers and the U.S. Fish and Wildlife Service Division of Migratory Birds to accomplish five primary objectives: 1) Collect broad-scale data over multiple years on the seasonal distribution and abundance of marine mammals (cetaceans and pinnipeds), marine turtles, and sea birds using direct aerial and shipboard surveys of coastal U.S. Atlantic Ocean waters; 2) Collect similar data at finer scales at several sites of particular interest to NOAA partners using visual and acoustic survey techniques; 3) Conduct tag telemetry studies within surveyed regions of marine turtles, pinnipeds and seabirds to develop corrections for availability bias in the abundance survey data and collect additional data on habitat use and life-history, residence time, and frequency of use; 4) Explore alternative platforms and technologies to improve population assessment studies; 5) Assess the population size of surveyed species at regional scales; and 6) Develop models and associated tools to translate these survey data into seasonal, spatially-explicit density estimates incorporating habitat characteristics.

During the first year of this project, 2010, the NMFS science centers conducted aerial surveys of continental shelf waters between Florida and Nova Scotia from July–September and deployed satellite telemetry tags on sea turtles along the U.S. Atlantic coast to collect data on movements, distribution, and dive-surface behaviors. Aerial surveys by the NEFSC and SEFSC employed line-transect survey methods, including double-observer approaches to estimate unbiased sighting probability, to collect data to estimate the absolute abundance of marine mammals and sea turtles throughout the survey range. The NEFSC survey covered 9,604 km of trackline observing 373 cetacean groups, 21 seal groups, and 69 turtles. The SEFSC survey covered 7,944 km of trackline and included 181 cetacean group sightings and 1,502 sea turtles. Two types of satellite telemetry tags were deployed on sea turtles between Georgia and New Jersey. Both tag types provide GPS location information and transmit summary dive-surface information. Fourteen loggerhead turtles were tagged off of New Jersey, and 30 were tagged off of Georgia and South Carolina. Tags were typically active for several months or longer, providing seasonal information on movements and dive behaviors.

In year two (2011), planned activities under the AMAPPS project include additional turtle telemetry studies, summer vessel surveys of offshore waters, and winter and summer aerial surveys. Achieving the objectives of AMAPPS will provide enhanced data to managers by addressing data gaps that are essential to supporting conservation initiatives mandated under the

National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), Migratory Bird Treaty Act (MBTA), and Endangered Species Act (ESA).

Dr. Lance Garrison is a Research Biologist at the National Marine Fisheries Service, Southeast Fisheries Science Center in Miami, Florida. He is the lead of the Marine Mammal Assessment unit within the SEFSC's Protected Species and Biodiversity Division. Dr. Garrison has broad expertise in quantitative ecology, stock assessment, trophic ecology, and population dynamics.

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THE MOVEMENTS AND HABITAT ASSOCIATIONS OF SEA TURTLES IN THE NORTHERN GULF OF MEXICO

Lance P. Garrison and Chris Sasso
Southeast Fisheries Science Center
National Marine Fisheries Service, Miami, Florida

Population assessments for marine turtles are confounded by the complexity of their life cycle and the multiple habitats occupied throughout their long life span. As a result, population assessments have relied primarily upon time series of the numbers of nesting females to evaluate status and trends. In-water population estimates would improve stock assessments by providing a direct metric of population size and by estimating the abundance of juveniles and early adults that are not reflected in nesting beach indices. Aerial surveys are a potential tool to address this gap, but developing unbiased estimates of abundance is confounded by the long time turtles spend beneath the water's surface. Seasonal and spatial variability in surfacing behavior may also drive variability in population estimates. While there have been multiple studies of sea turtle movements in the northern Gulf of Mexico using tag-telemetry, there have been very few studies of sea turtle dive-surface intervals. In addition, prior studies of habitats and movements based on tag-telemetry studies are made more difficult by lack of precision in ARGOS derived location data.

The goal of this study is to deploy satellite telemetry tags that transmit GPS accurate location data and summary information on dive-surface behavior on adult and sub-adult loggerhead and Kemp's Ridley turtles in northern Gulf of Mexico. Tags will be deployed on animals throughout the Gulf between Florida and Texas with a target total sample size of 60 tags spread evenly between loggerhead and Kemp's Ridley turtles. A small number of green turtles may be tagged, depending on opportunities. The tags will be Wildlife computers MK-10 tags that have Fast-Loc GPS capability and transmit summary information on the number of dives, depths of dives, and time at the surface. We expect to begin deployment of tags during May–June 2011 and continue deployments through 2012 into early 2013. The durations of these tags may be up to 180 days or longer, providing the opportunity to explore seasonal and spatial changes in dive behaviors. These data will be incorporated into analyses of turtle habitat use and to derive seasonally and spatially explicit correction factors for aerial surveys being conducted during 2011 and 2012. The combination of these studies will result in the first unbiased estimates of in-water sea turtle population sizes in the Gulf of Mexico.

Dr. Lance Garrison is a Research Biologist at the National Marine Fisheries Service, Southeast Fisheries Science Center in Miami, Florida. He is the lead of the Marine Mammal Assessment unit within the SEFSC's Protected Species and Biodiversity Division. Dr. Garrison has broad expertise in quantitative ecology, stock assessment, trophic ecology, and population dynamics.

Dr. Chris Sasso is a Research Fishery Biologist at the National Marine Fisheries Service, Southeast Fisheries Science Center in Miami, Florida. He is a sea turtle stock assessment biologist in the SEFSC's Protected Species and Biodiversity Division. Dr. Sasso has expertise in satellite tag-telemetry studies focusing on many species of sea turtles including green, leatherback, Kemp's ridley, and loggerhead turtles.

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SEISMIC SURVEY MITIGATION MEASURES AND MARINE MAMMAL OBSERVER REPORTS

Mary Jo Barkaszi, Michael Butler, Ross Compton, and Anne Unietis
RPS GeoCet

Protected Species Observer reports, comprising operational, observer effort, and protected species sighting data from marine seismic operations in the Gulf of Mexico were collated for the period 2003–2008. Sightings data is represented by 3,363 records collected during nearly 200,000 hours of observational effort. Sighting frequency, distance from the seismic source, behaviors and directional movements during four categories of seismic source status; full power, mitigation, ramp-up and silent were analyzed. Results demonstrated cetaceans taken as a whole to be sighted more frequently and at greater distances during full power, with variation among species groups. Behavior and directional movements also varied significantly between sources statuses. Key results are highlighted with suggestions for further work.

Mary Jo Barkaszi is president and founder of ECOES Consulting, Inc., where she manages the protected species division focusing on policy and implementation of the MMPA, ESA, and other regulatory requirements. Her work has concentrated on marine protected species issues for clients and agencies around the globe to develop best practices standards and providing top-quality compliance personnel. Ms. Barkaszi is working with Cornell Bioacoustic Research Program and Hydroscience Technologies Inc in the development and application of high-end bioacoustic monitoring systems for multiple industries. She continues to provide visual and acoustic observers to the seismic industry and is working on BOEMRE & DOE projects testing various detection techniques in conjunction with high definition aerial imaging. Mary Jo was recently appointed to the wind and wildlife task force by the AWEA as marine mammal/turtle advisor.

Ross Compton is currently the MMO & PAM Project Manager for RPS Energy, within the Europe, Africa & Middle East region, responsible for managing marine wildlife mitigation services for marine seismic operations and renewable energy developments. Previously working with marine seismic contractor, WGP Seismic, Ross was involved with passive acoustic monitoring system development. He is a graduate of ecology and marine science from the Universities of Edinburgh and Plymouth.

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OCS ACOUSTIC MONITORING

David Zeddies
JASCO Applied Sciences

JASCO was contracted to record and analyze acoustic data near the Cape Wind site in Nantucket Sound and at a lease site under consideration by Bluewater Wind in Delaware Bay. This pre-construction description of ambient sound levels provides a baseline for comparisons, such as during construction, operation, and maintenance of wind farms. These baseline descriptions can also be used for comparison with other sites. The recording and analysis period was one year, with the year subdivided into the four deployments.

A statistical description of ambient sounds levels was determined and presented as quartile, spectral-level histograms of the spectral density values. Quartile levels for the 5th, 25th, 50th, 75th, and 95th percentiles are given, where the 50th percentile is equal to the median of the spectral distribution and the 95th percentile is the level exceeded by 95% of the data. As a measure of relative overall sound levels and as an indication of possible sources of sound, the quartile levels were compared with the so-called Wenz curves that represent the contributions of various sound sources to ambient sound levels in the oceans. In general, the Wenz curves are reasonable predictors of the ambient noise levels at the two locations; though there are frequency bands and seasons when sound levels are greater than would be predicted by the Wenz curves. Although it was beyond the scope of this project, both manual and automatic detection and classification were performed on the recordings in an effort to identify prominent sources of sound. Anthropogenic sources, such as heavy shipping and boating, and biological sources, such as marine mammals and fish, were found at each site throughout the year. And, notably, apparent fish spawning events of prolonged duration contributed to the ambient sounds level and could exceed the Wenz curves predictions within some frequency bands.

David Zeddies is a senior scientist who joined JASCO Applied Sciences in 2011. His academic and professional work includes methods of acoustic measurement and assessment of risk to marine life due to anthropogenic sounds. He has published refereed articles in the fields of auditory neurophysiology, sound source localization by fish, and the impacts of intense sounds on fish hearing. David is involved with field operations for ocean acoustic measurements, acoustic modeling, and environmental assessment reporting.

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BOTTLENOSE DOLPHINS IN THE GULF OF MEXICO

Keith D. Mullin and Patricia E. Rosel
NOAA Fisheries, Southeast Fisheries Science Center

The bottlenose dolphin is one of 21 species of cetaceans that routinely inhabit the Gulf of Mexico and is the only species in the Gulf that inhabits coastal and bay, sound and estuary (BSE) waters. The U.S. Marine Mammal Protect Act of 1972 stipulates that marine mammal species should be managed on a stock basis and that stocks should remain a significant functioning element of the ecosystem they inhabit. Stocks are delineated as groups that have a very low rate of genetic exchange or groups that are essentially demographically independent populations. Stocks are often adapted to specific areas and are not easily replaced by individuals from adjacent areas. Based on oceanographic characteristics and geography, NOAA Fisheries currently defines 37 bottlenose dolphin stocks in the U.S. Gulf as follows: one oceanic (waters >200 m deep), one continental shelf (waters 20–200 m deep), three coastal (eastern, central and western; mainland to 20 m deep) and 32 BSE. Coastal and BSE stocks are at risk because individual dolphins can be resident to small geographic areas and because of the proximity of these habitats to a wide variety of human activities such as commercial and recreational fisheries, vessel traffic and oil and gas development, and impacts from wetland loss and habitat degradation. Additional concerns are the number of Unusual Mortality Events in the Gulf involving bottlenose dolphins that in some cases are linked to harmful algal blooms, and potential impacts of climate change. To provide context for evaluating the impacts of these risk factors, some basic biological information is needed: 1) which stock is being impacted, and 2) how many dolphins are in the stock and how that abundance changes over time. Most of the current BSE stocks have not been studied to determine if the stock structure has a biological basis. Studies need to be conducted to determine if the current structure is biologically meaningful, whether some of the current stock can be combined, or whether there are additional stocks. A variety of research techniques can provide information to elucidate stock structure (e.g., genetics, telemetry, stable isotopes, contaminants, photo-identification). However, genetics is the most informative because it provides a history of population connectivity and degree of interbreeding. There are few estimates of abundance for each of the stocks currently designated, or where estimates exist, in most cases, they are >eight years old and are not considered useful for management. To meet the mandates of the Marine Mammal Protection Act for coastal and BSE Gulf bottlenose dolphin stocks, NOAA Fisheries needs to (1) conduct winter and summer biopsy sampling of each BSE stock and the adjacent coastal waters to elucidate stock structure, and (2) estimate stock abundance every five to eight years by conducting mark-recapture sampling in each BSE and aerial line-transect surveys of the coastal waters.

Dr. Keith D. Mullin is a Research Fishery Biologist at the National Marine Fisheries Service, Southeast Fisheries Science Center in Pascagoula, Mississippi. He received his Ph.D. in zoology from Mississippi State University. Dr. Mullin is the SEFSC Marine Mammal Program coordinator and has been working on population assessments of marine mammals in the Gulf of

Mexico for over 25 years. He has expertise in marine mammal ecology and population dynamics including assessments using vessel and aerial line-transect surveys and distance analysis.

Patricia Rosel is a Research Geneticist with the NOAA Fisheries, Southeast Fisheries Science Center Marine Mammal Program. She earned her Ph.D. in marine biology from the Scripps Institution of Oceanography at the University of California, San Diego. Dr. Rosel's dissertation research focused on population genetics, phylogeography and phylogenetics of the porpoise family Phocoenidae, as well as application of genetic data to distinguish cryptic species of dolphins. After finishing her Ph.D., she completed two post-doctoral research positions applying molecular technologies to management of marine fish species. In 1997 she moved to the NOAA facility in Charleston, SC to return to research on marine mammal populations, completing work on harbor porpoises in the Atlantic and initiating a research program on population structure of bottlenose dolphins along the U.S. East Coast. Currently, she runs the Marine Mammal Molecular Genetics Laboratory, which is a component of the NOAA Fisheries Southeast Fisheries Science Center's Marine Mammal Program. The primary focus of the lab is to investigate genetic population structure of marine mammals in the western North Atlantic and Gulf of Mexico for the purpose of accurately delineating stocks for conservation and management. In addition, lab research focuses on developing or applying new molecular technologies to questions of marine mammal population structure, phylogenetics and health.

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SESSION 3A

NATURAL GAS HYDRATES

Chair: Bill Shedd, BOEMRE

Co-Chair: Roger Amato, BOEMRE

GEOPHYSICAL DATA ANALYSIS OF THE MC-118 (WOOLSEY MOUND, GULF OF MEXICO) HYDRATE OBSERVATORY SITE

James H. Knapp[1], Leonardo Macelloni[2], Camelia C. Knapp[1], Antonello Simonetti[1], and Carol Lutken[2]

[1]Department of Earth and Ocean Sciences, University of South Carolina

[2]Mississippi Mineral Resources Institute and Center for Marine Resources and Environmental Technology, University of Mississippi

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Camelia C. Knapp is an Associate Professor in the Department of Geophysics at the University of Southern California. She received her B.S. and M.S. degrees in geophysical engineering from the University of Bucharest and her Ph.D. in geophysics from Cornell, where she was a research assistant while completing her doctorate. She was a geophysicist for Chevron Overseas Petroleum Inc. USA and a research scientist at the National Institute for Earth's Physics in Bucharest, Romania.

Leonardo Macelloni was born in Rome, Italy, in 1975. In July 2001, he graduated in geology, *magna cum laude*, from the University of Rome "La Sapienza," and he received his Ph.D. in 2005 with a dissertation on digital processing of high and very high resolution marine seismic data. In November of 2005 he joined the Mississippi Mineral Research Institute Center for Marine Research and Environmental Technology (MMRI-CMRET) at the University of Mississippi, first as a Postdoctoral Research Assistant and later as a Research Professor. Current research interests include the following:

- physical and bio-geological characteristics of sea floor particular sites as mud volcanoes and cold seeps
- marine habitat mapping
- shallow subsurface hydrocarbon cycle
- gas hydrates occurrence and hydrates stability zones modeling
- sea floor and slope stability
- continental shelf morphology and morphodynamic
- beach nourishment and costal engineering

Dr. Macelloni is member of Geological Society of Italy, Italian Group of Earth Solid Geophysics, American Geophysical Union, and Mississippi Academy of Science.

Carol Blanton Lutken is Associate Director for Research at the Mississippi Mineral Resources Institute (MMRI), Center for Marine Resources and Environmental Technology (CMRET) and Seabed Technology Research Center (STRC), University of Mississippi. Her training is in biology and English (Duke University) and in geology (University of Mississippi). She has worked as a geologist on land and at sea, in the U.S. and overseas. She interacts with and promotes cooperations among Consortium members including a multitalented shop crew, Program Managers and Contracts Officers and is responsible for organizing cruise activities and for all technical reporting. Carol is a Registered Professional Geologist in the State of Mississippi.

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GAS HYDRATES OBSERVATORY AT MISSISSIPPI CANYON 118

Greg Easson and Carol Lutken
Mississippi Mineral Resources Institute, University of Mississippi

The Mississippi Mineral Resources Institute (MMRI) at the University of Mississippi leads and manages the Gulf of Mexico Hydrates Research Consortium (GOMHRC). The GOMHRC researches and observes hydrates *in situ* in the Gulf of Mexico to understand the hydrates stability zone and the factors that cause changes in the stability of hydrates on and below the seafloor over time. The MMRI and the GOMHRC have been conducting research at MC118 since 2001, and the block was set aside as a research reserve by the Minerals Management Service (now BOEMRE) in 2004. The hydrates research at MC118 is designed to meet the objectives of three federal agencies, BOEMRE, Depart of Energy and NOAA. This presentation will summarize the accomplishments to date of the GOMHRC at MC118.

The accomplishments to date include:

- documentation of hydrate accumulation in fine sediments
- successful prediction of the location of hydrates in the shallow subsurface
- relationships of faulting to fluid transport/geochemistry
- time series geochemistry in shallow subsurface and water column
- documentation of micro- and macro-faunal distribution at MC118
- role of microbes in hydrate association and dissociation
- student opportunities/support
- high resolution mapping of seafloor and features
- technology development and transfer
- baseline assessment of oil spill impact at MC118

The MMRI and researchers in the GOMHRC have six scientific cruises planned for the 2011 season that will continue the research at MC118.

Greg Easson is the Executive Director of the Mississippi Mineral Resources Institute (MMRI) at The University of Mississippi. Before that, Easson was a Professor in the Department of Geology and Geological Engineering where he taught GIS and Remote Sensing classes for the past 14 years. Easson was also the Executive Director of the Enterprise for Innovative Geospatial Solutions, a university-wide program to coordinate research activities in Geospatial Information Science and Technology (GIS&T) and the Director of the University of Mississippi Geoinformatics Center, an interdisciplinary research and educational initiative designed to increase the use and awareness of GIS&T. Easson received his Ph.D. from the University of Missouri–Rolla in geological engineering in 1995. He received his Master’s degree in geology also from the University of Missouri–Rolla in 1984 and a Bachelor’s degree from Southwest Missouri State University in 1981. Easson has more than 25 years of experience in the application of GIS&T in federal and state government, with employment at the Missouri Department of Natural Resources and the U.S. Geological Survey.

Carol Blanton Lutken is Associate Director for Research at the Mississippi Mineral Resources Institute (MMRI), Center for Marine Resources and Environmental Technology (CMRET) and Seabed Technology Research Center (STRC), University of Mississippi. Her training is in biology and English (Duke University) and in geology (University of Mississippi). She has worked as a geologist on land and at sea, in the U.S. and overseas. She interacts with and promotes cooperations among Consortium members including a multitalented shop crew, Program Managers and Contracts Officers and is responsible for organizing cruise activities and for all technical reporting. Carol is a Registered Professional Geologist in the State of Mississippi.

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GEOCHEMICAL STUDIES AT THE MC 118 GAS HYDRATE OBSERVATORY

Jeff Chanton, Rachel Wilson, and Laura Lapham
Florida State University
Department of Earth, Ocean and Atmospheric Sciences

Chris Martens
University of North Carolina at Chapel Hill
Marine Science Department

The overall objective of the geochemical group is to monitor changes in subsurface geochemical parameters and their flux to the water column to quantify gas hydrate dissolution and stability. A secondary objective is to illuminate the features described by geophysics to understand their significance and aid in their interpretation. In particular, we are interested in the surface expression of features identified by geophysical techniques and how changes in geophysical properties reflect changes in geochemical properties.

The MC 118 seafloor monitoring station was originally envisioned to follow changes in geophysical properties over time, to quantify variations in gas hydrate and free gas reservoirs, and to quantify hydrate stability. But how does one interpret changes in geophysical properties? Geochemical monitoring allows interpretation.

Specific Objectives of Geochemical Studies: Gas Hydrate Research Consortium

1. Develop an instrumented seafloor flux monitoring device to be put in place from the surface and deployed for six-month monitoring periods.
2. Determine spatial variability of chemical parameters at the monitoring station site particularly as related to seafloor faults and other conduits.
3. Relate chemistry to features identified by geophysical techniques.
4. Relate spatial variability to changes in chemistry over time (seep evolution model).
5. Investigate chemical and biological controls on gas hydrate stability and determine changes in surface flux and subsurface concentrations.
6. Use laboratory studies to understand how specific physical parameters influence hydrate stability and relate to observations of hydrate in nature

To achieve these goals we have developed seafloor monitoring devices of three types: an open topped chamber device for monitoring surface flux, the pore fluid array, *in situ* pore water samplers to collect time series data, and *in situ* pore water devices to collect samples from specific locations.

Jeff Chanton is a Gulf Coast native, born in New Orleans, Louisiana. He received his Ph.D. from the University of North Carolina at Chapel Hill. Awards include the title of Distinguished Research Professor and the John Winchester Professorship. He is an Aldo Leopold Fellow and was named the Florida Wildlife Federation's Conservation Communicator of the year in 2005.

He has authored or co-authored over 160 papers in the peer reviewed literature and received over 50 grants and contracts to support his research.

Rachel Wilson received her B.S. from Western Carolina University in chemistry in 2004. She received her Ph.D. in chemical oceanography from Florida State University in 2010. Her dissertation work dealt with the use of chemical tracers in nearshore food webs and particularly focused on habitat use by dolphins. She successfully used both stable isotopes and contaminants to resolve communities of dolphins both transverse and orthogonal to the coastline.

Laura Lapham received her B.S. in environmental chemistry from Florida State University. She then worked on gas hydrates at the Monterey Bay Research Aquarium Institute. She then went on to get her Ph.D. at the University of North Carolina-Chapel Hill where her dissertation research focused on the development of *in-situ* porewater sampling to understand hydrate stability. She received a National Energy and Technology Lab fellowship to return to Florida State University and continue her work on gas hydrates. She currently is a post-doctoral associate in Denmark.

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GULF OF MEXICO GAS HYDRATE JOINT INDUSTRY PROJECT: OVERVIEW OF LEG II LWD RESULTS

Matthew Frye
Resource Evaluation Division
Bureau of Ocean Energy Management, Regulation and Enforcement
Herndon, Virginia

The presentation titled, Recent Results of the JIP Cruise to Selected Gas Hydrates Sites in the Gulf of Mexico, summarizes the results of the Gulf of Mexico Gas Hydrate Joint Industry Project Leg II drilling campaign, which took place over the course of several weeks in the Spring of 2009. The drilling program confirmed the presence of gas hydrate-bearing sand reservoirs at locations predicted through the use of existing industry seismic and wellbore data. Gas hydrate was also confirmed in shale-dominated intervals that appear to be continuous over distances of several kilometers. Planning for Leg III of the project, where we will revisit the sites and extract pressure cores of the target intervals, is underway.

Matt Frye has been with BOEMRE for 12 years. Currently, he is a Senior Geoscientist with the BOEMRE Resource Evaluation Division in Herndon, Virginia, where he is leading the effort to prepare an assessment of gas hydrate resources on the U.S. Outer Continental Shelf. Matt was a member of the on-board science party for the 2009 Gas Hydrate Joint Industry project drilling expedition in the Gulf of Mexico.

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GEOPHYSICAL INDICATORS OF NATURAL OIL & GAS—TYPES, DISTRIBUTION, AND NUMBERS OF SEAFLOOR AMPLITUDE ANOMALIES IN THE GULF OF MEXICO

Bill Shedd, Kody Kramer and Paul Godfriaux
Bureau of Ocean Energy Management, Regulation and Enforcement

Since 1998, BOEMRE geoscientists (formerly MMS) have mapped over 21,000 geophysical amplitude anomalies on the seafloor. Those that have been visited by submersibles, ROVs, AUVs, camera sled surveys and trawls have been found to be caused by natural hydrocarbon seepage. Three types of seeps have been recognized: high positive amplitude anomalies, low positive/negative amplitude anomalies, and pockmarks.

High positive amplitude anomalies have been shown through direct observations to be caused by bacterially produced authigenic carbonate hardgrounds—thin pavements, boulder fields and thick outcrops – caused by low to moderate flux seepage. Occasionally, lithified sediment or sand flows from active vents have high positive amplitude, but do not display subsurface migration conduits on seismic cross-sections. To date, 16,278 high positive anomalies have been identified, all of which are potential substrates for chemosynthetic and coral communities.

Low positive/negative amplitude anomalies have amplitude response less than background amplitudes of soft-bottom mud. They are sometimes acoustically slower than water and have been shown through direct observation to be mud volcanoes (where sediment accompanies the hydrocarbon) and high-flux vent fields. To date, 2,271 negative amplitude anomalies have been identified.

Pockmarks are circular depressions where sediment has been removed, probably by rapid, explosive gas expulsion. Most are probably one-time events since very few have a high positive amplitude response or show active migration conduits in the subsurface. To date, 2,907 pockmarks have been identified.

Five major geological provinces appear to be controlling the distribution of the three anomaly types:

- Upper slope salt diapir/minibasin province
- Lower slope salt canopy province
- Sigsbee Escarpment province
- Abyssal plain province
- Florida Escarpment province

Most positive anomalies occur on the upper slope salt diapir/minibasin and on the face of the Sigsbee Escarpment where migration conduits for hydrocarbons are less restricted by salt cover. Most high-flux negative anomalies occur on the upper slope salt diapir/minibasin province. Both types are most common above the flanks of salt, which probably act as migration pathways.

Pockmarks are primarily located between 1,000 and 2,000 feet water depth in northern East Breaks and Garden Banks, where gas production is prevalent.

As per NTL 2009-G40, the oil industry's surface locations must be at least 2,000 feet outside of the outline of possible benthic communities, defined by the high positive polygons drawn by BOEMRE geoscientists.

William (Bill) Shedd received his B.A. in geology from the University of Rochester and his M.S. in geology from Louisiana State University. He worked for Shell Oil Co. from 1977 to 1981 and co-founded Independent Energy Corp. in 1989. From 1994 to 1997 he consulted for several large and small independent oil companies in exploration, development, log analysis, geophysical interpretation, and well site analysis. He joined the Minerals Management Service (now BOEMRE) as a geophysicist in 1997. He has worked in the Resource Evaluation Division and Research Studies Section, where he has been active in the submersible dive program and the methane hydrate assessment study.

Paul Godfriaux received his Bachelor's degree from Penn State in earth science with a minor in global business strategies for the earth, energy, and material industries. He received his Master's degree in geology at the University of Louisiana at Lafayette. Paul began working at the Bureau of Ocean Energy Management, Regulation and Enforcement (at the time MMS) in 2007. He works for the Resource Evaluation Division. His duties include interpreting geophysical data to identify potential seafloor hydrocarbon seeps and bottom simulating reflectors, assisting in site location for the hydrate JIP leg 2 drilling program; monitoring operations at the hydrate observatory in MC 118, performing broaching analyses for planned wells, and analyzing drilling plans.

Kody Kramer is a geologist working for the Bureau of Ocean Energy Management, Regulation and Enforcement, Gulf of Mexico OCS Office. Kody earned his Bachelor's degree in geology from Kansas State University in 2007 and completed his Master's degree in geology at Louisiana State University in 2011. At BOEMRE, Kody analyzes seismic amplitude data of the seafloor for natural hydrocarbon seeps and sensitive deep water chemosynthetic communities. Kody also searches seismic data for indicators of methane hydrates and conducts geologic reviews for drilling hazards of shelf and deep water proposed wells.

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SESSION 3B

OFFSHORE ECOLOGY I

Chair: James Sinclair, BOEMRE

Co-Chair: Maureen Mulino, BOEMRE

BIOMASS AND MASS BALANCE ISOTOPE CONTENT OF MUSSEL SEEP POPULATIONS

Philip Riekenberg, Robert S. Carney, and Brian Fry
School of Coast and the Environment
Department of Oceanography and Coastal Sciences
Louisiana State University

Mytilid mussels (*Bathymodiolus childressi*) are common seep constituents that form large populations at shallow (500–1,000 m) cold seep sites in the Northern Gulf of Mexico. These mussels utilize methane present at cold seep sites through symbiotic relationships with methanotrophic bacteria. This study compares mussel beds at two cold seep sites for variations in the stable isotope ratios of carbon, nitrogen and sulfur within the population. We found large variations in stable isotope values (5–8‰) for all isotopes measured and differences in values between sites. These differences indicate a system that has several isotopically distinct sources for carbon, nitrogen and sulfur. These variations in isotope composition are related to the location of the mussels and the sources in the surrounding environment. This indicates a large degree of heterogeneity in these chemosynthetic communities in a setting rich in microbial biogeochemical pathways.

Philip Riekenberg is a research associate in Dr. Brian Fry's stable isotope ecology lab at LSU. His duties range from field sampling to final data synthesis and include all phases of sample preparation and ratio mass spectrography. He is also enrolled in the master's program of the Department of Oceanography and Coastal Sciences. Robert Carney serves as chairman of his degree committee which focuses on the dynamics of cold seep mussel aggregations in the Gulf of Mexico through the use of CNS stable isotope techniques. He received his B.S. at the University of Texas at Austin in 2002.

Robert S. Carney is the former director of the Coastal Ecology Institute and a professor in the Department of Oceanography and Coastal Sciences. His research is broadly aimed at basic and applied issues of deep-sea ecology. Internationally, he has served as PI and Co-Director of the Continental Margin Ecosystems component of the Census of Marine Life. He has participated in MMS/BOEMRE supported work since 1984 in various capacities.

Brian Fry, a professor in the LSU Department of Oceanography and Marine Sciences, joined the faculty in 1998 after he worked at Harbor Branch Oceanographic Institution, Indiana University, Woods Hole Marine Biological Laboratory, and Florida International University. His pioneering research in stable isotope ecology began as a graduate student at the University of Texas and lead to his recognition as one of the most widely-cited authors in the field of ecology. He has made novel contributions to the understanding of a wide range of ecosystems from the Arctic to tropical mangrove forests and into the deep sea. The Gulf of Mexico continues to be of special

interest. Dr. Fry received his M.S. and Ph.D. from the University of Texas and undergraduate degree from Cornell.

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DIGITAL CONVERSION AND SELECTED ANALYSIS OF DIVE VIDEO FROM FIFTEEN DIVE SEASONS

Robert S. Carney and Harry H. Roberts
Department of Oceanography and Coastal Sciences
Louisiana State University

The seafloor video archive housed at LSU was converted to a common digital format and an initial database created for image content location and study. This conversion was done using Coastal Marine Institute funding. Video recording has been an integral part of human-occupied vehicle (HOV) investigation of the seafloor since the late 1970's when commercial-quality equipment was used to document discoveries at Pacific hydrothermal vents. With the advent of small recorders with an hour or greater capacity, entire bottom time was shot both as a log of dive activities and to document specific bottom features. Digital video along with desktop video editing has lead to the use of images as a primary data source, especially in the case of remotely operated vehicles (ROV) where images are the only means of human observation.

The LSU archive dates to 1989 and was shot from the HOV ALVIN, Johnson SeaLink and Pisces. Original tape formats include U-Matic, VHS, Hi8, DVCAM, and MiniDV. Final formats were MPEG files recorded on DVD disks and 1 terabyte hard drives. Analog tapes were digitized using Sony digital recorders and Windows computers. When computer control of the source drive was possible, tapes were broken into 5-min segments using Adobe Premier Pro software. A total of 3,341 tape segments (278 hours) were converted and logged in a relational database. The primary utility of these archives is to illustrate various aspects of the seafloor. With caution, the images might be used in long-term studies.

Video images are a boon to seafloor studies and a challenge to data management. To maintain the highest data quality, minimal or no compression can be applied to the data. To achieve this, massive storage capacity is required. Reasonable storage requires high levels of compression which lose much image detail. As a user of video-based data, BOEMRE must take an active role in standards development. These standards must assume mission-appropriate retention of image content during shooting as well long-term storage and access.

Robert S. Carney is the former director of the Coastal Ecology Institute and a professor in the Department of Oceanography and Coastal Sciences. His research is broadly aimed at basic and applied issues of deep-sea ecology. Internationally, he has served as PI and Co-Director of the Continental Margin Ecosystems component of the Census of Marine Life. He has participated in MMS/BOEMRE-supported work since 1984 in various capacities.

Dr. Harry H. Roberts is the former director of Coastal Studies Institute at LSU, an emeritus member of the Department of Oceanography and Coastal Sciences (School of the Coast and Environment), and a Boyd Professor. He has had a career in marine geology that spans more than

40 years and has worked in many foreign countries as well as in the United States. Recently, his research has focused on three themes: (a) modern deltaic sedimentation and processes, (b) shelf-edge deltas, and (c) surficial geology of the northern Gulf's continental slope. The latter research thrust has concentrated on building an understanding of the impacts of fluid and gas expulsion on the surficial geology and biology of the slope.

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ASSESSMENT OF BAROTRAUMA IN SALMON FROM IMPULSIVE SOUND

Michele B. Halvorsen[1,2], Brandon Casper[2], Christa M. Woodley[1], Thomas I. Carlson[1], and Arthur N. Popper[2]

[1]Pacific National Northwest Laboratory, Marine Sciences Laboratory

[2]University of Maryland, Department of Biology

Introduction

We investigated the effects of high-intensity impulsive sounds on juvenile Chinook salmon (*Oncorhynchus tshawytscha).* State-of-the-art equipment was developed and used to expose fish to simulated pile driving signals in the laboratory.

Exposure Device

The primary apparatus used in the study was a specially designed High Intensity Controlled Impedance–Fluid-filled wave Tube (HICI–FT). The HICI–FT is a stainless-steel tube with an electromagnetic shaker at each end.

Pile Driving Impact Signals

Eight pile driving signals, recorded during driving of steel shell pile and provided by Washington Department of Transportation, were used in these studies. The eight signals differed slightly in their spectral content and their time waveform, which were normalized to have the same single strike SEL. To simulate a normal pile driving operation, the eight signals were presented in pseudorandom order.

Sound Exposure Level Target

Fish were divided into treatment groups. Each treatment had a target cumulative sound exposure level (SEL_{cum}). Most treatments were paired using the same SEL_{cum}, which was reached by changing different metrics. One treatment group reached the SEL_{cum} by being exposed to 1920 strikes at a single strike sound exposure level (SEL_{ss}) or by being exposed to 960 strikes at a higher SEL_{ss}. This pairing was done to test if the same SEL_{cum} caused similar barotrauma injuries regardless of number of pile strikes and SEL_{ss}, i.e. the equal energy hypothesis.

Neutral Buoyancy

Experimental findings from rapid decompression studies indicated that at the time of exposure negatively buoyant physostomous fish (i.e. salmonids) were at lower risk of barotrauma than those that were neutrally buoyant. Thus, at the start of each experiment, juvenile salmon were allowed time to acclimate and fill their swim bladder, thus potentially gaining neutral buoyancy.

Data Management

All data went through a rigorous quality control, quality assessment protocol. Quality was achieved by utilizing a one-over system for data entry accuracy. After quality assurance was completed, the data for each fish went through a rigorous ranking assignment with justification for the ranking. The criteria for rankings included fish physiological condition, buoyancy at exposure, food in gut, compliance with experimental protocols during experimental procedures, etc. Finally, after removal of unacceptable fish, the data were analyzed.

Barotrauma Scoring

After exposure to pile driving signals, fish were individually examined for 63 barotrauma injuries. The occurrence of an injury was scored as a 1, absence as 0.

The list of injuries was reduced to about 20, after determining that many of the injuries did not occur during our studies. Each of the 20 remaining injuries was ranked by physiological importance to the individual fish, followed by categorization into mild, moderate, or mortal. Finally, a mathematical weight (5, 3, or 1) was applied, which was based on physiological injury effect. The combinations of these data were used in the computation of a response severity index (RSI).

The RSI Model

We created a model that reduced a complex panel of injuries into a single metric, the RSI. Computation of the RSI metric considers the rank of the injury by its physiological significance to the condition of exposed fish and the severity of observed injuries. The RSI metric has been found to have a wide dynamic range in that it is sensitive to the onset of injury at very low intensity exposures through mortal injuries at severe exposures.

The model accommodates normalization of outcomes between experiments separated in time which use separate fish populations by accounting for the condition of fish in addition to experimental control strategies.

Results

The distributions of results from experimental treatments showed a correlation between RSI and SEL_{cum}. It was found that as SEL_{cum} increased, there was an increase in RSI values. Furthermore, fish exposed to 960 strikes had a significantly higher RSI value ($p = 0.0145$) than those exposed to 1920 strikes at the same SEL_{cum}. In other words, for the same values of SEL_{cum}, higher levels of SEL_{ss} caused an increase in the number of injuries and the physiological significance of observed injuries.

The findings refute the equal energy hypothesis, which means that the single metric, $SEL_{cum,}$ is not sufficient to determine criteria. Other metrics are necessary and should be taken into consideration. Those metrics include, but are not limited to, SEL_{cum}, SEL_{ss}, and number of strikes.

Dr. Michele B. Halvorsen was, until November 2010, a research associate at the University of Maryland. As of November 2010, Dr. Halvorsen is staff Scientist at Battelle-Pacific Northwest National Laboratory's Marine Sciences Laboratory (MSL), headquartered in Sequim, Washington. Her graduate training focused on neuroethology and neurophysiology of mammals and fish, and her current research focus is on the effects of anthropogenic sound on the physiology and behavior of freshwater and marine fish. Recent research includes assessment of the barotrauma response of juvenile salmon to high energy impulsive sounds generated by pile driving and the effect of the U.S. Navy's low- and mid- frequency sonar on the hearing of several fish species.

Dr. Christa Woodley is a staff Scientist at Battelle-Pacific Northwest National Laboratory's Marine Sciences Laboratory (MSL) headquartered in Sequim, Washington. She has been working on barotraumas issues and fish condition for the past several years and has provided expertise and guidance in evaluation of effects seen in this project.

Dr. Thomas J. Carlson is a program manager at Battelle-Pacific Northwest Division and an expert on underwater acoustics and the effects of barotrauma, including pile driving, on fish. His work includes studies on the physical acoustics and effects on fish health and behavior of a wide range of stimuli ranging from pile driving, seismic exploration sounds, maritime construction activities, and open water and buried explosions to fish passage through hydropower dams. Dr. Carlson has also developed and applied acoustic telemetry systems and passive acoustic systems for the measurement of underwater noise and for the detection, classification, and localization of vocalizing marine mammals.

Dr. Brandon Casper is a postdoctoral fellow at the University of Maryland. He received his Ph.D. from the University of South Florida where he did studies of hearing in elasmobranch fishes (sharks and rays). His research focus is in hearing, animal physiology, and behavioral ecology. Over the course of the experiments, he has been heavily involved in doing assessments of hearing and in the barotraumas studies.

Dr. Arthur N. Popper is Professor of Biology, Co-Director of the Center for Comparative and Evolutionary Biology of Hearing, and associate dean of the Graduate School at the University of Maryland. He has over 35 years of experience in studies of fish hearing, and has published over 200 peer-reviewed scientific publications on hearing (mostly of fishes, but also of elasmobranchs and marine mammals) and he has edited over 40 books on hearing. The focus of his current work is on effects of human-generated (anthropogenic) sounds on aquatic organisms, and particularly fishes. Recent studies specifically examine effects of high intensity sounds such as pile driving and sonar.

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RECOVERY FROM EXPOSURE TO PILE DRIVING SOUNDS IN CHINOOK SALMON

Brandon Casper[1], Michele Halvorsen[1,2], Thomas Carlson[2], Frazer Matthews[1], and Arthur N. Popper[1]

[1]Department of Biology, University of Maryland, College Park, Maryland

[2]Battelle–Pacific Northwest Division, Sequim, Washington

This study investigated the recovery of Chinook salmon (*Oncorhynchus tshawytscha*) from physiological effects of pile driving over time. Fish were exposed to pile driving sounds using the same apparatus and same overall procedures discussed by Halvorsen et al. (this volume). However, in this study, physiological effects were noted immediately after exposure (day 0) and additional exposed animals were examined on days 2, 5, and 10 post exposure to determine if fish survived the exposure. Additionally, if the fish survived, do additional injuries appear post exposure or does healing of injuries occur?

Studies were done at 216 dB re 1 $\mu Pa^2 \cdot s$ and 210 dB re 1 $\mu Pa^2 \cdot s$ cumulative sound exposure level (SEL_{cum}). Results demonstrated that, over the 10 day post-exposure period, healing occurred for all physiological effects encountered on day 0, with no new physiological effects appearing. Moreover, all fish started to eat shortly after being returned to their home tank, and their in-tank behavior appeared typical of unexposed fish. There were no mortalities during the recovery period

A concern for salmon and other species is that even if they are not killed by pile driving exposure or had “mortal” injuries that are certain to lead to death, as occurs at higher SEL_{cum}, the injuries would still lower fitness and potentially result in increased predation or increased susceptibility to disease. While our lab results cannot be used to tell if fish would survive in the wild, they do demonstrate that fish have the potential for surviving after mild or moderate physiological effects and, equally importantly, the results show that no new injuries appear in the days following exposure.

Dr. Brandon Casper is a postdoctoral fellow at the University of Maryland. He received his Ph.D. from the University of South Florida where he did studies of hearing in elasmobranch fishes (sharks and rays). His research focus is in hearing, animal physiology, and behavioral ecology. Over the course of the experiments, he has been heavily involved in doing assessments of hearing and in the barotraumas studies.

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Dr. Thomas J. Carlson is a program manager at Battelle-Pacific Northwest Division is an expert on underwater acoustics and the effects of barotrauma, including pile driving, on fish. His work includes studies on the physical acoustics and effects on fish health and behavior of a wide range of stimuli ranging from pile driving, seismic exploration sounds, maritime construction activities, and open water and buried explosions to fish passage through hydropower dams. Dr. Carlson has also developed and applied acoustic telemetry systems and passive acoustic systems for the measurement of underwater noise and for the detection, classification, and localization of vocalizing marine mammals.

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BASELINE FISH AND BENTHIC HABITAT CHARACTERIZATION IN THE FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARY

Randy Clark, Marine Biologist
NOAA Center for Coastal Monitoring and Assessment, Biogeography Branch

The Flower Garden Banks National Marine Sanctuary (FGNMS) is located in the northwest Gulf of Mexico, about 97 nautical miles southeast of Galveston, Texas. One of the most pristine coral reefs in the tropical western Atlantic, the Sanctuary's coral community supports a high abundance of coral reef fishes and associated marine organisms. Currently, the Sanctuary is evaluating its management plan to better understand impacts to climate change, oil spill response, fishing, and other anthropogenic factors. To understand if the Sanctuary's resources are changing as a response to a stressor, the baseline is necessary to quantify that change.

Fish and benthic community data is being collected by four methods: visual SCUBA surveys (shallow 20–33 m; moderate depth 33–50 m via technical SCUBA), remotely operated vehicles (ROV) at depths of 50–140 m; hydroacoustics (all depth ranges). Each sampling method will be implemented annually over the span of three years (2010–2012). Data will be analyzed to determine the location of a research area and the appropriate biological metrics to monitor following the implementation of the research area.

To date, we have developed a sampling design, a biogeographic characterization report, and a sampling design tool for ArcGIS; we have conducted two ROV cruises and two shallow SCUBA cruises (2010–2011), one technical SCUBA cruise (2011); hydroacoustic fish surveys have been collected on all those cruises.

FY12 data collection is currently being planned. Future products include a report on the development and analytical approach for the baseline information, field data, maps, images, and more. It is planned to monitor the research area for at least eight years.

Randy Clark has been a marine biologist with NOAA's National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA), Biogeography Branch for 14 years. Currently, he is stationed at Stennis Space Center, Mississippi, and is interested in conducting marine biological spatial data analysis in the Gulf of Mexico. He is a scientific diver for NOAA and is involved with coral reef ecosystem monitoring in the Flower Garden Banks National Marine Sanctuary, Puerto Rico, St. Croix and St. John, USVI. He graduated from Texas A&M at Galveston with a B.S. in marine biology and an M.S. in wildlife and fisheries science.

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STUDIES OF BLUEFIN TUNA (*Thunnus thynnus*) LARVAE FROM THE GULF OF MEXICO

James Franks, Bruce Comyns[1], Eric Hoffmayer, Donald Johnson, Read Hendon, and Richard Waller

Center for Fisheries Research and Development
[1]Department of Coastal Sciences
Gulf Coast Research Laboratory
The University of Southern Mississippi, Ocean Springs

Atlantic bluefin tuna (ABT, *Thunnus thynnus*) are currently managed as two distinct populations, with western Atlantic "spawners" of the Gulf of Mexico (Gulf) comprising a population genetically distinct from the eastern spawners of the Mediterranean Sea. The spawning stock biomass of the western stock has declined precipitously over the past few decades, prompting attempts by the International Commission for the Conservation of Atlantic Tunas (ICCAT) to rebuild the population. Atlantic bluefin spawn in the Gulf between April–June (peak spawning, April and May), at which time substantial numbers of spawners are taken as bycatch in the yellowfin tuna and swordfish longline fisheries. Although there is no directed fishery for bluefin in the Gulf, bycatch mortality of spawning ABT in these pelagic fisheries is cause for concern.

The ecology of larval bluefin tuna in the Gulf is poorly known. During ichthyoplankton cruises conducted by the Gulf Coast Research Laboratory between 2003–2010, bluefin tuna larvae (> 800) were collected in surface neuston net tows made along transects (~ 100 km) aligned perpendicular to western and northern boundaries of the Loop Current (LC), providing evidence that LC boundary regions and associated oceanographic features (e.g., eddies) are larval bluefin habitat. Larval sampling was conducted with funding from NOAA Fisheries Southeast Area Monitoring and Assessment Program (SEAMAP) in support of the agency's development of fishery independent indices of spawning biomass of bluefin tuna in the Western North Atlantic Ocean.

The 2010 bluefin spawning season in the Gulf occurred during the *Deepwater Horizon* oil spill. Considering the depressed status of the western Atlantic bluefin stocks and the proximity of the spill to eastern Gulf bluefin spawning grounds, the potential for deleterious impacts from the spilled oil to bluefin life stages, critical habitats, and recruitment success was (is) of paramount concern.

Jim Franks is a senior research scientist with the University of Southern Mississippi's Gulf Coast Research Laboratory and Center for Fisheries Research and Development located in Ocean Springs. He is a 35-year veteran of fisheries research in the Gulf of Mexico and has published on a variety of topics during that time. His current research pertains to the biology and ecology of coastal fishes, including spotted sea trout, cobia, tripletail and tarpon, and offshore pelagic species such as tunas and sharks. He serves on NOAA's Marine Fisheries Initiative (MARFIN) and Highly Migratory Species advisory panels. He is the immediate-past Chair of the Gulf and Caribbean Fisheries Institute.

Bruce Comyns has 30 years of fisheries research experience with larval and juvenile Gulf of Mexico fishes. He specializes in morphological identification, age, growth, recruitment and habitat of young fishes, and was lead ichthyologist on GCRL larval bluefin tuna surveys during the 2000s. He has published extensively on the early life history of Gulf fishes.

Dr. Eric Hoffmayer is currently Research Fishery Biologist with National Marine Fisheries Service, Mississippi Laboratories. He received his Ph.D. from the University of Mississippi in 2003, where he studied stress physiology and energetics of coastal sharks. Following his Ph.D., he became a post-doctoral researcher in the Department of Coastal Sciences at the University of Southern Mississippi's Gulf Coast Research Laboratory studying the vertical and horizontal distributions of fish larvae at the Loop Current. Dr. Hoffmayer's research interests are relatively broad and encompass such areas as essential fish habitat, movement and habitat use patterns, life history, and ecological physiology of fishes.

Donald Johnson investigates the evolutionary coupling of marine life and consistent seasonal patterns of ocean circulation. He developed the early understanding of blue crab larval dispersion and natal retention for evolutionary advantage and population stability in the Gulf of Mexico (GOM) and, through numerical modeling, has contributed to current understanding of large scale red snapper larval dispersion in the GOM. He recently investigated jellyfish blooms and non-endemic invasive species coupled to advective processes in the GOM and the Caribbean Sea. He has contributed to understanding larval transport through internal bores of tidal frequency.

Read Hendon has extensive experience as a fisheries biologist working with estuarine and offshore fishes in the Gulf region. He has been a principal investigator on numerous research projects, including investigations of larval bluefin tuna, pelagic sargassum, spotted seatrout, tripletail and cobia. He is directly involved with the SEAMAP process for the Gulf region and serves on numerous fisheries committees in the region.

Richard Waller has 40 years of experience as a fisheries scientist, specializing in field collections of fishes and invertebrates from coastal and offshore regions of the northern Gulf of Mexico. As fisheries expert, he participates in larval bluefin tuna research cruises conducted by the GCRL.

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A REVIEW OF THE OCCURRENCE, DISTRIBUTION, AND MOVEMENTS OF WHALE SHARKS IN THE NORTHERN GULF OF MEXICO

Eric R. Hoffmayer[1], Jennifer A. McKinney[2], James S. Franks[2], and William B. Driggers III[1]

[1]National Marine Fisheries Service, Southeast Fisheries Science Center, Mississippi Laboratories, Pascagoula, Mississippi

[2]Center for Fisheries Research and Development, Gulf Coast Research Laboratory, The University of Southern Mississippi, Ocean Springs, Mississippi

Reports of whale sharks, *Rhincodon typus*, in the northern Gulf of Mexico date back to the 1930's; however, few studies have provided information beyond observational accounts. To address the lack of knowledge pertaining to whale shark biology, seasonal occurrence, distribution and movements in northern Gulf of Mexico, the University of Southern Mississippi's Gulf Coast Research Laboratory (GCRL) initiated the *Northern Gulf of Mexico Whale Shark Research Program* in 2003. One of the program's primary objectives was to document the distribution of whale sharks in the northern Gulf of Mexico via reports of sightings provided by collaborating fishers and offshore petroleum industry personnel. To date, over 400 sighting incidents have been reported with approximately one third of those involving aggregations of up to 200 individuals. This research has revealed that whale sharks are relatively abundant in the northern Gulf of Mexico and their seasonal occurrence is highly predictable. Additionally, satellite tagging data and photo identifications have established connectivity among whale sharks in the northern Gulf of Mexico, southern Gulf of Mexico and the Caribbean Sea. This presentation summarizes current knowledge on whale sharks in the northern Gulf of Mexico and addresses the topic of potential impacts to whale sharks of natural or human related environmental perturbations.

Dr. Eric Hoffmayer is currently Research Fishery Biologist with National Marine Fisheries Service, Mississippi Laboratories. He received his Ph.D. from the University of Mississippi in 2003, where he studied stress physiology and energetics of coastal sharks. Following his Ph.D., he became a post-doctoral researcher in the Department of Coastal Sciences at the University of Southern Mississippi's Gulf Coast Research Laboratory studying the vertical and horizontal distributions of fish larvae at the Loop Current. Dr. Hoffmayer's research interests are relatively broad and encompass such areas as essential fish habitat, movement and habitat use patterns, life history, and ecological physiology of fishes.

Jennifer McKinney is currently a Fisheries Management Biologist at the Louisiana Department of Wildlife and Fisheries. She received her M.S. from the University of Southern Mississippi in 2010, under the Department of Coastal Sciences at the Gulf Coast Research Laboratory. Jennifer's research interests include using active and passive telemetry coupled with spatial

analysis techniques to investigate the distribution, movement and habitat use patterns of pelagic and estuarine fishes.

Jim Franks is a senior research scientist with the University of Southern Mississippi's Gulf Coast Research Laboratory and Center for Fisheries Research and Development located in Ocean Springs. He is a 35-year veteran of fisheries research in the Gulf of Mexico and has published on a variety of topics during that time. His current research pertains to the biology and ecology of coastal fishes, including spotted sea trout, cobia, tripletail and tarpon, and offshore pelagic species such as tunas and sharks. He serves on NOAA's Marine Fisheries Initiative (MARFIN) and Highly Migratory Species advisory panels. He is the immediate-past Chair of the Gulf and Caribbean Fisheries Institute.

William Driggers is a Research Fishery Biologist with the National Marine Fisheries Service, Southeast Fisheries Science Center, Mississippi Laboratories. He received his Ph.D. in marine science from the University of South Carolina. His research interests focus on the distribution, ecology, life history and taxonomy of chondrichthyan fishes in the western North Atlantic Ocean.

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DEVELOPMENT OF THE ECOSPATIAL INFORMATION DATABASE (ESID) FOR THE BOEMRE ATLANTIC PLANNING AREAS

Lonnie Hearne[1], Keld Madsen[1], Brett Fritze[1], Jodie Lindsey[1], Jeff Albee[1], Adam Gelber[2], Beth Zimmer[2], Leslie Manzello[2], Doug Cribs[3], Kristen L. Metzger[4], William R. Sloger[4], Neal W. Phillips[4], David B. Snyder[4], Luis M. Lagera[4], M. John Thompson[4], Brian J. Balcom[4], Edmund A. Hughes[4], Keith D. Spring[4], and Frederick B. Ayer[4]

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The U.S. Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) is charged with leasing and managing offshore bottomlands in federal waters to the limits of the Exclusive Economic Zone (EEZ) for mineral and energy development. The U.S. Atlantic waters have been closed to oil and gas leasing for over 20 years, and new leases will require extensive environmental assessments. Recent advances in geospatial database technology offer an opportunity to greatly improve the manner in which relevant ecological data can be accessed for these assessments.

The EcoSpatial Information Database study is an on-going effort to gather ecological information for BOEMRE Atlantic Planning Areas in support of ecosystem based management, environmental judgments, and preparation of supporting documents for lease actions. Many studies have been conducted throughout this region with resulting information and data scattered in various locations and in differing formats. The information is being gathered into a database containing ecological and spatial information and is referred to as the EcoSpatial Information Database (ESID; pronounced “eesid”). The ESID references ecological information sources, describes their geographic coverage, and contains available spatially referenced data from those sources. The ESID database is accessible using a geospatial map interface based on ArcGIS software so that it is compatible with other systems such as the Multi-Purpose Marine cadastre.

The first part of the project was the collection, evaluation and documentation of ecological resources that would be incorporated into the database. Multiple companies providing expertise in scientific data collection and analysis was part of this process and a comprehensive procedural protocol was established up front to enable all team members to work in a consistent and unified manner. The protocol also established guidelines and directions for each task involved, responsibilities and relevant QA/QC procedures.

An established Internal Science Review Team (ISRT) consisting of a team of scientists was established to define the ecological topics of interest also referred to as the resource categories. The resource categories focused on ecological data and were directly related to information required for the NEPA process. The resource categories included the following: pelagic ecology, infauna/meiofauna, demersal fishes, coral and hardbottom, seagrass, water quality, and geology. The ISRT was also responsible for developing keywords that would be used in the geographically defined search for relevant literature and documents.

An associated project librarian used the previously developed keywords to search bibliographic and library sources, including Dialog® and OCLC™ WorldCat as well as Aquatic Commons and an internet search for EIS's. Two types of information were included in the data collection process. Documents (including peer-reviewed scientific literature, technical reports, and government documents) and data (including raw data and GIS data) located from websites.

The initial geographically defined search process yielded more than 37,000 applicable resource documents and more than 5,000 documented internet links. An evaluation and prioritization strategy was conducted to identify the most desirable information for inclusion in the system and a relevance matrix for each resource category was established to determine the value (rank) of the resource to the ESID.

Refworks™ was used as a bibliographic and data management system providing simultaneous, centralized access for multiple users through the internet as well as the ability for automatic upload of bibliographic input from Dialog® and OCLC™ WorldCat.

The second part of the project was to create spatial study footprints (geographic characterization) for the collected resources in the first part of the project and to extract data tables from applicable resource documents.

Spatial footprints were created for all high priority resources included in the ESID. All resources were evaluated for spatial extents and an appropriate geographic study boundary was created by GIS Analysts. The study boundary was created based on either a textual geographic location description or a study locator map within the resource or a combination of both.

Any resources that had their spatial footprints falling within potential offshore lease areas were subject to data table extraction. More than 8,000 MS Excel table sheets were extracted from approximately 1,200 resource documents.

The last stage of the project was to design and develop an appropriate geospatial database, populate the database with properly formatted data and to create applications that would allow the ESID data to be fully utilized for the BOEMRE management task.

The database is designed for sustainable and expandable use and is based on the ESRI ArcMarine Data Model because it is representative of the marine environment. Resource documents are stored in a file storage system and accessed through the geodatabase and search capabilities supported by Windows indexing services.

The ESID database is populated with all the collected resources, full bibliographic entries, extracted data tables, study footprints and associated metadata. This process will be supported by the ability to import these datasets for future expandability. Also, the design accommodates exporting the bibliographic entries to different formats.

Current scope of the access to the system is a desktop based interface for which the user would interact with the data. Discussions have been initiated to accommodate the design of the ESID for a web based interface once implementation starts. The interface will provide BOEMRE scientists with the ability to perform spatial and textual queries, generate reports based on results, load additional resources and data, and export to different formats.

Prepared under BOEMRE Contract No. M09PC00047.

Lonnie Hearne is a Senior Information Management Program Manager with AMEC Earth & Environmental in Nashville, Tennessee. He received a B.S. in engineering from the U.S. Naval Academy. He has over 36 years experience in program and engineering management of complex technologies for both civil and federal governments. In 1997 he co-founded a company that developed image processing and photogrammetry applications used in military targeting and 3D geospatial data extraction for both military and civil uses. Over the past 10 years he has been involved in a number of research and development projects for the federal government developing decision support systems and geospatial applications for transportation planning and environmental assessment. He is currently the overall program manager for the EcoSpatial Information Database.

Keld Madsen has six years of professional geospatial consulting services experience with AMEC Earth & Environmental in Nashville, Tennessee. He is the GeoSpatial Services Group Manager and is a member of the Information Management Department. His experience covers a wide range of geospatial service related functions including database development, GIS analysis, map production, raster creation and analysis, GIS implementations, application development support. Before current focus on the ESID project, Keld Madsen was the project manager for FEMA Map Modernization in the State of Kentucky overseeing an engineering/GIS team on multi-year, multi-county map modernization (DFIRM) projects. Mr. Madsen has an M.S. in planning and land management from Aalborg University, Aalborg, Denmark.

Brett Fritze is a Project Manager with the Information Management Group at AMEC Earth & Environmental Inc. in Nashville, Tennessee. He has over 10 years' experience in Geographic Information Systems. His project management focus is on application and database development projects, primarily Enterprise GIS databases and GIS web applications. Before working at AMEC, he developed GIS in the Unexploded Ordnance, Gas and Electric Utilities, and Flood Zone Determination industries. He has a B.S. in geography and environmental analysis from the University of Louisville.

Jodi Lindsey is a GIS Analyst for AMEC Earth & Environmental. She has three years of professional geographic information system (GIS) experience and has been continuously involved in geosciences and GIS related activities since 2003. Ms. Lindsey has taken part in many different projects; her experience includes database management, map production, flood insurance rate study profile creation, data manipulation, and floodplain boundary standards testing. Jodi Currently serves as a GIS Analyst at AMEC's Nashville office in Tennessee. She has a B.S. in geology from Western Kentucky University.

Jeff Albee has 13 years of professional technology consulting (IT) experience delivering solutions to government, educational, transportation, environmental, and energy clients around the world. Jeff's diverse background has built a strong foundation of technology and engineering knowledge, including extensive geographic information systems (GIS), water resources, system analysis, and infrastructure related project experience. Jeff is AMEC's Information Management Practice Lead and as a Certified Project Manager operating out of the Nashville, Tennessee office. He has an M.B.A. from Belmont University, a B.S. in management of information systems from Trevecca University, and an A.S. in computer information systems from Nashville State College.

Adam Gelber is group manager for the southeast coast of Florida for PBS&J, an Atkins company. He has over 16 years of experience in the ecological and environmental field where he has worked on a wide variety of projects, ranging from wetlands and groundwater remediation to seagrass and coral reef issues. Mr. Gelber has logged over 2,500 scientific and recreational dives. His work efforts have been concentrated throughout the southern peninsula of Florida as well as the Bahamas, Puerto Rico, Dominican Republic, and the Cayman Islands. He was a biological technician for five years with the National Park Service at Biscayne National Park and enjoys fishing the backcountry of Everglades National Park. He has a B.S. in wildland and wildlife management from the University of Miami.

Beth Zimmer has been working as an environmental scientist in south Florida for over 10 years. She has experience in a wide variety of services, ranging from NEPA documentation to seagrass and coral mitigation and monitoring, with a specialty in marine ecological resources. Ms. Zimmer has served clients in the government, transportation, and energy sectors. She currently serves as a Senior Scientist in the Miami, Florida office of PBS&J, an Atkins company. She is working toward an M.S. biology at Florida International University and has a B.S. in marine science/biology from the University of Miami.

Leslie Manzello has been working as an environmental scientist in south Florida for five years. She has been involved with a wide variety of projects and her areas of expertise include seagrass restoration/mapping, coral reef monitoring and mitigation, and water quality monitoring programs. She currently works in the ecological sciences division of PBS&J, an Atkins company, in the Miami, Florida, office. He has a B.S. in marine science from the University of Miami.

Doug Cribbs is a Senior Consultant for ESRI's Professional Services Division and has 15 years of professional geographic information system (GIS) experience focusing mainly on natural resources and environmental program support. Doug has provided GIS consulting support to many federal agencies including the National Park Service, USDA Forest Service, U.S. Fish and Wildlife Service, Minerals Management Service, National Oceanic and Atmospheric Administration, and U.S. Geological Survey, as well as other state organizations and nongovernmental agencies. Doug serves as a senior geodatabase designer and consultant at ESRI's corporate office in Redlands, California. He has an M.S. in management of information systems from the University of Miami and a B.S. in marine biology from Richard Stockton College.

Kristen L. Metzger is a librarian with more than 30 years experience working with scientists and engineers. Before joining CSA International, Inc. (CSA), Ms. Metzger was responsible for the development and administration of the Harbor Branch Oceanographic Institution library. Responsible for information storage and retrieval, she has extensive experience with database design and organization, storage, and retrieval of electronic information. She has an M.A. in library and information science from the University of South Florida and a B.A. in library science/education from the University of Florida.

William R. Sloger has over 18 years' experience specializing in project management and production of National Environmental Policy Act (NEPA) documents. Mr. Sloger has written, reviewed, and/or supervised the preparation of numerous Environmental Assessments (EAs) and Environmental Impact Statements (EISs), which cover a wide range of activities including dredging, Navy operations, and construction. Mr. Sloger was Head of the NEPA Compliance Section of Naval Facilities Engineering Command, Southeast (NAVFAC SE). He has an M.S. in environmental studies from MUSC/College of Charleston, an M.E. in civil engineering from the University of South Carolina, and a B.S. in civil engineering from Clemson University.

Neal W. Phillips is an experienced marine ecologist, impact analyst, technical writer, and editor. Since joining CSA International, Inc. (CSA) in 1983, he has been responsible for analysis, interpretation, and synthesis on numerous multidisciplinary projects for government and industry clients. These include environmental impact assessments, monitoring programs to evaluate pollutant effects, and baseline studies of the marine environment. Dr. Phillips is also an experienced scientific editor. He has edited several major literature reviews for CSA, including a synthesis of environmental and socioeconomic information for the deepwater Gulf of Mexico, the South Florida area, and the Texas and Louisiana continental shelf. He has prepared computerized annotated bibliographies for several projects. He has a Ph.D. in ecology from the University of Georgia, an M.S.in marine studies from the University of Delaware, and a B.A. in biological sciences from the University of Delaware.

David Snyder is an experienced marine ecologist and fish biologist. He has more than 25 years of experience in the ecology and taxonomy of western Atlantic and Gulf of Mexico shelf and shore fishes (particularly seagrass and reef-associated species). He has managed and participated in ichthyofaunal surveys of freshwater, estuarine, shelf, and coral reef habitats. He is currently working with colleagues at the Florida Museum of Natural History to assemble a comprehensive listing and assessment of marine fishes of southwest Florida and the Florida Keys. He is currently investigating habitat utilization by newly settled fishes on nearshore hard bottom habitats in Palm Beach County, Florida for the Florida Department of Environmental Protection. He has participated in coral reef damage assessment and restoration projects in south Florida, the Florida Keys, and the Federated States of Micronesia. He has an M.S. in marine biology/Ichthyology from Florida Atlantic University and a B.S. in zoology from the University of Florida.

Dr. Luis M. Lagera, a marine and estuarine ecologist with more than 19 years' experience in biological and environmental assessments, joined CSA International, Inc. (CSA) in 1992 and has worked on numerous environmental and biological assessments for various clients in the oil and gas industry, focusing mainly on impacts to water quality and biology/ecology. Dr. Lagera also was a co-author and geographic information system (GIS) Coordinator for the Environmental Report of the 5-Year Oil and Gas Leasing Program for seven OCS planning areas and co-author of the Environmental Assessment of Geological and Geophysical (G&G) Exploration in the Gulf of Mexico Outer Continental Shelf for the U.S. Minerals Management Service. Dr. Lagera has research interests and experience in several coastal systems, particularly tropical and temperate wetlands, seagrass beds, barrier island lagoons, estuaries, and reef communities. He has also participated as a data manager and observer in aerial surveys for marine mammals and sea turtles. He has a Ph.D. in environmental sciences (ecology) from the University of Virginia, an M.S. in biological sciences from Mississippi State University, and a B.S. in zoology from the University of the Philippines, Diliman.

M. John Thompson is a senior research scientist with over 35 years of U.S. and international experience as an environmental consultant. He joined CSA in 1980 and has served as a Project Manager and Chief Scientist on numerous, complex environmental risk and hazard assessment studies, including multidisciplinary baseline studies, remote sensing and mapping studies, and monitoring and mitigation development programs. Most recently (1999 to present), he has been Project Manager for the environmental assessments of a number of transnational Liquefied Natural Gas (LNG) projects. He is the author or co-author of 23 professional publications on subjects ranging from coral reef habitat mapping to wildfire modeling and mitigation planning. He as an M.S. in marine biology from Florida Atlantic University and a B.S. in biology from the University of Tampa.

Brian J. Balcom is a Senior Scientist in CSA International, Inc.'s (CSA's) Western Regional Office located in Salinas (Monterey County), California. He is a benthic ecologist with nearly 30 years of experience in biological baseline studies and assessments of the potential effects of man's activities on the marine environment. Mr. Balcom has prepared assessments related to noise effects (e.g., from offshore operations, sonars, and explosives) on marine mammals and sea turtles, with an emphasis on endangered and threatened species. Additionally, he has managed a diverse series of applied science study efforts (e.g., platform characterization, oil and oil dispersant toxicity testing, and biological field surveys). He has an M.S. in biology (marine biology emphasis) and a B.S. in biological sciences, both from the University of Southern California.

Edmund H. Hughes has over 14 years' experience with environmental studies, the majority focused in the marine environment. Mr. Hughes has worked both locally and abroad, and project locations have included Florida, New England (offshore Georges Bank) and the Gulf of Mexico (coastal and offshore areas of Louisiana and Alabama), as well as international locations—Australia, the Caribbean (Trinidad and Puerto Rico), and Sakhalin Island, Russia. Before joining CSA, Mr. Hughes worked for the Florida Department of Environmental Protection (FDEP), where he served as an aquatic biologist for the Watershed Monitoring Program. Before his work with FDEP, Mr. Hughes worked as a research assistant, in conjunction with the U.S. Geological Survey, on several research cruises to Georges Bank that involved benthic survey work using remotely operated and manned submersibles, as well as collecting benthic fauna using an assortment of dredging and video equipment. He has an M.S. in oceanography from GSO-University of Rhode Island and a B.S. in marine biology from the University of Miami.

Keith T. Spring is a marine biologist with over 29 years' oceanographic and environmental science experience. He is currently the Director of the Coastal and Ocean Sciences Division at CSA International, Inc. and has been a Project Manager and/or Chief Scientist on numerous oceanographic studies, including multidisciplinary baseline studies, environmental monitoring programs, nearshore hard-bottom and reef characterization surveys, habitat damage assessment surveys, photo documentation surveys for outer continental shelf oil and gas lease areas and pipeline right-of-ways, and site clearance studies. He has been the Chief Scientist on more than 140 oceanographic surveys in the Gulf of Mexico, off the east coast of Florida, and within the Caribbean. Mr. Spring has extensive experience as a scientific diver, performing more than 1,700 dives in the past 29 years. He has directed or participated in biological surveys of nearshore and offshore reefs, seagrass beds, and soft-bottom habitats in connection with beach restoration and dredging projects on both the east and west coasts of Florida. He has an M.S. in biological oceanography from Florida Institute of Technology and a B.S. in biological sciences from the State University of New York at Brockport.

Frederick B. Ayer, II, is Vice-President and General Manager for CSA. He has over 30 years' experience in marine science and technology. Mr. Ayer is responsible for planning, budgeting, scheduling, instrumenting, and overall coordination of all field operations for CSA. He has also directly participated in a number of CSA's long-term and multidisciplinary monitoring programs and baseline studies concerning oil and gas activities. Mr. Ayer's strongest areas of expertise are the applications and use of navigation and bathymetry systems; remotely operated vehicles and towed underwater video and still camera systems; side and sector scanning sonar, subbottom profilers, and magnetometers; vibracorers; current meter, wave gauge, transmissometer, and sediment trap moorings; and a wide variety of other *in situ* and shipboard data and sample collection and handling devices and systems. He has a B.S. in marine biology from New College of Florida.

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SESSION 3C

AVIAN RESEARCH AND MONITORING STRATEGIES TO ASSESS POTENTIAL IMPACTS RELATED TO OFFSHORE OIL AND GAS DEVELOPMENT

Chair: Jeff Gleason, BOEMRE

Co-Chair: Dave Moran, BOEMRE

IT AIN'T OVER TILL IT'S OVER: INDEPENDENT INFORMATION FLOW AND PROTECTION OF THE OCEAN ENVIRONMENT

W. A. Montevecchi
Cognitive and Behavioral Ecology Program
Departments of Psychology, Biology and Ocean Sciences
Memorial University of Newfoundland, Canada

Global location sensors (GLS) and satellite tags (ST) are used to track marine birds to assess risks associated with offshore hydrocarbon activities. All Northern gannets in the Gulf of Mexico originate from Canadian colonies, yet they are the third most oiled bird in the Gulf, following resident laughing gulls and brown pelicans; gannets also incur the highest proportion of oiling among recovered birds. Tracking data indicate that more than 125,000 gannets or about 25% of the North American population winter in the Gulf of Mexico. Limited information on entry and exit dates suggest that (1) most adult gannets would have departed the Gulf of Mexico before the *Deepwater Horizon* explosion (April 20, 2010) and subsequent environmental damage and (2) most of the mortality was incurred by immature birds. Ongoing GLS tracking and mark-recapture efforts are being used to assess potential biological consequences of the pollution.

In Canada, tracking information obtained from GLS- and ST- equipped common and thick-billed murres are used to assess risk in the NW Atlantic Ocean. Murres occur in proximity to offshore oil platforms and to deep water exploration sites. Seabirds are at times oiled at these sites, but because there are no robust and independent monitoring programs, it is not possible to assess seabird mortality.

Other examples of weak regulatory control in eastern Canadian waters are provided with suggestions for strengthening regulatory regimes, as seems to be underway in the U.S. Maximization of independent information from offshore oil installations and activities is critical for proper environmental assessment. Current circumstances facilitate the misperception that the lack of information indicates the absence of problem. It is essential that regulatory agencies require the design and implementation of potent research programs to capture uncertainty about low-level and episodic catastrophic mortality. It's never over.

W.A. (Bill) Montevecchi, Ph.D., is a University Research Professor, Cognitive and Behavioral Ecology Program, Departments of Psychology and Biology and Ocean Sciences Centre, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. He directs an interdisciplinary research program on the behavioral ecology of marine birds focusing on seabird responses to climate and anthropogenic change and on seabirds as indicators of fish and ocean conditions. Bill has authored more than 300 publications, including 160 peer-reviewed journal papers. With Les Tuck, he co-authored *Newfoundland Birds: Exploitation, Study, Conservation* (1987, Nuttall Ornithology Club, Harvard University). He wrote and narrated a Canadian Broadcasting Company Ideas Documentary *Seabirds: Oceanic Barometers*.

D.A. Fifield was awarded his Master of Science degree in October 2010.

Dr. April Hedd is the lab manager at Memorial University of Newfoundland, Canada.

L. McFarlane-Tranquilla and C.M. Burke are member's of Bill Montevecchi's lab at Memorial University of Newfoundland, Canada, working on their Ph.D. programs.

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DEVELOPMENT OF A SEABIRD SURVEY AND OBSERVATION SPATIAL DATABASE FOR THE U.S. ATLANTIC

Andrew Gilbert
GIS Program Director, BioDiversity Research Institute

Beth Gardner
Department of Forestry and Environmental Resources
North Carolina State University

Allan F. O'Connell
U.S. Geological Survey, Patuxent Wildlife Research Center

Offshore development proposed for U.S. Atlantic waters requires that regulatory agencies such as the Bureau of Ocean Energy Management, Regulation and Enforcement and the U.S. Fish and Wildlife Service assess the effects of activities, such as the building and operation of wind turbines on marine bird populations. Information on the occurrence, distribution, and behavior of seabirds and factors influencing their distribution is needed to adequately assess the potential for impacts, especially for species considered threatened, endangered, or whose species are in decline. Unfortunately, conducting surveys of the marine environment is difficult, and sampling of seabirds in this region has been haphazard over several decades, with the information collected varying among surveys. In addition, the need to quickly consider alternative energy options leaves little time to establish new region-wide sampling programs that compile consistent data over many years. To address this gap in knowledge we retrieved and compiled datasets of seabird occurrence data from a variety of sources including government agencies, academic scientists, non-government organizations, and private individuals. We first created a dataset catalog to contain metadata (compliant with federal standards) for each dataset. Datasets were then processed to re-organize and standardize data fields, and transferred to GIS databases to generate distribution maps. We estimated that we acquired >85% of the seabird occurrence information for the U.S. Atlantic currently. The database currently includes 65 datasets and >400,000 seabird occurrence records from 64 datasets for the northwest Atlantic from Florida to Maine and one from Atlantic Canada. Significance of the data in this compendium almost certainly increases when datasets are viewed collectively rather than individually. These data can now be used to produce mappable products in a GIS environment, and the records are stored a single relational database. Given the complexity of the data, we suggest that the best way to understand the distribution of seabirds is to develop multi-scale (spatial and temporal) hierarchical models that include environmental covariates. Maintenance of the current data and future expansion of the database will require commitment and communication on the part of responsible and interested agencies organizations.

Andrew Gilbert is the GIS Program Director at BioDiversity Research Institute where he oversees all aspects of data management within BRI as the Data Management Director. Before

joining BRI, he received his Master's Degree in wildlife ecology from the University of Maine, Orono, on black tern nesting ecology. Following his degree at UMO, he conducted work on forest songbirds in New York and began his work at the Patuxent Wildlife Research Center. He worked on a variety of projects at Patuxent including the development of an historical and current seabird database for the U.S. Atlantic waters.

Beth Gardner is an Assistant Professor in the Department of Forestry and Environmental Resources at North Carolina State University. She received her Ph.D. from Cornell University and then spent four years as a post-doctoral research associate at Patuxent Wildlife Research Center. Her research focuses on the development of spatial capture-recapture models, hierarchical models of animal abundance and occurrence (e.g., site-occupancy models), Bayesian analysis in ecology, and spatial modeling.

Allan O'Connell is a research wildlife biologist with the U.S. Geological Survey's Patuxent Wildlife Research Center in Laurel, Maryland. He has 30+ years of experience with the U.S. Department of Interior as a field biologist, natural resource and science program manager, administrator, and most recently as a research scientist at Patuxent. He has held a variety of positions during his government tenure including Acting Chief of the National Bird Banding Laboratory (USGS, Patuxent), first director of the National Park Service's (NPS) Cooperative Research Unit at the University of Maine's flagship campus in Orono (NPS and USGS), Division Chief for Natural Resource Management and Science at Acadia National Park (ME) and Fire Island National Seashore (NY).

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IMPACT OF THE *DEEPWATER HORIZON* OIL SPILL ON MIGRATORY SHOREBIRDS: THE GULF AND BEYOND

Bryan J. Sigel, Jessica Henkel, Caz Taylor, and Thomas W. Sherry
Tulane University

Several species of migratory shorebird use the region in the Gulf of Mexico contaminated by the *Deepwater Horizon* oil spill during the winter. Impacts of oil on shorebirds include direct effects, such as mortality, and indirect effects, such as reduced or altered resources. These effects potentially cause reduced population size and lower reproductive success. On the breeding grounds shorebirds may provide critical resources to arctic predators, especially during low phases of the lemming cycle. Through migration, the impacts of the *Deepwater Horizon* spill may be felt in ecosystems far distant from the site of the contamination.

Bryan J. Sigel is a conservation ecologist interested in how human activities affect biodiversity at multiple spatial scales. He was granted a Ph.D. from Tulane University in 2007 where he studied the effects of forest fragmentation on lowland tropical bird communities in Central America. He is a postdoctoral fellow under the direction of Dr. Caz Taylor at Tulane University investigating the impacts of the *Deepwater Horizon* oil spill on shorebird and intertidal invertebrate communities.

Jessica R. Henkel is a Ph.D. student at Tulane University. She is interested in how environmental changes and habitat degradation are impacting coastal habitats of the U.S. Gulf of Mexico and the effects these changes are having on migratory shorebirds. Jessica received her M.S. from the University of New Orleans. She is focusing on the impacts of sea level rise and the *Deepwater Horizon* oil spill on the migration ecology of near-arctic breeding shorebirds.

Thomas W. Sherry is a population ecologist interested in avian migration ecology. He was granted a Ph.D. from the University of California, Los Angeles in 1980. Dr. Sherry is interested in the migration ecology of birds that migrate long distances between tropical and temperate ecosystems and the factors that control or limit their populations. He is an associate professor at Tulane University.

Caz. M. Taylor is a population ecologist interested in how mathematical or computational methods can be combined with field experiments to investigate the dynamics of species. She is particularly interested in how movements of species that are spatially distributed affect their population dynamics. Dr. Taylor earned a Ph.D. from University of California Davis and is an assistant professor at Tulane University.

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ASSESSING THE IMPACT OF OIL POLLUTION ON MARINE WILDLIFE: A EUROPEAN PERSPECTIVE TO STUDY THE EFFECTS OF CHRONIC OIL POLLUTION AND MAJOR SPILLS ON SEABIRD POPULATIONS (1950–2010)

C. J. (Kees) Camphuysen
Royal Netherlands Institute for Sea Research (NIOZ)
Department of Marine Ecology

The impacts of chronic oil pollution and major oil spills on marine wildlife from various sources have been well documented. Probably the best known to North America is the loss of birds and marine mammals associated with the *Exxon Valdez* tanker spill in Alaska. Probably less well known are the seven major spills that have occurred in European seas since 1978. I, along with many of my colleagues, have been studying the impacts of these spills since the late 1970s. In addition, I have been conducting long-term monitoring of oiled wildlife, including seabirds, using systematic beached bird surveys. At least in European waters, it appears that the number of oiled seabirds has been declining over time. This decline may be attributable to fewer major spills (usually tankers that run aground) and possibly also to reduced levels of chronic oil discharges. It is possible that newer technologies and additional regulations, laws, and policies may be resulting in fewer major incidents in Europe and throughout the world. Unfortunately, the recent incident (March 16, 2011) in which the *MS Oliva* ran aground on Nightingale Island (Tristan da Cuñha) represents another potential environmental disaster for the marine wildlife in that area. Particularly hard hit appear to be a species of penguin.

In this presentation, I discuss and summarize nearly 60 years of research and impact assessment work in which I have been involved. I argue that decision-makers must remain vigilant and agency personnel charged with oversight of oil and gas activities must continue their efforts to ensure that regulations are followed. Furthermore, it is critical that environmental laws, regulations, and policies (NEPA in U.S.) be used in a form of adaptive management and that long-term monitoring programs (e.g., beached bird surveys) be implemented where not already utilized. Our experience indicates that the data from such a program, in adddition to a standardized procedure for processing carcasses (www.oiledwildlife.eu), is invaluable for determining injury assessment, predicting potential impacts associated with future spills, determing species vulnerability to oil spills, risk assessment, and documenting changes in oiling rates of birds (tracking oiling through space and time).

Kees Camphuysen is a researcher at the Royal Netherlands Institute for Sea Research (NIOZ) in Texel. Kees has been conducting research with NIOZ since 1992. He began researching seabirds in 1973, became involved in Beached Bird Surveys in 1974 assessing the impacts of chronic oil pollution, and has been co-coordinator for this project since 1977. Kees has been involved with impact assessments on seven European oil spills dating back to the *Amoco Cadiz* oil spill in 1978. He is a member of the scientific committee and supervisor of scientific research and impact assessments of the *Prestige* oil spill in Spain (2002–2003), and is responsible for scientific research and impact assessments for the Dutch portion of the *Tricolor* oil spill in 2003. He is the primary author of the *European Handbook on Oil Impact Assessment*. Kees has authored or co-authored over 450 refereed and non-refereed publications, book chapters, and reports.

Click here to view the slide show that accompanied this presentation.

HIERARCHICAL MODELING OF SEABIRD DISTRIBUTIONS IN THE U.S. ATLANTIC

Beth Gardner
Department of Forestry and Environmental Resources
North Carolina State University

Allan F. O'Connell
U.S. Geological Survey, Patuxent Wildlife Research Center

Andrew Gilbert
GIS Program Director, BioDiversity Research Institute

The pressure from offshore wind energy development and potential oil spills and climate change require regulatory agencies to assess the potential impacts to a number of sea bird species. To help inform such decisions, we developed a spatially-explicit log-linear hierarchical model that allows for estimation of species distribution patterns from a suite of historic surveys. The framework we developed provides a mechanism for the incorporation of disparate surveys across the northwest Atlantic Ocean, making the most efficient use of a variety of data sets. To actuate the model, we placed a ¼ degree latitude grid over the study region (from Maine to Florida, extending out past the continental shelf) and assigned all survey data from a variety of historic surveys to a grid cell. We then model the spatially-referenced count data for individual species as a function of biophysical covariates, such as sea-surface temperature, chlorophyll, and bathymetry, and include an offset to account for variation in survey effort. We also note that this flexible framework can be updated to include new survey data as they become available. Modeling sea bird distributions is an important first step in understanding the potential impacts that may result from wind energy development, but also from broad scale changes associated with global climate change.

Beth Gardner is an Assistant Professor in the Department of Forestry and Environmental Resources at North Carolina State University. She received her Ph.D. from Cornell University and then spent four years as a post-doctoral research associate at Patuxent Wildlife Research Center. Her research focuses on the development of spatial capture-recapture models, hierarchical models of animal abundance and occurrence (e.g., site-occupancy models), Bayesian analysis in ecology, and spatial modeling.

Allan O'Connell is a research wildlife biologist with the U.S. Geological Survey's Patuxent Wildlife Research Center in Laurel, Maryland. He has 30+ years of experience with the U.S. Department of Interior as a field biologist, natural resource and science program manager, administrator, and most recently as a research scientist at Patuxent. He has held a variety of positions during his government tenure including Acting Chief of the National Bird Banding Laboratory (USGS, Patuxent), first director of the National Park Service's (NPS) Cooperative Research Unit at the University of Maine's flagship campus in Orono (NPS and USGS),

Division Chief for Natural Resource Management and Science at Acadia National Park (ME) and Fire Island National Seashore (NY).

Andrew Gilbert is the GIS Program Director at BioDiversity Research Institute where he oversees all aspects of data management within BRI as the Data Management Director. Before joining BRI, he received his Master's Degree in wildlife ecology from the University of Maine, Orono, on black tern nesting ecology. Following his degree at UMO, he conducted work on forest songbirds in New York and began his work at the Patuxent Wildlife Research Center. He worked on a variety of projects at Patuxent including the development of an historical and current seabird database for the U.S. Atlantic waters.

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GULF COAST JOINT VENTURE OIL SPILL HABITAT RESPONSE STRATEGIES

William G. Vermillion, Barry C. Wilson,
Michael G. Brasher, and Mark W. Parr
Gulf Coast Joint Venture

The Gulf Coast Joint Venture (GCJV) is a bird habitat conservation partnership of private, state, and federal organizations that operate across the coastal portions of Texas, Louisiana, Mississippi, and Alabama. On April 20, 2010, the *Deepwater Horizon* explosion occurred. As potential impacts of the subsequent oil spill to migratory birds became apparent, the GCJV office received requests from the U.S. Fish and Wildlife Service, the Natural Resources Conservation Service (NRCS), the National Fish and Wildlife Foundation and the Western Hemispheric Shorebird Reserve Network for habitat response strategies designed to mitigate those impacts. GCJV staff, with input from GCJV partner organizations, developed numerous habitat response strategies. To assess potential habitat impairment, GCJV staff developed five scenarios of hypothetical oiling extent. These scenarios were used to first calculate potential shorebird and waterfowl habitat impairment, and subsequently to estimate compensatory habitat required to offset those impacts. This information contributed to the development and implementation of the NRCS Migratory Bird Habitat Initiative (MBHI), which provided incentives to agricultural and aquaculture producers to provide habitat for waterfowl and shorebirds to offset potential oil spill impacts through conservation measures promoted by the GCJV before the spill. Evaluation of the effectiveness of the MBHI is underway.

William (Bill) Vermillion is Bird Conservation Specialist for the Gulf Coast Joint Venture (GCJV), a partnership of state, federal, and non-governmental organizations dedicated to conservation of priority birds in the Gulf of Mexico region from Texas to Alabama. He graduated from the University of Southwestern Louisiana in 1986 with a B.S. in zoology-wildlife management. Upon graduation, Bill worked approximately five years as an interpretive naturalist for the City of Lafayette, Louisiana, before taking a biologist position with the Louisiana Department of Wildlife & Fisheries Natural Heritage Program. In 2001, he joined the U.S. Fish and Wildlife Service as a Fish and Wildlife Biologist in the Louisiana Ecological Services Field Office. In 2005, he accepted his current position with the GCJV. His major duties include developing population and habitat objectives for priority non-waterfowl species in the GCJV region, reviewing and ranking bird conservation grant proposals, assisting partner agencies with bird habitat project planning and implementation, and collaborating with researchers and biologists to address information needs relative to bird conservation planning.

Barry Wilson has, for 14 years, been on the staff of the Gulf Coast Joint Venture, a bird habitat conservation partnership spanning the coastal portions of Texas eastward to Alabama. Currently a U.S. Fish and Wildlife Service employee, he has also worked for Ducks Unlimited, as a refuge biologist for the Louisiana Department of Wildlife and Fisheries, and as a research associate for Delta Waterfowl Foundation in a career spanning 18 years. His academic background includes an M.S. from Louisiana State University and a B.S. from Midwestern State University. His professional interests include bird habitat-population relationships, waterfowl population dynamics, and wetland habitat management.

Michael (Mike) Brasher is Biological Team Leader for the Gulf Coast Joint Venture bird habitat conservation partnership, where he coordinates conservation science and planning for waterfowl in the Western Gulf Coast. Mike joined Ducks Unlimited, Inc. and the Gulf Coast Joint Venture in 2005. He is stationed in Lafayette, Louisiana, within the USGS National Wetlands Research Center. Mike earned a Ph.D. in natural resources and the environment (2010) from The Ohio State University, where he studied waterfowl conservation values of actively and passively managed wetlands in Ohio. He received his M.S. in wildlife ecology (2000) and B.S. in wildlife and fisheries science (1997) from Mississippi State University. His Master's research examined the reliability of indicated breeding pair criteria for estimating mallard breeding populations. Mike is Vice Chair of the North American Waterfowl Management Plan Science Support Team.

Mark Parr graduated from the Ohio State University in 1990 with a B.S. in forest resource management, received an M.S. in forest science from the University of Georgia (1992) and a Master of Forestry, GIS/Remote Sensing from Colorado State University (2000). Mark has worked as a research assistant, botanist, forester and GIS/ Remote Sensing Analyst for a variety of agencies and organizations ranging from the University of Georgia, Oregon State University, University of Washington, the U.S. Forest Service, the Colorado State Forest Service, to private sector work with space imaging in Portland, Oregon, before joining the U.S. Fish and Wildlife Service as a staff member of the Gulf Coast Joint Venture in 2004.

SESSION 3D

SHALLOW SEDIMENT TRANSPORT

Chair: Roger Amato, BOEMRE

Co-Chair: Bill Shedd, BOEMRE

RESULTS OF A GEOPHYSICAL AND SEDIMENTOLOGICAL EVALUATION: TIGER-TRINITY SHOALS AS SOURCES OF SAND FOR COASTAL RESTORATION

Harry H. Roberts, DeWitt Braud and Clint H. Edrington
Coastal Studies Institute, School of the Coast and Environment
Louisiana State University

Syed M. Khalil
Louisiana Office of Coastal Protection and Restoration

If coastal land loss during the 20th century were not detrimental enough, south Louisiana is projected to lose an additional 500 mi^2 (1,295 km^2) of coastline over the next 50 years. To mitigate expected losses, one approach is to rebuild Louisiana's beaches and offshore barrier islands, as they serve as physical buffers between open-marine processes and the marshlands that lie behind them. This study reevaluates the quantity and quality of sands within the offshore Trinity-Tiger Shoals Complex, because it represents a potential sand-borrowing site for restoring Marsh Island and the adjacent eastern Chenier plain. An initial survey gathered over 750 miles (1,200 km) of high-resolution sub-bottom profiles, magnetometer, side-scan sonar, and fathometer data. This data collection was later followed by a coring campaign in which 46 vibracores were collected. Cores were processed using a GEOTEK core logger, imaged, described lithologically, and sampled at 20 in (50 cm) intervals for grain-size analyses. All geophysical and lithological data were integrated using 3-D visualization software. Trinity Shoal, the most seaward and by far the larger of the two shoals, is an arcuate sand body composed entirely of very fine sands, with a thin transgressive sand sheet that protrudes from its northwest quadrant. These transgressive sands ultimately weld to Tiger Shoal's western perimeter. Tiger Shoal is also composed of mostly very-fine sands, except in its most extreme eastern section where medium-size sands exist. Total sand volume within the Trinity-Tiger Shoal Complex is ~ 933 million yd^3 (731 million m^3), which is 2.73 times smaller than a previous study's calculated volume. However, petroleum-industry infrastructure is extensive across the shoal complex and constrains where sands may be safely targeted: only ~ 543 million yd^3 (346 million m^3) of sand are available for extraction.

Clint Edrington was born and raised on the Mississippi Gulf Coast and has degrees in geology and geophysics from University of New Orleans and LSU. In 2008, he began working on a doctorate at LSU, where he is now studying the sedimentology, stratigraphy, and depositional history of the Trinity and Tiger Shoals Complex offshore Louisiana.

Dr. Harry H. Roberts is the former director of Coastal Studies Institute at LSU, an emeritus member of the Department of Oceanography and Coastal Sciences (School of the Coast and Environment), and a Boyd Professor. His career in marine geology spans more than 40 years and he has worked in many foreign countries as well as in the U.S. Recently, his research has focused on three themes: (a) modern deltaic sedimentation and processes, (b) shelf-edge deltas, and (c)

surficial geology of the northern Gulf's continental slope. The latter research has concentrated on building an understanding of the impacts of fluid and gas expulsion on the surficial geology and biology of the slope.

DeWitt Braud is a researcher in the Louisiana State University Coastal Studies Institute. For over 30 years he has specialized in remote sensing and Geographic Information Systems (GIS) applications involving major projects in Louisiana related to coastal and statewide issues. Mr. Braud has also developed numerous image processing and GIS methods for analysis of satellite imagery and spatial data, image classification, multitemporal image analysis, land-water interface detection and extraction, coastal wetland analysis, change detection, and land loss.

Syed M. Khalil is a geologist and advisor to the Executive Director & Division Chief of Governor's Office of Coastal Protection & Restoration, Louisiana. His primary focus is on the geo-scientific issues/sediment management pertaining to Integrated Coastal Zone Management for restoration, mitigation, and management of coastal environment to address severe and chronic wetland loss, including the design and implementation of the Louisiana Sediment Management Plan (LASMP) to efficiently manage the use of sediment resources to restore and sustain the Mississippi River Delta.

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WAVE, CURRENT AND SEDIMENT TRANSPORT MODELING AT TIGER AND TRINITY SHOALS, OFF MARSH ISLAND, LOUISIANA

Felix Jose and Mohammad Nabi Allahdadi
Coastal Studies Institute and
Department of Oceanography and Coastal Sciences
Louisiana State University

Two oceanographic surveys were conducted at the Tiger-Trinity shoal complex during December 2008 and March–April 2009. Tripods equipped with ADCP, PCADP, ADV, OBS and pressure sensors were deployed along a shore normal transect for monitoring waves, currents and sediment transport in the shoal complex. During the 2008 deployment, which lasted for two weeks and with a single tripod deployed over Tiger shoal, three cold fronts crossed the study area and significantly influenced the hydrodynamics of the region. The maximum wind speed observed was 14.2 m/s while the maximum wave height recorded was less than 1 m. This substantial wave attenuation observed for Tiger Shoal can be attributed to the nature of the bottom sediments. During the 2009 spring deployment, the influence of fine grained sediments, debouched from the Atchafalaya River, was noticed at the shoal complex; particularly for the Tiger shoal, which would occasionally be blanketed by river-borne sediments, when the peak discharge coincides with the passage of cold fronts.

A suite of hydrodynamic models was also implemented to estimate the effect of waves and currents on the shoal dynamics. MIKE 21 wave and hydrodynamic models, developed by DHI Water and Environment®, were implemented for the Tiger and Trinity shoal system. A substantial reduction in wave height was observed seaward off Trinity Shoal. This can be attributed to rapid increase in depth gradient off Trinity Shoal. Also, the hydrodynamic model data demonstrated that strong currents existed over the shoal region, which are critical in the redistribution of sediments. The model results also confirm the southeastward migration of sediment plumes from Atchafalaya River during the post-frontal phase of winter storms.

Dr. Felix Jose received Master's and Ph.D. degrees from Cochin University in India and did post-doctoral work at the University of Azores in Portugal. He began his work with Dr. Greg Stone at the Coastal Studies Institute at LSU in 2004 and specializes in numerical modeling for sediment transport and other marine processes in the Gulf. He also is managing the WAVCIS ocean observation program at LSU.

Mohammad Nabi Allahdadi is a coastal and marine modeler having over 10 years' experience in implementing modeling projects for rivers, coastal areas and marine environments. Modeling efforts have mainly focused on wind-induced waves, currents, and sediment transport. Since joining LSU as a Ph.D. student at the Coastal Studies Institute, he has been involved in a number

of coastal modeling projects along the northern Gulf coast. He has presented his research and modeling work at Coastal Sediments 2011 conference and other scientific venues.

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GEOPHYSICAL AND GEOLOGICAL INVESTIGATION OF THE INCISED SABINE-TRINITY RIVER VALLEY SYSTEM AND SABINE AND HEALD BANK

Timothy Dellapenna, James Garrison and Andre Cardenas
Texas A&M University, Department of Marine Sciences, Galveston

James Flocks
U.S. Geological Survey, St. Petersburg, Florida

Juan Moya
Atkins North America, Austin, Texas

The inner portion of the mid-continental shelf in the northern Gulf of Mexico contains a series of shore parallel banks, the largest of which is Sabine Bank, at 600 km^2 and is situated approximately 30 km offshore, in 5–12 m of water. The second largest is Heald Bank, at 475 km^2, 45 km offshore, and in 9–15 m of water. These two banks are situated on the incised Sabine-Trinity valley, which runs parallel to the coast at the location of the banks. Much research and exploration of Sabine Bank has previously been conducted. The focus of this study was to collect a few additional cores on both Sabine and Heald Bank and to characterize the sediments in various types of other stratigraphic targets found within the incised channels off of the banks, which have largely been ignored in previous investigations. The study site was located on the Sabine River submerged paleo-channel, Sabine Bank, Heald Bank, Shepard Bank and Trinity River submerged paleo-channel, called Paleo-Sabine-Trinity Marine Features (PSTMF). This project was funded from 2009–2010 by BOEMRE, through an agreement with the Texas General Land Office and was conducted by the Coastal Geology Laboratory at Texas A&M University at Galveston, in partnership with the USGS. The project included three phases, 1) literature review of existing data and reports of the study area; 2) field geophysical data collection and data analyses; 3) field sediment core collection; 4) sediment core analyses and report preparation. During the field phase of the study, 690 line-km of high-resolution chirp seismic-reflection profiles were collected from the R/V Manta. The chirp data were evaluated and specific stratigraphic coring targets were identified both on the banks as well as off of the banks within both incised valleys. During the coring phase 27 submersible vibracores were collected aboard the R/V Gilbert from 25 different sites. The cores had a maximum length of 5.6 m, so only targets this deep or shallower could be sampled. The results revealed that all of the targets identified within the incised valleys off of the banks were mud-filled with only thin sand layers which did not represent viable sand resources. Similar stratigraphic sequences were found on both Sabine and Heald Bank; in each case, there were three sand-bearing units identified. Facies C is the basal sand bearing facies. It is composed of a sandy mud, with less than 50% sand. Facies B sits directly atop Facies C and is composed of a muddy sand. Facies A is composed of sand and shell gravel hash. From this study, new, revised estimates of total sand for each bank were made. For Heald Bank, Facies C is estimated to contain $81x10^6$ m^3, Facies B is estimated to contain $273x10^6$ m^3, Facies A is estimated to contain $364x10^6$ m^3, for a total of $718x10^6$ m^3. For Sabine Bank, Facies C is estimated to contain $638x10^6$ m^3, Facies B is estimated to contain

338×10^6 m^3, Facies A is estimated to contain 413×10^6 m^3, for a total of $1{,}389 \times 10^6$ m^3. These estimates are 18.5 and 13.6% higher, respectively than the estimates for sand volume made by Morton et al. (1995).

Reference

Morton, R.A. and J. C. Gibeaut. 1995. Physical and environmental assessment of sand resources: Sabine and Heald Banks second phase 1994–1995. Report to the U.S. Department of the Interior 14-35-0001-30635. 62 pp.

Dr. Timothy M. Dellapenna is an Associate Professor at Texas A&M University and holds joint appointments with the Department of Oceanography (TAMU-College Station) and Marine Sciences (TAMU-Galveston). He operates the Coastal Geology Laboratory at TAMUG. His research is presently focused on sedimentary processes in estuarine, inner and mid shelf systems along the northern Gulf of Mexico. Included in this work is the impact of hurricanes on various coastal systems, the geology of oyster reef, geological controls on habitats and geological framework studies for sand source investigations. In addition to his Ph.D. in marine science, he has an M.S. in hydrogeology and an M.S. in geology. He has authored or co-authored 28 journal publications and over 40 technical reports.

Dr. James Garrison holds a Ph.D. in geological sciences from the University of Texas at Austin and held a Post-Doctoral Fellowship at the University of Tennessee at Knoxville. He has spent his career as a research scientist and as a lecturer in both academic institutions and the energy industry. Dr. Garrison has published 42 technical papers and has made 38 technical presentations at professional society meetings and is currently working as an independent consultant for the energy industry.

Andre Cardenas is a graduate student at Texas A&M University at Galveston pursuing a Master of Marine Resource Management degree through the Department of Marine Sciences. His master's thesis topic is addressing the relative economic value of Sabine Bank as a fisheries habitat and as a sand resource. Mr. Cardenas holds a B.S. from the University of Texas at Brownsville in environmental science.

James Flocks is a geologist with the U.S. Geological Survey, St. Petersburg Coastal and Marine Science Center. His main research focuses on geologic framework in coastal zones, shoreline evolution, sediment resources, and contaminant inventories in marine and lacustrine environments. Mr. Flocks received a B.S. in geology at the Florida State University, and an M.S. in geology at the University of Southern California. He has been with the USGS since 1992 and is currently studying the evolution of barrier island systems in the northern Gulf of Mexico.

Dr. Juan Moya is Senior Geoscientist with Atkins North America in charge of the Coastal Planning and Restoration Group. He is working on Regional Sediment Management Studies for habitat restoration and Beneficial Use of Dredge Material opportunities for coastal projects. He

also works on the management of contaminated dredged sediments. He is working with coastal municipalities on coastal management plans for future infrastructure. For 11 years, Juan Moya worked with all the habitat restoration and coastal infrastructure programs at the Texas General Land Office (GLO).

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SHALLOW SEDIMENT TRANSPORT MODELING OFF THE NORTHEAST COAST OF FLORIDA

Gary A. Zarillo
Florida Institute of Technology and
Scientific Environmental Applications, Melbourne, Florida

Kim A. Zarillo
Scientific Environmental Applications, Melbourne, Florida

The geology of modern and ancient marine sand bodies has been discussed in numerous technical reports and publications and has been the subject of study for more than 75 years within the research laboratories of the oil and gas industry. Many of the world's largest oil and gas reservoirs are within marine sandstones due to the sequence stratigraphy that is associated with sand body development. Fine-grained estuarine silts and clays at the base of the sequence provide the source material for petroleum. The clean tide and storm processed sands of shoreface connected shoals provide the porous reservoir units. Mud deposited over the nearshore and shoreface successions during sea-level transgressions provide the confining rocks. These same sedimentary features can be found in modern sand ridges, which are frequently mined for sand and gravel resources. Since these sand bodies occur mostly in shallow water near modern shorelines, excavation of large volumes of sand has a potential to influence the local wave regime and associated littoral processes. This potential was quantified in the coastal waters offshore of northeast Florida where numerous sand shoals have been identified as containing significant sand and gravel resources. Four model grids were established over large areas of the inner continental shelf and used to apply the Coastal Modeling Scheme (CMS) developed by the U.S. Army Corps of Engineers Engineering and Research Development Center (ERDC). The CMS combines wave (CMS-WAVE) and circulation (CMS-FLOW) models with sand transport topographic change calculations. Time advancing model runs of up to two years over each of the grids were run with and without sand excavation pits placed in the topography of sand shoals represented in the model bathymetry. Model boundary conditions were established from measured and predicted water level data, hind-cast directional wave data, and wind stress derived from meteorological data. Where possible, predicted data were validated against measured wave data. Model data were examined for differences in local wave regime and in littoral processes at the shoreline landward of shoal positions. Analysis of the model data showed that the topography of single and multiple excavations produced variations in local wave patterns over the shoals and landward of the shoals for a substantial distance. The influence of the excavation pits was most apparent during high wave and storm conditions that were included in the model forcing. In the littoral zone near the shoreline, predicted topographic changes were compared along with predicted annual littoral sand budgets. This analysis showed that inshore of some of the shoals that were investigated, the differences among the test cases were spatially organized in the alongshore direction, indicating a small but detectable zone of influence arising from the location of excavations on the crest of the shoals. The range of differences in this zone of influence of +/- 500 m^3/yr compared with total annualized rates of littoral sand transport of more than 150,000

m^3/yr. Analysis of the variability of predicted transport rates also indicated that the impact of offshore excavation within the zone of influence at the shoreline was relatively small since the predicted difference in transport among the test cases was well below the temporal standard deviation of sand transport predicted for any location on the shoreface. The overall conclusion is that sand excavation as typically designed will likely have a small but detectable impact on littoral sediment transport rates along the shoreline of Northeast Florida. However, compared to the annual sand budget and natural inter-annual variability, the impact is likely to be very small and almost indistinguishable from natural variability. On the other hand, it can be shown that predicted patterns of topographic change over the crest of all shoals examined in this study will be altered by the presence of borrow excavation. This is consistent with the expected changes in wave height that can occur as long-period and high waves generated by storms pass over the sand ridges.

Gary Zarillo is Professor of Marine Science at the Florida Institute of Technology in Melbourne, Florida. He also co-founded Scientific Environmental Applications, Inc., also in Melbourne, the firm that completed this and other environmental studies in support of the BOEMRE Marine Minerals Program. Dr. Zarillo has more than 30 years of experience in coastal processes, marine geology and physical oceanography. He has conducted applied and basic research on continental shelf sediment dynamics, tidal inlet hydraulics, dynamics of barrier island systems, sediment transport mechanics and the hydrodynamics of nearshore and estuarine environments. He has conducted geophysical surveys and geotechnical investigations for sand source studies and beach renourishment projects. For the past 11 years, Dr. Zarillo has been a key member of the model development team for the Coastal Modeling System (CMS) sponsored by the Coastal and Hydraulics Laboratory of the U.S. Army Corps of Engineers Engineering and Research Development Center (ERDC).

Kim Zarillo, President of Scientific Environmental Applications, Inc. (S.E.A.) has 29 years of experience in the private and public sectors conducting ecological and physical assessments, feasibility studies, public policy analysis and public education. Ms. Zarillo was responsible for project management and preparation of final deliverables for two BOEMRE projects: Biological Characterization/Numerical Wave Model Analysis within Identified Borrow Sites Offshore the West Coast of Florida/Physical Implications of Sand Dredging on the Topography of the West Florida Shelf and Biological Characterization/Numerical Wave Model Analysis within Identified Borrow Sites Offshore the Northeast Coast of Florida.

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BANK EROSION OF NAVIGATION CANALS IN THE WESTERN AND CENTRAL GULF OF MEXICO

Stephen Hartley, Scott Wilson and Cindy Thatcher
U.S. Geological Survey, National Wetlands Research Center, Lafayette, Louisiana

Erosion of navigation canal banks is a direct cause of land loss, but there has been little quantitative analysis to determine why certain major canals exhibit faster widening rates (indicative of erosion) than others in the coastal zones of Texas, Louisiana, Mississippi, and Alabama. We hypothesize that navigation canals exhibit varying rates of erosion based on soil properties of the embankment substrate, vegetation type, geologic region (derived from digital versions of state geologic maps), and the presence or absence of canal bank armaments (that is, rock rip-rap, concrete bulkheads, or other shoreline protection structures). The first objective of this project was to map the shoreline position and substrate along both banks of the navigation canals, which were digitized from three different time periods of aerial photography spanning the years of 1978/79 to 2005/06. The second objective was to quantify the erosion rates of the navigation canals in the study area and to determine whether differences in erosion rates are related to embankment substrate, vegetation type, geologic region, or soil type. To measure changes in shoreline position over time, transects spaced at 50-m (164-ft) intervals were intersected with shorelines from all three time periods, and an annual rate of change was calculated for each transect. Mean annual rates of shoreline change ranged from 1.75 m/year (5.74 ft/year) on the west side of the Atchafalaya River, Louisiana, where there was shoreline advancement or canal narrowing, to -3.29 m/year (-10.79 ft/year) on the south side of the Theodore Ship Channel, Alabama, where there was shoreline retreat or erosion. Statistical analysis indicated that there were significant differences in shoreline retreat rates according to geologic region and marsh vegetation type and a weak relationship with soil organic content. This information can be used to better estimate future land loss rates associated with navigation canals and to prioritize the location of restoration and erosion mitigation efforts. Combining all canals together, our results also showed that canal erosion rates have slowed in recent years, with an average canal widening rate of -0.99 m/year (-3.25 ft/year) for the 1996/98–2005/06 time period compared to -1.71 m/year (-5.61 ft/year) for the earlier 1978/79–1996/98 time period. Future research could focus on obtaining detailed vessel traffic information for individual canals, which is likely a factor that influences canal bank erosion rates.

Steven Hartley is a geologist with the U.S. Geological Survey's National Wetlands Research Center in Lafayette, Louisiana. His research focus is on delta environments, climate change, coastal hazards, and data integration. He has degrees in geology from the University of Louisiana and Louisiana Tech and has been with the USGS since 2000.

Scott Wilson is the Chief of the Spatial Analysis Branch in the U.S. Geological Survey's National Wetlands Research Center. The Spatial Analysis Branch focuses on developing and using the latest technology to provide natural resource managers with advanced analysis

techniques and spatial data to make informed decisions. He received his Ph.D. and Master's from the University of Louisiana in computer engineering and received his B.S. at the University of New Orleans in electrical engineering.

Cindy Thatcher is a geographer at the U.S. Geological Survey's (USGS) National Wetlands Research Center in Louisiana. Her current research focus is on delta environments, climate change, coastal hazards, and data integration. She previously worked at the USGS Southern Appalachian Field Branch for several years, where she was involved in GIS-based wildlife habitat modeling, with a main focus on the Florida panther. She has a Master's degree in geography from the University of Arkansas and an undergraduate degree from James Madison University.

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SESSION 3E

OFFSHORE ECOLOGY II

Chair: James Sinclair, BOEMRE

Co-Chair: Maureen Mulino, BOEMRE

DISTRIBUTION, ABUNDANCE, RECRUITMENT, AND GENETIC AFFINITIES OF CORALS ON PLATFORMS IN THE GULF OF MEXICO

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***Current Address**

Summary

Introduction

Approximately 14,000–20,000 years ago, at the end of the Pleistocene, sea level was 100 m below its present level. It is likely that coral reefs occurred regularly along the shoreline, which would currently be the edge of the continental shelf. Sea level rose thereafter and most banks did not grow upward at rate sufficient to pace sea level rise. Most of these features became drowned reefs. Only two grew at approximately the same rate as sea level rise; these were the East and West Flower Garden Banks (FGB). These banks occur 120 miles S-SE of Galveston, TX on top of salt domes and are the only only true coral reefs and shallow substratum between Mexico and the Florida Keys.

In the 1940s, the U.S. began to drill for oil on the continental shelf. To date, there have been approximately 30,000–40,000 wells drilled on the continental shelf of the northern Gulf of Mexico. By law, the platforms must be removed within one year of cessation of production. Over the past few decades, these platforms have been renowned for their fishing. During the 1980s, corals were also observed to have colonized the platforms.

Questions:

The research program described herein is comprised of three projects, posing a set of questions about the impact of the presence of oil and gas platforms on coral community structure, recruitment processes, and genetic affinities of scleractinian corals in the region. Each project represents a phase of the overall program:

<u>Phase I</u>

- To what degree have corals colonized platforms – around the FGB and in NW Gulf?
- What is the relationship between coral population/community characteristics and distance from FGB?
- What are the coral recruitment patterns on these platforms *vs.* on the FGB?
- What are the genetic affinities of coral populations between the FGB and neighboring platforms?

<u>Phase II</u>

- What are the coral distribution and abundance patterns on platforms throughout the northern GOM?
- What are the genetic affinities between coral populations throughout the northern GOM – at the macro-scale?

<u>Phase III</u>

- Are toppled R2R structures facilitating coral community development in the N. Gulf of Mexico?
- Do these coral communities vary from those on standing oil/gas platforms?

Phase I: Coral Community Results – Platforms near the FGB

In this first phase of this program, we focused on 13 platforms in the NW Gulf of Mexico around the Flower Garden Banks. The study area had a radius of ~60 km around the FGB and was oval-shaped. Surveys were performed by up to seven teams of SCUBA divers on a given platform. The surveys revealed that this set of platforms had been colonized by 11 spp. of scleractinian corals. The three most abundant hermatypic/zooxanthellate corals found were *Madracis decactis*, *Diploria strigosa*, and *Montastraea cavernosa*, in order of abundance.

A number of ahermatypic/azooxanthellate corals were also found. The most abundant was *Tubastraea coccinea* – an invasive Indo-Pacific coral, which surpassed the abundance of the other species by orders of magnitude. The second most abundant ahermatype was *Oculina diffusa*, the common ivory coral. The third most abundant ahermatype was *Phyllangia americana.*

The general results of this project were that there was no significant relationship between distance from the Flower Garden Banks, and coral abundance or species diversity. A positive relationship was found, however, between coral density and platform age. A similar positive relationship was revealed between platform age and species diversity, which increased with platform age. This was confirmed through analysis of the coral community data as revealed by analysis by PATN, a pattern-seeking analysis. The results showed that ten of the platforms grouped together being clearly differentiated from the other three – out of a total 13 platforms considered. The 10 platforms had all been deployed $\geq$ 15 yrs; the other three were $\leq$ 15 yrs old.

Phase II vs. Phase I Design

In Phase I, no relationship was found between coral abundance or any other community or population variable and distance from the Flower Garden Banks. We suspected that the spatial scale assessed here was insufficient to reveal any distance relationships. Therefore, the spatial scale was extended by an order of magnitude – from Matagorda Island, Texas to Mobile, Alabama. In addition, platforms on the continental shelf were sampled across the continental shelf from 20 km offshore to just beyond the edge of the shelf break. Four transects were sampled: off Matagorda Island, TX; off Port Arthur/Lake Sabine, TX; off Terrebonne Bay, LA; and off Mobile, AL.

We found that hermatypic coral species diversity exhibited a unimodal distribution, peaking around the Flower Garden Banks. That peak fell off rapidly in all directions, except inshore to Port Arthur/Lake Sabine, which represented an extension of the coral community on the FGB. This was the first evidence that hermatypic corals on the platforms were generally recruiting from the FGB.

This pattern was mimicked when the total density of hermatypic/zooxanthellate corals was considered—a peak near the FGB, with decreasing abundance in all directions. This reinforced the conclusion that the corals were generally coming from the Flower Garden Banks.

When one considers individual species, *Diploria strigosa* exhibited the same pattern. This result was counter-intuitive, however, because *D. strigosa* is a broadcaster, and it is believed that their larvae are dispersed much greater distances than brooded larvae. The observed pattern one might expect from a brooding coral.

Madracis decactis, a brooding coral, exhibited the same general pattern of abundance throughout the northern Gulf of Mexico. It did exhibit a peak in the near-eastern sector, however, which was counter-intuitive because it is not near a local larval source. Brooded larvae are not believed to travel far before settling. The observed pattern may be due to larvae drifting east until they prefer to settle, which may peak after several days of drifting.

The ahermatypic corals for the most part exhibited a different pattern of response. *Tubastraea coccinea* abundance peaked in the east, but not near the FGB. This suggests that it was either colonized from the Loop Current or through a repeated invasion via the New Orleans port. *Oculina diffusa* density peaked near the FGB and appears to have been derived from there. It is *Phyllangia americana,* on the other hand, exhibited a cline in abundance, peaking in the west. This suggests that the population is derived from Mexico or the Caribbean, with larvae being carried by a clockwise current around the perimeter of the Gulf of Mexico.

Phases I & II: Genetic Affinities between Platforms and the FGB - Molecular Genetics

Phase I

- The two species analyzed for genetic affinities were the hermatypic *Diploria strigosa* and *Madracis decactis.* Their population numbers were the only ones sufficiently large for molecular genetic analysis. *D. strigosa* is a broadcast spawner. *Madracis decactis* is a brooder.

- *Diploria strigosa* displayed high self-recognition with respect to its sites or platforms of origin and a low level of cross-recognition between sites. This means that populations of this coral were unique with respect to those around them – that there was a low level of gene flow between platforms and potentially a high level of self-seeding. This is counter-intuitive for a broadcasting coral.

- *Madracis decactis*, on the other hand, exhibited a moderate level of self- and cross-recognition between sites. This means that gene flow (larval dispersal and success of recruitment) between sites was higher. There was still, however, evidence of self-seeding and possibly Founder Effect, since sites were exhibiting self-recognition. When the genetic distance between *Madracis decactis* populations was considered as a function of geographic distance between sites, genetic distance increased significantly as geographic distance in a curvilinear manner. This analysis included all combinations and permutations of platforms and the Flower Garden Banks as sites.

Phase II – Genetic Distance between Coral Populations across the Northern Gulf of Mexico

- *Madracis decactis* exhibited a clear genetic affinity with the Flower Garden Banks, with its average level of affinity on the platforms decreasing steadily towards the east, moving away from the FGB. An unusual secondary peak in genetic affinity was also observed off Mobile, Alabama, on the eastern side of the Mississippi River.

- The ahermatypic coral *Tubastraea coccinea* exhibited no genetic affinity with the FGB, and, as revealed by its generally flat distribution, appears to have reached an equilibrium in this region. An isolated severe and punctuated point of low genetic affinity occurred south of Terrebonne Bay. This indicates that a population exists there that is completely different from others around it. In addition, there is a precipitous drop in genetic affinity in the populations near Mobile, Alabama. This indicates that they are not related to populations on the Flower Garden Banks and may have been seeded from elsewhere – perhaps the Alacran region or via the Caribbean Current and the Loop Current.

- When a detailed comparison was made of populations of *Madracis decactis* on the east and west sides of the Mississippi River mouths, it was found that there was absolutely no genetic relationship between them. These two sets of populations were completely isolated. There was also little or no connectivity between different platforms within a given side of the river. When *Tubastraea coccinea* was analyzed in a similar manner, once again, no genetic connectivity could be found between eastern and western sides of the river mouth, but the platform populations were found to exhibit a higher cross-recognition within a side. This indicates that T. coccinea larvae have higher dispersal and recruitment capabilities, consistent with its highly successful invasive capabilities.

Coral Recruitment on the FGB vs. the Platf's

Coral settlement experiments performed on the east Flower Garden Bank revealed that the most abundant recruits on settlement plates over the period of a year were *Agaricia* spp. The second most abundant recruit was *Porites* spp. Both are very common recruits in the Caribbean and are generally representative of a normal, healthy reef environment. The E-FGB exhibited these standard recruitment patterns in terms of species composition and density.

Coral settlement plates that were implanted on the platforms, however, revealed that the most common settlers there were *Tubastraea coccinea* and *Madracis decactis*. This was highly unusual for a normal reef community. In addition, the densities were very low, particularly in comparison to the E-FGB populations.

Phase III – Coral Community Development on Rigs-to-Reefs Structures vs. Standing Platforms

Many types of structures have been used as artificial reefs, and, since the 1970s, this has included retired oil and gas platforms. There are numerous federally designated "Rigs-to-Reefs" (R2R) artificial reef sites in the Gulf of Mexico on the continental shelf. A study was conducted to determine whether corals were colonizing these structures in Texas and Louisiana. The study sites in this part of the project were the FGB, five R2R structures, and two standing structures. An ROV was used to to survey the structures for corals, including an SeaBotix LBV-300 owned by BOEMRE and LUMCON's Deep Ocean Engineering Phantom 2.

Tubastraea coccinea and *Madracis decactis* were the most abundant coral species on the R2R structures. *Phyllangia americana* were more abundant on standing platforms, and *Oculina diffusa* was equally abundant on the two types of structures. This species-specific response of density to platform-type averaged out to an overall lack of difference between structure-types in overall density.

Depth-distribution of corals on R2R and Standing Platforms

- When considering the depth distribution of all corals together, there was a significant difference between the standing platforms and the toppled ones. Corals were distributed more deeply on standing platforms. It is possible that this was due to the lack of disturbance associated with explosive removal or a lack of perturbation of sediment exposure associated with toppling.

- It was clear that *Madracis decactis*, a zooxanthellate hermatypic coral, was restricted to shallower water because of its need for light. This was evident on both types of structures. The azooxanthellate coral *Oculina diffusa* does not require light for survival and was observed occurring over the full depth of the platforms.

Conclusions

In summary, it was noted that the Flower Garden Banks have a high coral species diversity compared to surrounding platforms. This is to be expected on the basis of sheer habitat area alone. There were 11 coral spp. found on the platforms, and the dominants were *Madracis decactis*, *Diploria strigosa*, and *Montastraea cavernosa.* Coral abundance and species diversity both increase with platform age.

Coral settlement rates on the Flower Garden Banks are typical of other healthy Caribbean reefs, and were generally high, although the variance was also high. Coral recruitment on the platforms was very low, and the species composition of coral spat was atypical for normal reefs.

Corals have colonized platforms throughout the Northern Gulf of Mexico. Densities and species diversity of the hermatypic corals is high at shelf edge and generally low inshore and near the Mississippi River plume. Brooding species of corals appear to be more effective at larval dispersal than broadcasters.

In considering the genetic affinities of corals in the northern Gulf of Mexico at the meso-scale, *Diploria strigosa*, a broadcaster, displayed a highly limited colonization of nearby platforms. On the other hand, *Madracis decactis*, a brooder, exhibited a much broader colonization pattern with higher genetic affinities between platforms, indicating that it is a more effective disperser and colonizer. At a finer scale of spatial resolution, in both *M. decactis* and *T. coccinea*, there was a strong split between the east and west sides of the Mississippi River in genetic affinity. There was very little gene flow between the eastern and western sides of the river, identifying the Mississippi River as a substantial physical geographic barrier to gene flow in this region. *Madracis decactis* exhibited very high site-fidelity and self-recognition. *T. coccinea,* however, exhibited higher gene flow/dispersal within a sector, but still effective no dispersal across the mouth of the Mississippi River.

The densities of *Tubastraea coccinea* were higher on R2R structures than on standing platforms. Densities of the hermtypic coral *Madracis decactis* were essentially the same, but *Phyllangia americana* showed the opposite pattern, with its densities being higher on standing platforms. Densities of *Oculina diffusa* were the same on R2R and standing platforms. The sum of these opposing individual patterns averaged out to no significant overall pattern in coral density.

With respect to all corals pooled, the mean depth of their distribution was shallower on the R2R structures. *Madracis decactis* was limited to shallow water on both the R2R and standing platform structures. *Oculina diffusa* was found in deeper waters on standing platforms.

Paul W. Sammarco, a Professor at the Louisiana Universities Marine Consortium (LUMCON), Chauvin, Louisiana, has been researching coral reef ecology for over 40 years in the western Atlantic and on the Great Barrier Reef, Australia. He has over 265 publications and has served as an Assistant Professor at Clarkson University (New York), a Senior Research Scientist at the Australian Institute of Marine Science, and Executive Director and Professor at LUMCON. He also served as the Director of Environmental Research, Resource Assessment Commission, Dept. Prime Minister and Cabinet (Australia) for several years—the Prime Minister's personal commission on key, controversial, national natural resource issues and environmental issues. Recently, he served as Executive Director of the Association of Marine Laboratories of the Caribbean (AMLC), Chairman of the State Commission for the South Louisiana Wetlands Discovery Center (SLWDC), and Council Chairperson, First United Methodist Church of Houma. He has served as Associate Editor of *Marine Biology* and currently serves as such for *Aquatic Biology*. His Ph.D. is in ecology and evolution. He is currently examining coral communities associated with oil and gas platforms in the Gulf of Mexico (support: U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement – BOEMRE), determining sources and sinks of coral larvae, and documenting expansion of coral populations throughout the northern Gulf.

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James Sinclair has a B.S. in marine biology from Texas A&M University at Galveston and an M.S. in biological sciences from the University of New Orleans. His past work includes the culture of cephalopods, aerobic and anaerobic filtration, analysis of benthic community structure, propagation and restoration of submersed aquatic vegetation, artificial reef development and assessment of oil and gas refinery impacts. He currently serves as a marine ecologist for the US Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) where he works to protect sensitive habitats in Federal waters of the Gulf of Mexico and Atlantic. He is a member of the BOEMRE Seafloor Monitoring Team and serves as a scientific diver.

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INVASION OF A NEW INDO-PACIFIC CORAL – *Tubastraea micranthus* – IN THE GULF OF MEXICO *VIA* OIL/GAS PLATFORMS: FIRST RESULTS

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Introduction

Exotic species have become a major problem globally. Many species that we consider part of our natural environment today are actually invasive species which were introduced either by accident or purposefully by humans. In the marine environment, exotic species reach new regions via a number of pathways. They are introduced via the accidental release from mariculture units into a foreign environment or the deliberate release by aquarium hobbyists, particularly from the Indo-Pacific to the Atlantic. For example, *Pterois volitans*, the lionfish, was introduced into the western Atlantic in 1992 from Key Biscayne. It is not certain whether the release was accidental or deliberate, but the distribution of these fish in the Atlantic now extends throughout the western Atlantic, from Massachusetts, to Barbados, and their geographic distribution continues to expand. One characteristic that makes the invasion of these fish so successful is that that they have high reproductive and recruitment success rates. For example, given ideal environmental conditions, the lionfish will produce eggs and reproduce prodigiously.

Another pathway by which marine species can invade new environments is “hitch-hiking” in the ballast water of larger commercial vessels such as freighters and tankers, on the hulls of these ships, or on the surface of oil or gas platforms which are towed to new sites, either in the same ocean or between oceans. With respect to scleractinian corals, there have been only two well-documented cases of successful introductions of corals from the Indo-Pacific into the Atlantic. The first is *Tubastraea coccinea*, commonly known as the “sun coral,” and invaded via “hitch-hiking.” This species was introduced in the early 1940s, most likely transported on the hull of a ship. It is presumed that it came through the Panama Canal and initially colonized Curacao, Netherlands Antilles. From there, it spread eastward, westward and northward. It was reported to occur in the Gulf of Mexico in 1999 and in the Florida Keys in 2005. Based on our previous studies, its distribution is clearly still expanding. Our research has confirmed that this species is now the dominant species on artificial reefs in the northern Gulf of Mexico.

A second species of coral which was unintentionally introduced to the Caribbean was *Fungia scutaria*, commonly referred to as the mushroom coral. In the late 1960s, colonies of this Indo-Pacific species were brought live from Palau to Discovery Bay, Jamaica for purposes of study. They were kept in open running seawater tables within the Discovery Bay Marine Laboratory for at least 6–7 yrs. These corals are brooders and spawned fully-developed planula larvae into the tanks. The larvae were inadvertently released into the lagoon from the seawater system discharge. They are now common in this bay and most likely other sites on the north shore of Jamaica. There have been no other reports of this species in the Caribbean.

In 2000, Sammarco's research team began surveying oil and gas platforms in the northern Gulf of Mexico for scleractinian corals. We surveyed approximately 50 platforms in waters of the continental shelf and beyond from Corpus Christi, Texas to Mobile, Alabama, covering ~30 km from the coast to $\leq$ 180 km offshore. In addition, Porter surveyed another 30 platforms independently for scleractinian corals and related organisms. Here, we have pooled our data to demonstrate the distribution of an invasive scleractinian coral.

We found one species that was different from all others encountered. It occurred on GI-93-C at a depth of 18 m. The species was identified by S.D. Cairns as *Tubastraea micranthus* (Ehrenberg 1834), a coral known to occur in the Philippines, Japan, and elsewhere in the western Indo-Pacific.

Here we report the preliminary results of surveys on GI-93-C and additional surrounding platforms to determine whether this species had begun to expand its distribution through further colonization and to what extent. Data on its distribution and abundance in this region have been collected.

Materials and Methods

To determine the distribution and abundance of *Tubastraea micranthus* on these platforms, we surveyed GI-93-C plus eight more platforms. Additional surveys are planned for other nearby platforms. At this stage, data from three platforms have been fully processed and five have been partially processed. The surveys were performed using LUMCON's Deep Ocean Engineering Phantom-2 Remotely Operated Vehicle (ROV). Data were collected on both *T. micranthus* and *T. coccinea*.

Platforms were surveyed from 8 m to within 4 m of the maximum platform depth—in the case of these sites, down to 126 m. ROV videos were then analyzed on a Dell Precision T3400 computer using Adobe Premier Pro for viewing and EXCEL to log coral data. The characters recorded were platform, depth, coral species, colony size, colony numbers, competitors, competitive interactions (win, loss, simultaneous win and loss, association only), associated species, and orientation of pilings (vertical or horizontal). In this report, we will concentrate only on density, size, and percent-cover of the corals. Some of these variables were considered with respect to geographic location and depth.

Results and Discussion

Presence/Absence, Density, and Colony Size

- *Tubastraea coccinea*: With respect to *Tubastraea coccinea*, the percent-cover and density were very high on the three platforms processed at the time of this report. This species was present on all eight platforms. We also found that there was a positive correlation (70%) between percent-cover and density when the sampling quadrat data were used as the basis for comparison. This correlation increased greatly to 99%) when percent-cover and density were considered with respect to depth.

- *Tubastraea micranthus:* With respect to *Tubastraea micranthus*, its percent-cover was relatively high on GI-93-C. It was also abundant on GI-90-A and MC-311-A. It was present on GI-115-A and GI-116-A. It was absent on the three platforms to the west of GI-93-C – ST-185-A, ST-185-B, and GI-94-B.

- *T. micranthus* density was high on GI-93-C, averaging ~20/m^2 for the entire platform. This is high enough to merit concern. This species and its congeners have multiple methods of reproduction, including asexual reproduction through budding, stolon production, and colony growth, and sexual reproduction through the production of free-swimming planula larvae.

- Based on simple presence or absence data, it was clear that the geographic distribution of *T. micranthus* was expanding to the north, south, and east - but not the west.

- Regarding average colony size for *T. micranthus*, large colonies were observed on GI-93-C. This is consistent with the hypothesis that this was the site of original colonization. Smaller colonies were observed on GI-90-A – again, consistent with this hypothesis. Interestingly, the largest colonies at these sites occurred on MC-311-A, to the east of GI-93-C, although the densities were lower. The low density could indicate that the platform is far enough away from GI-93-C for swimming larvae to be subjected to substantial diffusional processes that would decrease larval density and probability of their reaching the platform. The larger average colony sizes there might indicate better conditions for growth – or environmental conditions closer to its native habitat in the Pacific Ocean. MC-311-A is located in a “blue-water” environment, off the edge of the continental shelf, whereas GI-93-C occurs in a more turbid, less saline setting.

Depth Distributions: Depth distributions were calculated for both *Tubastraea* spp. They were also calculated on the basis of percent-cover and density, respectively. These two characters relate to different parts of the life-history of the organism (growth *vs.* colonization).

- *Tubastraea coccinea*

  Percent-Cover: *Tubastraea coccinea* exhibited a unimodal peak in its percent-cover on GI-90-A and MC-311-A at 20-32 m and 7–13 m depth, respectively. GI-93C, on the other hand, exhibited a bimodal distribution, with peaks at 13-25 m and 43–49 m depth. These depth distributions suggest that Mississippi River discharge may be excluding this species from shallower depths on GI-90-A and GI-93-C. It also suggests that *T. coccinea* is capable of successfully colonizing and growing at deep depths.

  Mean density: When depth distribution was calculated using mean density, the patterns resembled those using percent-cover. The peak density observed on GI-90-A was 19–25 m. It was broader on MC-311-A, namely 7–31 m. Again, on GI-93-C, the peaks were bimodal, mimicking those calculated using percent-cover. One important point became is that *T. coccinea* occurs down to 126.5 m depth. With its wide distribution and abundance throughout the western Atlantic, now knowing its potential depth distribution, it can in no way be considered a candidate for eradication.

- *Tubastraea micranthus*

  Percent-Cover: *T. micranthus'* presence on GI-90-A was confined to 13–19 m only. This would appear to be the depth with the highest probability of initial colonization, based on the data accumulated thus far. The shallow *T. micranthus* population on GI-93-C peaked at 13–25 m, and the colonies that occurred there were flourishing. On MC-311A, however, the peak was observed at 43-61 m depth. This is relatively deep and is most likely due to this species being azooxanthellate and not requiring light for growth and survival. It is an indicator that, if eradication of this species is to be pursued, it needs to be considered very soon. *T. micranthus* may have a greater maximum depth of survival than *T. coccinea*, and the greater the depth, the more difficult the access.

  Density: The depth distribution of *T. micranthus* using density as a basis for calculation paralleled that found using percent-cover for all platforms considered thus far. It is important to note that on MC-311A, once again, highest densities were observed at deeper depths, confounding potential eradication efforts.

<u>Mean Colony Size</u>

- *T. micranthus*: Large colonies of *T. micranthus* were observed on GI-90-A, although colony densities were low. The colonies on GI-93-C were smaller, but the densities were much higher. MC-311-A possessed a small number of colonies, but their size was quite large compared to those on the other platforms. This again suggests that there are most likely excellent conditions for growth on MC-311-A, i.e., blue water.

Can *Tubstraea micranthus* be Eradicated from the North-Central Gulf of Mexico?:

- Questions arise regarding population growth of *Tubastraea micranthus*, its spread through the northern Gulf of Mexico and beyond, potentially throughout the western Atlantic, and the possibility of controlling its spread and eliminating it. There are several examples of successful eradications of invasive species. One is the elimination of *Terebrasabella heterouncinata*, an ectocommensal which invaded abalone populations in California. If it is executed early, rapidly, and thoroughly, one can indeed eliminate unwanted introductions.

- Problems arise if one waits too long to take decisive action. There are several well-known examples of this. The first is the case of *Solenopsis invicta*—commonly known as the fire ant. This species was accidentally introduced in 1930s to the port of Mobile, Alabama, by ship. Its distribution in 2010 is now remarkable, stretching around the margins of the U.S. borders, from the state of Washington to New Jersey, and as far north in the Great Plains as Kansas and Missouri.

- If one waits too long to initiate eradication procedures against an unwanted invasive, the action can actually cause more problems than it solves. This was the case in the late 1800s with cats which had been introduced onto Macquarie Island, Australia, a site which was declared a World Heritage Site in the 1997. The population of cats rapidly established themselves, becoming feral and reproducing in large numbers. This created a large population there. Because of the recently declared status of the island, and because of the cats' non-native status, they were eliminated entirely several years ago. Major problems have arisen since that time. Firstly, the rabbit population dramatically increased because it had previously been kept in check by the cats. As a result, vegetation on the island decreased by 60% due to grazing by the increased rabbit population. Subsequent to this, the bird populations decreased and are continuing to do so, due to loss of vegetation and associated cover, and habitat destruction. The ecological community had reached a new stable point or stable equilibrium after a long-period of time following the introduction of non-native cats. Removal of the cats triggered an abrupt shift in community structure, and the community is now approaching a new stable point or a new stable equilibrium.

Concluding Remark

Initial results suggest that *Tubastraea micranthus* is currently spreading through the GI and MC sectors of the northern Gulf of Mexico on oil and gas platforms. They show varying degrees of growth in different habitats, but seem to grow particularly well in a blue-water environment. They have the ability to colonize deep-water, most likely because they are azooxanthellate and do not require light to survive. If eradication is to be pursued, it should be done as soon as possible to avoid the possibility of not being able to do so effectively later. In addition, a delay in eradication may cause greater problems within the benthic communities which they have successfully invaded.

Paul W. Sammarco, a Professor at the Louisiana Universities Marine Consortium (LUMCON), Chauvin, Louisiana, has been researching coral reef ecology for over 40 years in the western Atlantic and on the Great Barrier Reef, Australia. He has over 265 publications and has served as an Assistant Professor at Clarkson University (New York), a Senior Research Scientist at the Australian Institute of Marine Science, and Executive Director and Professor at LUMCON. He also served as the Director of Environmental Research, Resource Assessment Commission, Dept. Prime Minister and Cabinet (Australia) for several years—the Prime Minister's personal commission on key, controversial, national natural resource issues and environmental issues. Recently, he served as Executive Director of the Association of Marine Laboratories of the Caribbean (AMLC), Chairman of the State Commission for the South Louisiana Wetlands Discovery Center (SLWDC), and Council Chairperson, First United Methodist Church of Houma. He has been Associate Editor of *Marine Biology* and currently serves as such for *Aquatic Biology*. His Ph.D. is in ecology and evolution. He is currently examining coral communities associated with oil and gas platforms in the Gulf of Mexico (support: U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement – BOEMRE), determining sources and sinks of coral larvae, and documenting expansion of coral populations throughout the northern Gulf.

James Sinclair has a B.S. in marine biology from Texas A&M University at Galveston and an M.S. in biological sciences from the University of New Orleans. His past work includes the culture of cephalopods, aerobic and anaerobic filtration, analysis of benthic community structure, propagation and restoration of submersed aquatic vegetation, artificial reef development and assessment of oil and gas refinery impacts. He is currently a marine ecologist for the U.S. Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) where he works to protect sensitive habitats in Federal waters of the Gulf of Mexico and Atlantic. He is a member of the BOEMRE Seafloor Monitoring Team and serves as a scientific diver.

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CHANGES IN COASTAL FISH COMMUNITIES FOLLOWING *DEEPWATER HORIZON* OIL SPILL

John F. Valentine
Dauphin Island Sea Lab

The April 20, 2010, explosion of the *Deepwater Horizon* (DWH) oil rig off the coast of Louisiana triggered expressions of extreme concern from scientists, researchers, environmental managers, and conservationists. Because of public health concerns, state and federal authorities quickly closed many areas of the northern Gulf of Mexico to recreational and commercial fishing. What impacts the uncontrolled releases of oil from the accident site, and the cessation of fishing pressure on local resources, remain currently unknown. Immediately after the catastrophic failure of the DWH, scientists at the Dauphin Island Sea Lab began collecting baseline data characterizing the composition and abundances of commercial and recreational fishes in the nearshore waters of Mississippi and Alabama. Here, we present preliminary results of a rapid response environmental assessment of changes in coastal and offshore fish communities. Specifically, we document changes in overall abundance and biomass by making comparisons of pre-impact trawling efforts (April–June 2010) to post-impact (August–October 2010) data. Although more years of replication are needed to parse out the impacts of seasonal variability in these assemblages, our results indicate surprisingly that the abundances and biomass dramatically increased for many species (both those intentionally exploited and those considered "bycatch"). We hypothesize that this increase is due to indirect effects of the oil spill, primarily through the cessation of commercial and recreational fishing. These data also show that assessments of the impacts of the DWH event will require assessments of the impacts of government management actions.

Dr. John Valentine is the Executive Director of the Dauphin Island Sea Lab (DISL). Before becoming the lab's director, he was chair of the Sea Lab's University Program. He has written or co-authored 72 extramural grants and contracts (44 of which were funded) to support research at DISL. Funding has come from a diverse group of federal and state agencies including the National Science Foundation (both Bio. Oce and EPSCoR), National Oceanographic and Atmospheric Administration, Northern Gulf Institute, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, the Alabama Department of Conservation and Natural Resources, the Alabama Center for Estuarine Research, the Alabama Oyster Restoration Program, the Mobile Bay National Estuary Program (MBNEP) and The Nature Conservancy. He serves on the Mississippi-Alabama's Sea Grants Board of Directors, the Mobile Bay National Estuary Program's Executive Committee, and the State of Alabama's Forever Wild Board. For more information about Dr. Valentine's research and publications go to
http://marineconservationlab.disl.org/index.html

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THE MARINE ENVIRONMENTAL SCIENCES CONSORTIUM

John F. Valentine
Dauphin Island Sea Lab

Dr. John Valentine is the Executive Director of the Dauphin Island Sea Lab (DISL). Prior to becoming the lab's director, he served as chair of the Sea Lab's University Program. He has written or co-authored 72 extramural grants and contracts (44 of which were funded) to support research at DISL. Funding has come from a diverse group of federal and state agencies including the National Science Foundation (both Bio. Oce and EPSCoR), National Oceanographic and Atmospheric Administration, Northern Gulf Institute, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, the Alabama Department of Conservation and Natural Resources, the Alabama Center for Estuarine Research, the Alabama Oyster Restoration Program, the Mobile Bay National Estuary Program (MBNEP) and The Nature Conservancy. He serves on the Mississippi-Alabama's Sea Grants Board of Directors, the Mobile Bay National Estuary Program's Executive Committee, and the State of Alabama's Forever Wild Board. For more information about Dr. Valentine's research and publications, go to http://marineconservationlab.disl.org/index.html

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CAN INJURIES TO THE WATER COLUMN BY THE *DEEPWATER HORIZON* SPILL BE RESOLVED FROM ZOOPLANKTON COMMUNITY ANALYSIS?

Monty Graham, Rob Condon, Laure Carassou, Frank Hernandez, Jr., Brian Dzwonkowski, and Amy Hunter

Dauphin Island Sea Lab and University of South Alabama

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GULF SERPENT: AN ACADEMIC-INDUSTRIAL PARTNERSHIP TO EXPLORE LIFE IN THE DEEP GULF OF MEXICO

Mark C. Benfield
Department of Oceanography and Coastal Sciences
Louisiana State University

The Gulf SERPENT Project is a regional component of the Scientific Environmental ROV Partnership using Existing Industrial Technology (SERPENT) Project, a global partnership between the oil and gas industry and academia. The project utilizes remotely operated vehicles (ROVs) and other instrumentation to conduct research at deepwater exploration and production platforms. By taking advantage of periods of operational stand-by time, both observations and experiments can be conducted without any additional cost to industry.

The rationale behind Gulf SERPENT is simple. There are too few ROVs in the North American academic fleet to provide more than brief snapshots of life in the depths at infrequent intervals. In contrast, the oil and gas industry operates hundreds of highly capable ROVs from stable sites that remain in one location for months to years. This provides the potential for a time-series that cannot be obtained from an ROV deployed from a research vessel.

The goal of the Gulf SERPENT Project is to establish a deep-sea biological observation system focused on (1) mesopelagic and bathypelagic plankton and nekton; and (2) deep-sea benthic and demersal organisms. Specific questions to be answered include: What organisms are present? Where do they occur (latitude, longitude, depth)? When do they occur? and What are they doing?

The benefits to academia are obvious: access to a highly capable fleet of ROVs, opportunities for scientific research, and educational programs. For industry, the program provides a mechanism to showcase corporate commitment to the environment, provides offshore and onshore evidence of a pristine environment below the facility that is worth protecting, and provides valuable piloting training to ROV pilots, which translates into better piloting skills for their primary task. Finally, SERPENT surveys provide invaluable baseline data on what conditions were like before to any potential incident.

Gulf SERPENT surveys are conducted in coordination with the ROV team. Once training has been completed and offshore personnel are familiar with the survey protocols, the surveys are undertaken by the ROV personnel whenever time is available. Gulf SERPENT is funded by BOEMRE with industrial partners BP, Shell, Chevron, Nexen and Petrobras and ROV operators: Oceaneering, Saipem-America and Subsea7.

Recent notable observations have included the massive oarfish and giant medusa *Stygiomedusa gigantea*. We are also accumulating a large library on the distributions of mesopelagic and bathypelagic organisms in the Gulf of Mexico.

Mark Benfield is a Professor in the Department of Oceanography and Coastal Sciences in the School of the Coast and Environment at Louisiana State University. He received his B.Sc. from the University of Toronto, M.Sc. from the University of Natal, and his Ph.D. from Texas A&M University. He was a Postdoctoral Investigator at the Woods Hole Oceanographic Institution where he currently has an adjunct appointment (Guest Investigator) in the Biology Department. Mark is a zooplankton ecologist with interests in understanding the physical and biological factors that determine spatial distributions of zooplankton from scales of meters to kilometers. He uses *in situ* imaging systems, high-frequency acoustics, and nets as tools to investigate zooplankton ecology. Mark is the past-chair of the International Council for Exploration of the Sea (ICES) Working Group on Zooplankton Ecology. Most recently, he has been working with the oil and gas industry in the Gulf of Mexico to use deepwater ROVs for scientific research on life in the mesopelagic and bathypelagic.

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GULF SERPENT AND THE MC252 SPILL

Mark C. Benfield
Department of Oceanography and Coastal Sciences
Louisiana State University

The Gulf SERPENT Project is a collaboration between Louisiana State University and the oil and gas industry that is designed to advance our understanding of biodiversity in the depths of the Gulf of Mexico from 200 m to the seafloor. With funding from BOEMRE, Gulf SERPENT has been operational in the Gulf of Mexico since 2007. SERPENT survey data were some of the only data available on conditions in the water column and on the seafloor prior to the MC252 spill. The *Deepwater Horizon* (DWH) was a Gulf SERPENT participant and the ROV on the DWH conducted surveys of the seafloor around MC252 during February and March 2010.

Following the spill, new quantitative seafloor survey methodologies were developed by Gulf SERPENT to provide data on the distribution and abundance of benthic megafauna around the Macondo well. These surveys, which were a modification of the BOEMRE pre-bottom survey design, consisted of 24 radial transects extending for 250 m at bearing intervals of 15 degrees. Matlab simulations of the survey design suggested that it was capable of providing accurate estimates of the densities of marine life with smaller error bars than the original BOEMRE design (six, 100 m long radial transects at bearing intervals of 60 degrees).

In August 2010, the ROVs aboard the MV Olympic Challenger conducted surveys of the water column and seafloor at sites located 2,000 m N, S, W, and E of the Macondo well and at a site located 500 m north of the well. In addition, the ROVs aboard the *Development Driller 2* (DD2) rig conducted surveys at frequencies of 7–10 days at a site (MC252#2) located approximately 750 m SW of the Macondo well from early August through early November 2010. In March 2011, the ROV aboard the *Development Driller 3* (DD3) conducted surveys at sites located at MC252#2, 2,000 m north and 2,000 m west of the Macondo well and at a site 3.5 km north of the Macondo well in MC208. Analysis of these datasets is ongoing and will be part of the Natural Resource Damage Assessment process.

Mark Benfield is a Professor in the Department of Oceanography and Coastal Sciences in the School of the Coast and Environment at Louisiana State University. He received his B.Sc. from the University of Toronto, M.Sc. from the University of Natal, and his Ph.D. from Texas A&M University. He was a Postdoctoral Investigator at the Woods Hole Oceanographic Institution where he currently has an adjunct appointment (Guest Investigator) in the Biology Department. Mark is a zooplankton ecologist with interests in understanding the physical and biological factors that determine spatial distributions of zooplankton from scales of meters to kilometers. He uses *in situ* imaging systems, high-frequency acoustics, and nets as tools to investigate zooplankton ecology. Mark is the past-chair of the International Council for Exploration of the Sea (ICES) Working Group on Zooplankton Ecology. Most recently, he has been working with the oil and gas industry in the Gulf of Mexico to use deepwater ROVs for scientific research on life in the mesopelagic and bathypelagic.

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LONG-TERM MONITORING AT THE EAST AND WEST FLOWER GARDEN BANKS, 2009–2010

Marissa F. Nuttall, Emma L. Hickerson, John A. Embesi, Ryan J. Eckert, and G.P. Schmahl
Flower Garden Banks National Marine Sanctuary

The East (EFGB) and West (WFGB) Flower Garden Banks (FGB) are the northernmost coral reefs in the continental United States and are part of a discontinuous arc of reefs and banks along the outer continental shelf in the Northwestern Gulf of Mexico. They are located in federal waters, approximately 110 nautical miles directly south of the Texas/Louisiana border, and are managed by NOAA's Office of National Marine Sanctuaries (ONMS). The Flower Garden Banks National Marine Sanctuary (FGBNMS) encompasses both the East and West Flower Garden Banks, in addition to Stetson Bank. This study provides information on the health and status of the coral reefs of the East and West FGB. This report discusses the progress of the 2009 and 2010 long-term monitoring efforts by the researchers from FGBNMS, Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), and Texas A&M University Galveston.

The biotic assemblage of the FGB is characterized by a high coral/low algal cover reef community with a diverse fish population. In more than twenty years of continuous monitoring, the coral reefs of the FGB have maintained high levels of coral cover, suffered minimally from hurricane damage, coral bleaching, outbreaks of disease, and supported diverse and abundant fish and invertebrate populations. While the rest of the Caribbean has experienced declines in scleractinian coral cover and subsequent increases in macroalgal cover the FGB remains a relatively stable coral reef system, with coral cover measuring over 50 percent.

The 2009 data was collected from August 16 to 21. The 2010 data was collected during August 16–20, October 11–13, and November 8–10. The data collection was conducted within the 100m x 100m study site at both EFGB and WFGB. At each bank, approximately 40 repetitive 8 m^2 photostations were photographed each year. In addition, nine deep repetitive stations were photographed at the EFGB, adjacent to the study site, at depths to 40 m. These repetitive photographs will be assessed for substrate percent cover, species dominance, total live cover, mortality, species frequency, presence, diversity, and evenness. Lateral growth stations were photographed to monitor the lateral growth and regression of selected heads of symmetrical brain coral (*Diploria strigosa*). Sixteen 10m randomly placed photographic and/or video transects were captured at each site. Small cores of mountainous star coral (*Montastraea faveolata*) are taken bi-annually to measure coral accretion. Video transects were collected along study site perimeter lines for general reef health observations. A minimum of 24 Bohnsack-Bannerot (1986) fish surveys were conducted at each bank, and assessed for reef fish abundance, diversity, and biomass. At night, two 2 m x 100 m transects were conducted at each bank along the perimeter lines to establish current population levels of sea urchins (*Diadema antillarum*) and lobsters (*Panulirus argus* and *Panulirus guttatus*). Temperature and salinity data was recorded at the reef crest of each bank using a datasonde and a backup thermograph. Water samples were collected quarterly and analyzed for nitrogen, nitrate, nitrite, dissolved ammonia, soluble reactive phosphorous and total phosphorus, and chlorophyll-a.

The project design and history will be presented along with preliminary results from the 2009 and 2010 monitoring efforts. Annual comparisons and long-term trends will also be presented. A brief summary of activities conducted by the FGBNMS in response to the *Deepwater Horizon* event will also be discussed.

Marissa Nuttall is a Research Assistant at the Flower Garden Banks National Marine Sanctuary (FGBNMS). She graduated from Texas A&M University at Galveston with a Bachelor's degree in marine biology, and is currently pursuing a Master's degree also in marine biology. Her research interests focus on coral reef ecology, long-term monitoring of coral reefs, mesophotic coral ecosystems, and habitat suitability modeling. Marissa is a part of the Flower Garden Banks Research Team working on the recently acquired Long-Term Monitoring Project co-funded by BOEMRE and FGBNMS.

Emma L. Hickerson has held the position of Research Coordinator of the Flower Garden Banks National Marine Sanctuary since 1997. She began her career at the Sanctuary while still a graduate student at Texas A&M University, conducting satellite tracking studies on loggerhead sea turtles living on the reef. During her tenure in the current position with the Sanctuary, she has coordinated or participated in over 120 research cruises, including SCUBA, ROV, and submersible operations. She has logged over 1,000 SCUBA dives, and a handful of submersible dives as the pilot. Her interests and research include most ecological and biological aspects of coral reefs, with recent efforts being placed on the deepwater habitats of the Sanctuary, and adjacent areas, and monitoring of coral reef ecosystems.

John A. Embesi is a Research Specialist at the Flower Garden Banks National Marine Sanctuary (FGBNMS). A graduate of Texas A&M University at Galveston, he has twenty years of experience in marine research. John is a member of the FGBNMS Research Team that is currently working on the Long-Term Monitoring Project co-funded by BOEMRE and FGBNMS.

Ryan Eckert is a Research Assistant at the Flower Garden Banks National Marine Sanctuary in Galveston, Texas. Since graduating from Florida State University in 2009 with a B.S. in biological science he has worked for the past several years on the Long-Term Monitoring project co-funded by BOEMRE and FGBNMS. His research interests include coral reef ecology and coral monitoring.

George P. ("G.P.") Schmahl is the superintendent of NOAA's Flower Garden Banks National Marine Sanctuary. As Sanctuary superintendent, he is involved with an array of Marine Protected Area management issues including research, education and resource protection. After obtaining a Master's degree in zoology from the University of Georgia, he held a variety of positions relating to marine research, coastal management, resource planning and environmental regulation. His primary interest is the ecology and management of coral reefs and associated ecosystems.

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DRAFT MANAGEMENT PLAN—SANCTUARY EXPANSION PROPOSAL

Emma L. Hickerson and G.P. Schmahl
Flower Garden Banks National Marine Sanctuary

The East (EFGB) and West (WFGB) Flower Garden Banks (FGB) are the northernmost coral reefs in the continental U.S. and are part of a discontinuous arc of reefs and banks along the outer continental shelf in the Northwestern Gulf of Mexico. They are located in federal waters, approximately 110 nautical miles directly south of the Texas/Louisiana border, and are managed by NOAA's Office of National Marine Sanctuaries (ONMS). The Flower Garden Banks National Marine Sanctuary (FGBNMS) encompasses both the East and West Flower Garden Banks, in addition to Stetson Bank.

The Flower Garden Banks NMS (FGBNMS) created a Sanctuary Advisory Council (SAC) in October 2005, and held its first meeting in November 2005. A "State of the Sanctuary" report was developed in preparation for a management review process. This document reported on the status and accomplishments of the sanctuary since designation, described ongoing management programs, outlined proposed goals and objectives for future management, and identified emerging issues that may need to be addressed. The process of identification of issues was both worked through the FGBNMS SAC and through public scoping meetings in Houston, Corpus Christi, and New Orleans. This led to development of priority issues, analysis and action plans. A Draft Management Plan was produced and sent out for public comment. Analysis of the public comments is ongoing, and will lead into the development of the Final Management Plan.

In August 2005, the issues identified by the FGBNMS SAC as the highest priority issues were boundary expansion, fishing impacts, visitor use, water quality, Education/Outreach, and enforcement.

A Boundary Expansion Working Group was created to work through the issue. This Working Group was chaired by FGBNMS SAC Oil and Gas representative Clint Moore.

An issue description was developed which was: potentially vulnerable geological and biological features associated with protected areas are outside the current Sanctuary boundaries. Additional features were revealed through the collection of high resolution multibeam bathymetry after the present sanctuary boundaries were established. Numerous banks associated features in the northwestern Gulf of Mexico may be ecologically linked to the FGBNMS and, like the FGB, may be highly vulnerable to certain anthropogenic impacts that alter the physical, chemical, biological, or acoustic environment. It is proposed that selected features be evaluated for inclusion under the management and protection through the Flower Garden Banks National Marine Sanctuary.

The Boundary Expansion Working Group worked through a ranking criteria process, which included assessing established regulatory measures and infrastructure in regards to industry. The

Working Group provided an Alternative Package to the FGBNMS SAC in September 2007. On September 27, 2007, the Sanctuary Advisory Council voted on their preferred alternative for boundary expansion of the FGBNMS. It included adjustments to the existing boundaries of East Flower Garden, West Flower Garden and Stetson Banks, and the addition of nine new areas, including Horseshoe, MacNeil, Rankin, 28 Fathom, Bright, Geyer, McGrail, Sonnier and Alderdice Banks. All of these areas, with the exception of Horseshoe Bank, have already been designated as Habitat Areas of Particular Concern (HAPC) by the GMFMC and also contain No-Activity Zones, as designated by the Minerals Management Service (now BOEMRE).

The SAC also recommended that the boundaries of the new areas be drawn so as to have a minimal impact on oil and gas activity in the area, while providing adequate protection to the critical biological features.

On December 6, 2007, the Sanctuary Advisory Council voted to recommend that the boundaries of the new expansion areas consist of the core biological area plus a 500-meter buffer.

The FGBNMS Draft Management Plan is on track for release in Fall, 2011. This document will propose to move forward with the Sanctuary Boundary Expansion. Environmental Assessments and additional Public Comments will be required before this process is finalized.

Emma L. Hickerson has held the position of Research Coordinator of the Flower Garden Banks National Marine Sanctuary since 1997. She began her career at the Sanctuary while a graduate student at Texas A&M University, conducting satellite tracking studies on loggerhead sea turtles living on the reef. During her tenure in the current position with the Sanctuary, she has coordinated or participated in over 120 research cruises, including SCUBA, ROV, and submersible operations. She has logged over 1000 SCUBA dives, and a handful of submersible dives as the pilot. Her interests and research include most ecological and biological aspects of coral reefs, with recent efforts being placed on the deepwater habitats of the Sanctuary, and adjacent areas, and monitoring of coral reef ecosystems.

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SESSION 3F

PHYSICAL SCIENCES

Chair: Holli Ensz, BOEMRE

Co-Chair: Margaret Metcalf, BOEMRE

AIR/SEA INTERACTION MEASUREMENTS: SUMMARY AND INITIAL DATA CHARACTERIZATION

C. MacDonald[1], A. Ray[1], P. Roberts[1], W. Gibson[2], J. Hare[3], L. Bariteau[3], C.W. Fairall[4], S. Pezoa[4], and C.H. Huang[5]

[1]Sonoma Technology, Inc. (STI)

[2]Coastal Studies Institute, Louisiana State University

[3]Cooperative Institute for Research in Environmental Science (CIRES) University of Colorado

[4]National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL), Physical Sciences Division

[5]Environmental Sciences Section Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE)

A unique partnership of corporate, government, and university researchers has collaborated to develop a marine environmental observations program on an offshore platform in the Gulf of Mexico. The primary goals of this project are to provide data to (1) improve our understanding of boundary layer processes and air-sea interaction over the Gulf of Mexico; (2) improve regional-scale meteorological and air quality modeling; and (3) provide a framework for advanced offshore measurements to support future needs such as emergency response, exploration and lease decisions, wind energy research and development, and meteorological and air quality forecasting. In October 2010, meteorological and oceanographic sensors were deployed for an extended period (approximately 12 months) on a Chevron service platform (ST-52B, 90.5W, 29N) to collect boundary layer and sea surface data sufficient to support these objectives. This project has significant importance, given the large industrial presence in the Gulf, the large regional population nearby, and the recognized need for precise and timely dispersion forecasts. Observations from this project include surface meteorology; sodar marine boundary layer winds; microwave radiometer profiles of temperature, relative humidity, and liquid water; ceilometer cloud base heights; water temperature and current profiles; sea surface temperature; wave height statistics; downwelling solar and infrared radiation; and air-sea turbulent momentum and heat fluxes. This project will result in the collection of an unprecedented set of boundary layer measurements over the Gulf of Mexico that will capture the range of meteorological and oceanographic interactions and processes that occur over an entire year. The project is being led by Sonoma Technology, Inc. (STI) with significant participation from project partners including Louisiana State University; University of Colorado; National Oceanic and Atmospheric Administration; and the Bureau of Ocean Energy Management.

Clinton P. MacDonald is the Manager of Meteorological Measurements and Analysis at Sonoma Technology, Inc. Clinton holds M.S. and B.S. degrees in atmospheric science from the University of California at Davis. He has over 14 years of experience performing meteorological and air quality data analyses and measurements. His work focuses on managing radar wind profiler and sodar field operations; developing conceptual models of processes that control air pollution; and supporting the EPA's AIRNow Program by developing ozone and particulate matter forecasting methods and conducting forecasting training courses. Mr. MacDonald has published several journal articles about meteorology and air quality, co-authored the EPA's guidance document regarding the development of an air quality forecasting program, and authored many formal reports on air quality transport and dispersion. He is the principal investigator for the maintenance and operation of five radar wind profilers (RWPs) for the South Coast Air Quality Management District and project manager for several meteorological measurement projects including the BOEMRE Air/Sea Interaction Study. Mr. MacDonald is also an adjunct professor of meteorology at Santa Rosa Junior College.

Dr. Paul Roberts is STI's Executive Vice President and Senior Manager of the Air Quality Measurement Division. At STI since 1986, Dr. Roberts has designed and managed aerometric field, data management, and data analysis projects. Most of these projects involve the collection of field data and the use of analysis methods to understand important meteorological and air quality phenomena; to identify source contributions to high pollutant concentrations; to develop, apply, and evaluate meteorological and photochemical models; and to evaluate the effectiveness of ambient air quality and meteorological networks in meeting various regulatory and technical requirements. These field, analysis, and modeling projects have been performed throughout many regions of the U.S. and overseas, including California, the desert southwest, the Lake Michigan area, the mid-Atlantic and northeastern states, Texas, the El Paso/Juarez airshed, the Gulf of Mexico, and Cairo, Egypt. Specifically in the Gulf of Mexico, Dr. Roberts designed and managed the field measurements and data analyses for the MMS-sponsored Gulf of Mexico Air Quality Study in 1993 and for the Breton Aerometric Monitoring Program (BAMP). Dr. Roberts was the Principal Investigator for the MMS-sponsored Boundary Layer Study in the Central and Western Gulf of Mexico and has led and performed several other aerometric data analysis projects in the Gulf. Dr. Roberts has performed air monitoring instrument development and application studies using first-generation monitors in desert, coastal, mountain, urban, and rural environments; in aircraft, in a hot-air balloon, and on offshore oil platforms. From 1981 to 1986, Dr. Roberts was chairman of several oil-industry trade association committees that sponsored air quality research, was a consultant to the environmental affairs group of Chevron, and testified at federal hearings. From 1975 to 1986, he planned and directed research and development projects at Chevron Research Company and helped apply the results to operating plants in various Chevron refineries. He was also involved in numerous methods development and methods evaluation projects. Previously, he had worked in oil-field production laboratories, and in oil and gas reservoir engineering positions.

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YEAR 2008 GULFWIDE EMISSION INVENTORY STUDY

Darcy Wilson and Richard Billings
Eastern Research Group, Inc. (ERG)

Introduction and Background

The *Year 2008 Gulfwide Emission Inventory Study* serves as an update to the *Year 2005 Gulfwide Emission Inventory Study* and the year 2000 *Gulfwide Emission Inventory Study for the Regional Haze and Ozone Modeling Effort*. The studies are designed to assess the potential impacts of air pollutant emissions from offshore oil and gas exploration, development, and production sources in the Outer Continental Shelf (OCS). The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) inventories are air pollution emission inventories of all OCS oil and gas production-related sources in the Gulf of Mexico, including non-platform sources. The methods to collect the monthly platform activity data, develop the platform and non-platform source emission estimates, and allocate the non-platform mobile source emission estimates throughout the OCS are discussed in detail in each study report, and the resulting emission estimates are presented and evaluated. The reports and emission inventory data sets are available on-line at:
http://www.gomr.boemre.gov/homepg/regulate/environ/airquality/goads.html.

The 2008 Gulfwide emission inventory corresponds with the U.S. EPA onshore periodic emissions inventory and will assist states and regional planning organizations that conduct modeling for State Implementation Plan (SIP) demonstrations. The inventory will also be used to enhance the BOEMRE National Environmental Policy Act (NEPA) process by providing an inventory to compute emissions trends and to perform necessary air quality impact assessments.

Pollutants covered are the criteria pollutant— carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter-10 (PM_{10}), $PM_{2.5}$, and volatile organic compounds (VOC); as well as greenhouse gases—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). BOEMRE attempted to collect activity data from every major active offshore oil production platform in the Gulf of Mexico on the OCS; operators were also required to identify minor sources such as caissons and wellhead protectors. Operators were provided with the Gulfwide Offshore Activities Data System (GOADS-2008) Visual Basic activity data collection software for compiling monthly data for calendar year 2008. Data were submitted for a total of 3,154 active oil and gas production platforms; 1,534 of these were flagged as minor sources. The monthly activity data collected from the platform operators were used to calculate the platform production equipment emission estimates. Non-platform sources are also included in the inventory, such as pipelaying vessels, drilling vessels, support helicopters and vessels, commercial marine vessels, and the Louisiana Offshore Oil Port (LOOP). Base year 2008 activity data for non-platform sources were collected from sources including BOEMRE, the Offshore Marine Service Association, and the U.S. Environmental Protection Agency (EPA), and combined with emission factors to develop emission estimates. Non-platform emission estimates were allocated using Geographic Information System (GIS) software to lease blocks and areas.

Year 2008 Gulfwide Emission Inventory Study Results

The inventory results indicate that OCS oil and gas production platform and non-platform sources emit the majority of criteria pollutants and greenhouse gases in the Gulf of Mexico on the OCS, with the exception of PM and SO_2 (primarily emitted from commercial marine vessels), and N_2O (from biological sources). OCS platform and non-platform sources account for 93% of total CO emissions, 74% of NO_x emissions, 41% of PM emissions, 36% of SO_2 emissions, and 76% of VOC emissions. Oil and gas production platforms account for the majority of the CO and VOC emissions. Non-platform OCS oil and gas production sources such as support vessels and drilling vessels emit the majority of the estimated NO_x emissions. For greenhouse gases, platform sources account for almost all of the CH_4 emissions. Commercial marine vessels are the top-emitting non-OCS oil and gas production sources in the inventory for CO, NO_x, PM, SO_2, and CO_2 emissions. Biological sources are the top-emitting non-OCS oil and gas production sources in the inventory for VOC, CH_4, and N_2O emissions.

Comparison of 2008 and 2005 Emission Estimates

The results of the *Year 2008 Gulfwide Emission Inventory Study* are similar to the results of the *Year 2005 Gulfwide Emission Inventory Study* for some criteria pollutants. For platform sources, the CO, NO_x, and PM emission estimates show slight decreases in emissions from 2005 to 2008 (less than 10%), as shown in Table 3F.1. The SO_2 emission estimate, however, shows a 48% decrease. This decrease is due primarily to the amine unit emission estimates. The VOC emission estimate shows a 28% increase (up over 14,000 tons) from 2005 to 2008. The majority of this increase is from vents, pneumatic pumps, pressure level controllers, glycol dehydrators, and fugitives. For non-platform sources, the overall NO_x and VOC emission estimates show slight differences in emissions from 2005 to 2008 (less than 2%). The CO emission estimate shows a 31% increase from 2005 to 2008, primarily from drilling rigs, helicopters, and commercial marine vessels. The increased PM and SO_2 estimates, both over 100%, are due to the commercial marine vessel estimates.

Table 3F.1

Comparison of criteria pollutant emission estimates for base years 2008 and 2005.

Base Year	CO Emissions (tpy)	NO_X Emissions (tpy)	PM_{10} Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
2008	125,269	382,846	11,647	81,311	94,295
2005	122,295	392,961	6,088	40,559	80,933
Percent Difference	2%	-3%	91%	100%	16%

The results of the *Year 2008 Gulfwide Emission Inventory Study* are also similar to the results of the *Year 2005 Gulfwide Emission Inventory Study* for some greenhouse gases. As shown in Table 3F.2, greenhouse gas emission estimates for platform equipment follow a similar trend to the criteria pollutant emission estimates—estimates for losses from flashing, diesel engines, natural gas engines, and natural gas turbines are relatively unchanged; estimates for drilling equipment, and mud degassing show a decline in emissions; and estimates for vents, fugitive sources, glycol dehydrators, pneumatic pumps, and pressure level controllers, boilers/heaters/burners, and combustion flares show an increase in emissions.

All non-platform sources had larger greenhouse gas emissions than estimated in 2005 except for support vessels, which indicates a reduction in the Gulf fleet. The largest increase in greenhouse gas estimates for OCS oil/gas related sources is seen in the helicopter emission estimates, (based on the updated helicopter emission factors) and in drilling rigs, (due to the increase in drilling activity between 2005 and 2008).

Table 3F.2

Comparison of greenhouse gas emission estimates for base years 2008 and 2005.

Base Year	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)
2008	25,525,811	441,874	2,666	35,631,616
2005	24,334,447	216,484	2,803	29,749,541
Percent Difference	5%	104%	-5%	19%

Plans for the 2011 Inventory

Future inventory development efforts will build upon the foundation developed in previous BOEMRE inventories. Where possible, improvements or enhancements will be made that allow for development of more accurate emission estimates. Recommendations for future inventory efforts for platform sources in the Gulf of Mexico on the OCS focus on validating or updating the range check values, surrogate stack parameters, and surrogate fugitive component counts and emission factors, given changes in offshore platform operations (e.g., deepwater platforms are more now common) and on continuing to track studies of flare combustion efficiencies. Fugitive emissions are calculated using out-of-date methods and surrogate component counts. BOEMRE will continue to review published emission factors and available emissions data to make sure the most up-to-date emission factors, including greenhouse gas factors, are used in future emission inventories. For flares and vents, BOEMRE now collects monthly volume vented and flared data from production operators via OGOR forms. 30 CFR Part 250, Oil and Gas and Sulphur Operations in the Outer Continental Shelf-Oil and Gas Production Operators are now required to meter flared and vented gas volumes on facilities that process more than 2,000 barrels of oil per day and report flared gas separately from vented gas on the OGOR forms. Future inventory development efforts will use these reported data in lieu of GOADS activity data.

For marine vessels, Portvision is under contract with BOEMRE with their Automatic Identification System (AIS), tracking vessel identification, position, course, and speed. If future inventory efforts could match AIS vessel tracking data with vessel characterization data, more accurate estimates of activity and emissions could be developed for marine vessels. Portvision data include vessels that visit the LOOP. In order to get a complete mapping of vessel traffic patterns in federal waters, Portvision will need to install transponders on offshore platforms to extend their coverage out from state waters. At this time, it is uncertain whether these additional transponders will be installed.

A new source will also be included in the 2011 Gulfwide Emissions Inventory Study—the Gulf Gateway Energy Bridge LNG deepwater port. The Title V permit is available for this LNG port and will be used to develop emission estimates.

The schedule for the completion of the Year 2011 Gulfwide Emissions Inventory Study calls for ERG to submit a draft report and inventory databases to BOEMRE by November 30, 2012 and a final report and databases by June 15, 2013.

Darcy Wilson is a Senior Program Manager and Vice President with Eastern Research Group (ERG) with over 20 years of air quality experience dealing with greenhouse gases, criteria air pollutants, and hazardous air pollutants. Her expertise includes air pollutant emission inventory and emission factor development, database development, and data analysis. Ms. Wilson is nationally recognized by the U.S. Environmental Protection Agency (EPA) and state/local/tribal agencies for her development of air toxics emissions inventories. She has served as the Program Manager on ERG's BOEMRE Air Quality Emissions Inventory Studies since 1999.

Richard Billings has a M.S. in environmental science and engineering from Virginia Tech, and has worked with Eastern Research Group (ERG) for 19 years. The focus of most of his work has been the quantification of air emissions from nonroad emission sources such as marine vessels and helicopters. These nonroad projects have been developed for the U.S. EPA, the U.S. Department of Transportation, the Texas Commission for Environmental Quality, the Houston Advance Research Center, the California Energy Commission, and the California Air Resources Board, as well as BOEMRE. In addition to his mobile source activities, he has developed emission estimates for marine biogenic and geogenic sources.

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OVERVIEW OF FEDERAL LAND MANAGERS' AQRV WORKGROUP (FLAG)

Jill Webster
U.S. Fish and Wildlife Service

The Clean Air Act Amendments of 1977 give Federal Land Managers (FLMs) an affirmative responsibility to protect visibility and other air quality related values (AQRVs) of certain national parks and wilderness areas (Class I areas) from the adverse impacts of air pollution. In 2000 the National Park Service, Fish and Wildlife Service, and Forest Service cooperatively produced a report to ensure better consistency among the FLMs when they are evaluating the effects of new sources of air pollution on air quality related values. This report is known as the Federal Land Managers' Air Quality Related Values Workgroup (FLAG) 2000 report. Work has taken place over the last five years to update the 2000 report, and these revisions became final in October 2010.

Jill Webster is an air quality specialist with the U.S. Fish and Wildlife Service. She holds an undergraduate degree in meteorology from North Carolina State University and a Master of Environmental Studies from the University of Pennsylvania. Her professional experience includes five years at environmental consulting firms, six years with the U.S. EPA Region III Air Program, and two years as a U.S. Peace Corps volunteer.

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A STUDY OF LONG-TERM TRENDS IN ENVIRONMENTAL PARAMETERS ALONG THE LOUISIANA/MISSISSIPPI OUTER CONTINENTAL SHELF USING OCEAN COLOR REMOTE SENSING DATA

Eurico D'Sa
Department of Oceanography and Coastal Sciences
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The Mississippi River is the primary riverine source of freshwater, nutrients, organic/inorganic particulate and dissolved matter to the Louisiana/Mississippi continental shelf and to the Gulf of Mexico. It strongly influences the biological, chemical, geological, and physical processes resulting in a very dynamic ocean environment. Energetic meteorological events such as storms/ hurricanes and man-made hazards such as oil spills necessitate better environmental monitoring of the continental shelf waters of the northern Gulf of Mexico. Ocean color satellite remote sensing with its synoptic and repeated coverage allows monitoring of both short- and long-term environmental parameters such as phytoplankton chlorophyll biomass, colored dissolved organic material (CDOM) absorption, and suspended particulate matter (SPM).

As part of this study we used field bio-optical data to examine optical properties and assess ocean color algorithms for the Louisiana coastal and shelf waters (D'Sa et al. 2007; D'Sa and DiMarco 2009; Singh et al. 2010; Naik et al. 2011). Satellite ocean color derived environmental parameters such as phytoplankton chlorophyll, CDOM absorption and SPM were used to study short-term variability due to storms and hurricanes (D'Sa and Ko 2008; D'Sa 2008; D'Sa et al. 2011) while long time-series (1998–2008) ocean color data were used to examine seasonal and inter-annual variability and trends along the shelf waters influenced by the Mississippi and Atchafalaya Rivers (D'Sa and Korobkin 2009a, b). The presentation provides a sampling of the results that have been published as part of the project.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.