Abstracts for Oral Presentations

Organized by Session

001: Synthesis, Integration, Collaboration, and Linkages: Moving Complex Data into the Right Hands

An Overview of the DIVER Data Management System and How It Integrates Regional Data with Tools for Data Collection, Reporting, Search, and Visualization

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The DIVER (Data Integration Visualization Exploration and Reporting) application is a collaborative data management platform supporting integrated environmental data management and sharing in the Gulf of Mexico. The DIVER application is a central part of the funded effort under the Deepwater Horizon (DWH) Natural Resource Damage Assessment to build a gulf-wide data management system. DIVER relies on general best practices for data management along with specific guidelines developed by the DWH Trustee Council to achieve integrated tracking and monitoring of the regional restoration efforts being implemented by state and federal trustees across the many resource types impacted by oil spill. The DIVER application has a suite of tools that support this effort. The DIVER Restoration Portal supports project information management and integrated reporting across all Trustees. The DIVER Data Warehouse is designed for data upload and integration, while the DIVER Explorer query tool supports searching, filtering and downloading data and results. The DIVER Explorer query tool additionally integrates with the Environmental Response Management Application (ERMA) mapping and visualization application to provide spatial context for the environmental data and results.

NRDA Restoration Monitoring Data Integration into DIVER Application

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A central goal of NRDA restoration monitoring is to look at restoration monitoring projects across time and assess their level of success, and potentially adapt the management approach. This type of management relies on integrating different data types and data sources into common structures to support filtering and analyzing data. NRDA funded restoration is using the DIVER platform to support this challenge. Across the Gulf of Mexico, many different datasets need to be standardized in order to be integrated in an efficient and repeatable process. One aspect of our approach is to come up with tools and processes that allow data to be standardized prior to submission to DIVER. Work is ongoing in developing templates (Electronic Data Deliverables or EDDs) that accept metrics and parameters that are broadly applicable across restoration types and span data types including biological, field measurements, and both chemistry and non-chemistry type data. Our efforts to develop data templates spurred us to document our system with an Environmental Data Specification which is available on the public DIVER website. This data specification describes the underlying data structures and data exchange methods, including field information and valid values. The data specification includes core fields required to organize and categorize data brought into DIVER, as well as general requirements regarding submission of structured and unstructured data and metadata and appendices defining fields across different data categories, valid values, and a chemical dictionary.

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In addition to providing templates for data delivery on the Forms and Guidance section of the DIVER website, NOAA also provides template testing tools, and additional forms and guidance that NOAA and project partners use across many different environments.

Exploring Coastal Vulnerabilities to Oil Spills with the Tactical Analysis and Coordination for Oil Spills (TACOS) Suite

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The purpose of this presentation is to introduce both practitioners and scholars to a new, open source, decision support platform known as the Tactical Analysis and Coordination for Oil Spills suite, or "TACOS". TACOS allows users to explore and geovisualize the spatial and temporal elements of deep and ultra-deep water oil spills and develop strategies for minimizing the potential environmental, economic and social impacts of spills by optimizing the allocation of response crews and equipment. The TACOS decision support suite consists of two core components.

BLOSOM is a vetted, integrated system designed to simulate offshore oil spills resulting from deepwater (greater than 500 feet) and ultra-deepwater (greater than 5,000 feet) well blowouts. BLOSOM assists with risk assessment and serves as a comprehensive tool for spill response planning. The second component, TACOS, consists of three mathematical planning models that provide provably optimal, tactical response plans for oil spills and their cleanup in open water, the allocation of exclusion booms for protecting sensitive shorelines, and a pre-planning model that optimally locates equipment storage areas and staging locations to enhance the efficiency of response teams during cleanup deployments. Lastly, TACOS is coupled with a web-based geovisualization platform for automated scenario planning/comparison efforts. A simulated oil spill with the potential to impact Mobile Bay (Alabama) in the United States is used as an illustrative example for this presentation.

Use of Open Data Science to Inform Restoration Projects in Estuaries: A Tampa Bay Example

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As a result of the legal settlements stemming from the 2010 Deepwater Horizon oil spill large, comprehensive and concerted efforts to restore Gulf of Mexico (GOM) coastal ecosystems are currently underway. In particular, large investments are being made to reduce effects of coastal development and nutrient enrichment in several GOM estuaries in the form of water quality and habitat restoration projects. Evaluating the environmental outcomes of past restoration investments will help identify how, where and when future resources can be invested so that restoration efforts will have the greatest benefit for Gulf Coast communities. However, despite significant and long-term investments in restoring water quality in some estuaries, less attention has focused on programmatic evaluation of restoration effects through data synthesis at a watershed/estuary scale. This study synthesized multiple decades of a comprehensive water quality dataset with several restoration

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activity datasets in the Tampa Bay Estuary to identify 1) types of restoration projects that produced the greatest improvements in water quality, and 2) which time frames are most relevant for having the largest perceived water quality benefits. Changes in chlorophyll concentrations as a proxy of eutrophication were used to quantify water quality changes from investments in restoration activities. This study applied open science tools to synthesize and evaluate publicly available data using a reproducible workflow. This presentation will demonstrate how these tools improved collaboration between the authors, and more importantly, how the open science workflow will enable application of our analysis to other restoration activities and estuaries.

Incorporating Deepwater Horizon Data into Core NCEI Databases to Improve the Quality of Data Products in the Gulf of Mexico

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Data collection efforts in the Gulf of Mexico during and since the Deepwater Horizon incident have been significant under the Response and Damage Assessment phases as well as through the Gulf Research Initiative (RGI). Two large oceanic datasets recently archived at NOAA's National Centers for Environmental Information (NCEI) are the Deepwater Horizon (DWH) Data Integration, Visualization, Exploration, and Reporting (DIVER) system's Natural Resource Damage Assessment (NRDA) data submitted from NOAA's Office of Response and Restoration and the GRI data collections submitted via Gulf of Mexico Research Initiative Information and Data Cooperative (GRIIDC). These datasets include the environmental data gathered and utilized during the Response and Assessment phases of the Deepwater Horizon Incident in the Gulf of Mexico. Included are raw and processed data, laboratory results, logs, data summary reports, imagery and photographs from a wide range of platforms, sensors and sampling methods. These data compile a comprehensive environmental account of the DWH Damage Assessment and form the baseline for Restoration efforts and scientific research going forward.

Much of the oceanographic data (e.g. CTD, ADCP, Thermosalinograph (TSG) etc.) in the archive submissions include data in their raw formats which allows for additional processing and quality control procedures to be applied. To improve the usability, quality and discoverability of these valuable datasets, NCEI-MS has begun to incorporate the DWH data collections into associated NCEI developed databases. For example, water profile data from the DIVER and GRI collections will be included in the World Ocean Database (WOD) and further be utilized to improve the World Ocean Atlas and the Gulf of Mexico Data Atlas. The surface underway *in-situ* observational data will be included in the NCEI Global TSG Database. Ocean Current observations can be incorporated into the Global Ocean Current Database. Additional data quality assurance and quality control (QA/QC) will be conducted and data will be converted to corresponding uniformly formatted data for each database. We expect both quantity and quality and usability of data in the northern Gulf of Mexico will be greatly improved by inclusion of the DWH data into NCEI foundational products and services.

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A Call for a Consistent and Transparent Framework for Habitat Mapping in the Gulf of Mexico

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Maps are recognized to be an effective means of communication between scientists, decision-makers, and other stakeholders because they present information in a common frame of reference: geographical space. More specifically, marine habitat maps produced from the combination of environmental data with *in-situ* biological observations are considered to be among the best spatial decision-support tools currently available. However, habitat maps resulting from interdisciplinary efforts are merely simplified representations of real habitats, and are strongly influenced by the many decisions involved in their production.

In this paper, I demonstrate how even small variations in data characteristics, treatment, and analysis can produce very different habitat maps. In addition, I show how these variations may not be captured by traditional measures of map accuracy and model performance, which can mislead decision-makers. In order to establish a consistent and replicable framework for spatial data synthesis, integration, and visualization, I recommend moving away from single static maps and towards interactive, open-access webGIS. Such GIS would host all spatially- and temporally-explicit data on the Gulf of Mexico (GoM), and would (1) enable dynamic interaction with multiple maps, (2) facilitate data selection by regrouping available data and identifying data gaps, (3) enable the proper integration of metadata for each dataset (e.g. data quality, scale) (4) facilitate the use of habitat mapping, modeling, and error and uncertainty propagation tools, (5) offer a scalable environment, (6) enable the exploration of new geovisualization techniques for multi-dimensional environments, and (7) combine information about the social, economic, natural, and management perspectives.

In summary, such GIS would be based on an adaptive framework wherein data, tools, maps, and models could be iteratively updated and refined with new developments. This would offer replicable and transparent options for processing and analysis, enabling valid comparisons of maps of all areas of the GoM and time periods to be made. The GIS would enable the production of different visuals (e.g. story maps) to effectively communicate information to the appropriate audiences and would be accessible to anyone (including data and tools).

RECOVER Virtual Lab: Utilizing RECOVER Data through a Virtual Lab Application to Disseminate and Communicate Oil Spill Science

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The RECOVER Consortium developed a web-based interactive educational website and application to effectively educate and disseminate oil spill science and research to students - ranging from elementary to collegiate levels - and the general public. The RECOVER Virtual Lab application allows users to conduct virtual experiments and collect virtual data on the impacts of oil on fish physiology, similar to those of RECOVER researchers. By using the Virtual Lab, students, teachers and the general public are able to understand the real world applications of data, experimental designs, and results generated by RECOVER researchers. Guided by the virtual lab narrator, a RECOVER scientist, the

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students present their data in easily understood graphics. The virtual lab includes a Teacher's Workbook, and explanations from the researcher themselves, that have been used in classrooms throughout the United States. Utilizing the data produced by GoMRI scientists and delivered to students and the public via the RECOVER Virtual Lab, the reach of the consortium and oil spill science has increased to individuals that may not otherwise have access to oil spill science and data. The virtual lab serves as an outreach tool and as a GoMRI legacy product. This research was made possible by a grant from The Gulf of Mexico Research Initiative. Grant No: SA-1520; Name: Relationship of Effects of Cardiac Outcomes in fish for Validation of Ecological Risk (RECOVER). Data are publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) at https://data.gulfresearchinitiative.org.

Predictive Neural Network Model for Real-Time Nowcasting of Recreational Water Quality Advisories along the Gulf Texas Beaches

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The economic impact by beach closures is enormous. In many instances, beach closures are associated to the presence of high bacterial contamination induced by deteriorating water quality. The U.S. EPA Beaches of Environmental Assessment and Coastal Health Act or BEACH Act of 2000, introduced a series of indices and it includes the level of *Enterococci*, as an index in defining the beach conditions for swimming and recreational activities.

The procedures required to generate a beach advisory is long and tedious. As an example, the water samples are collected since 2005 around approximately 167 stations of 67 recreational beaches along the Texas coast weekly during the peak swimming season (May - September), and bi-weekly for the rest of the year. The samples may take a day or two to complete the laboratory test analyses. In this study, deep learning algorithm with explanatory variables is applied to evaluate a predictive model of *Enterococci* concentration along the Texas recreational coasts using swimming season in the 2 years period of May 2016 to September 2017. The predictive model developed in this study can be used in combination with readily available real-time environmental and weather forecast data, such as river discharge, river nutrients, sea water salinity, sea water temperature, wind speed and direction, wind stress and wind stress curl, weather types, and various types of antecedent rainfalls that are now available to the public. The resulting predictive model can be utilized to nowcast and forecast beach water quality, and hence, advance beach closure warnings that can greatly reduce the risk to human health.

Migratory Connectivity in Cuba: Synthesis and Conservation

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The Nature Conservancy is studying migratory pathways to identify key habitats in the life cycles of marine species in the Gulf, the critical regions connecting them, and the threats migratory species encounter that can impede migration. Critical migratory pathways and threats to species migration are essential information for effective marine conservation planning and species survival, yet are poorly understood. By identifying these blueways and hotspots, marine conservation planners can aim to

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protect these locations and improve species survival. The Conservancy has gathered animal tracking data from over 100 researchers and institutions in the United States, Mexico, and Cuba to assess migratory pathways in the Gulf of Mexico, including Cuba. The goal of its Migratory Species Conservation framework is to enhance migratory biodiversity by conserving important pathways within the Gulf of Mexico and improving ecological connectivity. More specifically migratory connectivity refers to the links individual animals or species populations provide to their ecosystems based on their use of and fidelity to specific habitats or geographic areas. For example, birds of one breeding population that stay together throughout migration and wintering have strong connectivity, while birds that breed in the same area but disperse during migration and wintering have weak connectivity. Migratory connectivity is important for preserving other relevant ecological processes and the health of the entire Gulf of Mexico large marine ecosystem. In this presentation we share the results of our recent migratory connectivity assessment for Cuba. This project aims at highlighting the geographic role Cuban marine environments in maintaining the regional migratory connectivity. The results highlight the different levels of connectivity of marine megafauna in Cuban waters, and regionally within the North Atlantic. Examples are presented of migratory pathways of fish, sea turtles, marine mammals and birds, and their demographic and habitat connections across the region, with emphasis in the Gulf.

Deepwater Horizon Data Collaboration: Advancing Approaches to Managing and Sharing Environmental Data

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Significant efforts are underway to conduct research and restoration actions in response to the Deepwater Horizon Oil Spill. Understanding the scope and outcomes of those efforts is critical to informing future actions. Over the past 2 years NOAA has sponsored workshops and working groups with the express purpose of fostering collaboration and data integration across the many entities working on the research and restoration efforts in the Gulf of Mexico. These workshops have brought together managers, scientists, and practitioners from across academia, governmental agencies, and non-governmental groups to discuss and prioritize the path forward on integrating environmental datasets and promoting consistent and standardized data management and data sharing. The first workshop, held in June 2017, tackled big questions and resulted in 3 working groups focused on addressing data standards, the ability for data systems to interact, and improving the discovery and accessibility of scientific data. The second workshop, held in Dec. 2018, focused on distilling the working groups' efforts into specific best practices, products, and concrete steps that project managers and data managers can take to collect and share high quality data. The workshop also focused on defining the remaining challenges and identifying strategies to continue making progress in data collaboration efforts across the Gulf of Mexico in support of restoration and science.

002: Turbulent Behavior of Deepwater Blowouts

Modeling Deepwater Oil and Gas Releases: Brief History and the Current Status

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Deepwater oil spills are much less frequent than near surface spills. But when they occur, they tend to cause large scale environmental impact. IXTOC I spill (not so deep at 50 m) 40 years ago and the Deepwater Horizon spill (in very deep water at 1500 m) in the Gulf of Mexico are examples of massive underwater releases of oil and gas. Models simulating the behavior of oil/gas from such releases are needed for monitoring and decision making during an accidental spill, contingency planning, designing relief systems for a potential spill, and in post spill damage assessment. Modeling deepwater spills are much more complex than surface spills. Some of many reasons for the complexity are that oil is mixed with gases, high pressure, and cold water temperature. In these conditions, gases combine with water to form hydrates. Hydrates dissolve as they travel up and simultaneously revert to free gas. Whether dissolution or dissociation dominates depend on multiple factors. Therefore, models need to deal with 4 phases: oil, gas, hydrates, and water. Each phase affects the transport and fate of other. It is a 4-dimensional (x, y, z, and t) problem requiring integration of hydrodynamics, plume and gas thermodynamics, and gas chemistry. It gets more complex when turbulent dynamics of the plume is considered, where oil breaks into a spectrum of droplets due to initial instabilities and subsequent turbulent droplet breakup and coalescence. Further, oil interacts with marine sediments and alter the fate of oil and sediments both. This talk briefly discusses the deepwater oil/ gas modeling history from almost nothing, 30 years ago, to the status today. Oil and gas processes that takes place during the travel in water column, how to model them, comparison of simulations with limited data available, and the formation of underwater plumes will be explained. Furthermore, detailed simulations will be shown to illustrate the behavior of oil and gas plumes released underwater.

Numerical Modelling of Flow Through an Orifice Plate and the Effects that Obstructions Have on Deepwater Jets

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The distribution and fate of oil released from a deep-water blowout is strongly dependent on the size of the droplets that form. The breakup of the hydrocarbon jet is a local process that is determined by the turbulent flow fields in the vicinity of the jet. In the decade since the Deepwater Horizon blowout there has been significant effort in finding methods to determine the size of droplets. As field scale experiments are intractable, the focus has been on developing scaling laws based on the Weber and Reynolds Number that have been calibrated using lab and meso-scale apparatuses. The use of straight pipes in these experimental works is a potential issue as they do not accurately represent the geometry of the damaged structures - e.g. risers and wellheads. These features may be critical in determining the turbulence of the jet. In the Macondo event, the riser was cut off at the Lower Marine Riser Package (LMRP), where for a few days the oil was able to flow freely into the Gulf of Mexico. During this time the flow of the oil and gas was complicated by the Blowout Preventer (BOP) stack below the LRMP. Inside the BOP was a series of rams and preventers, including the failed Blind Shear Ram and Upper Annular Preventer (UAP). These obstructions significantly altered the flow field leading up to the outlet at the LRMP. Directly modelling the flow through the BOP is complex. As a first approach, we look at simulating flow through an orifice plate-like obstruction, which is a reasonable analog to the UAP. The effect that the location and size that the restriction has on the jet is investigated using both Reynolds Averaged Navier Stokes (RANS) and Scale Resolving Simulations (SRS). In particular, we show that the turbulence created by this restriction is not just limited to the pipe, but is advected into the jet and surrounding medium, significantly altering the characteristics of the turbulence field that will govern

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the break up process. Our modelling results provide an initial prediction of the potential impact of obstructions on the turbulence field inside and outside the pipe and thus the potential effect on the break up process.

Large-Eddy Simulations of Effects of Gas Bubble Dissolution on Dynamics of Deep-Sea Hydrocarbon Plume

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Hydrocarbon plumes released from deep-sea wellhead blowouts are typically formed by a mixture of gas bubbles and oil droplets. For the dynamics of the nearfield plume, the buoyant gas bubbles play a critical role by driving the plume to rise. When rising towards higher elevation, two processes occur simultaneously and induce opposite effects on bubble buoyancy: (i) the bubbles expand while rising due to the decrease of hydrostatic pressure; (ii) a considerable amount of natural gas in the bubbles is dissolved into seawater, which significantly reduces the bubble buoyancy. The combined effect of these two processes together with the seawater stratification eventually determines the characteristics of the plume dynamics. In this study, the effect of gas bubble dissolution on the dynamics of deep-sea hydrocarbon plumes is studied using large-eddy simulation (LES). A new Eulerian gas dissolution model is developed and applied to simulate the reduction of gas bubble concentration due to dissolution of gas in seawater, as well as the effect on the overall plume dynamics. A set of LES runs are performed to cover various blowout scenarios with different initial bubble sizes. The results show that plumes that have smaller initial bubble size exhibit faster relative bubble dissolution rate compared to plumes with larger initial bubble size. As a result, the plumes with smaller bubbles also have lower peel and trap heights than those with larger bubbles. For comparison, a second set of LES runs with identical conditions but without including the gas dissolution effect are also performed for comparison purposes. The data analysis shows that the exclusion of gas dissolution causes overestimation of plume peel and trap heights, highlighting the importance of accounting for gas dissolution effects for predictions of nearfield hydrocarbon plume characteristics. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

Turbulent Structure of Oil Plumes in Oceanic Environment

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The overall fate and transport of oil after a deep-water blowout depends heavily on the vertical distribution of effluent, set predominantly by turbulent plume dynamics. Of primary modeling importance is understanding how long effluent parcels remain in the water column, what fraction reach the surface and what is the surface expression of individual effluent constituents. Previous laboratory experiments and numerical simulations of thermal and gas bubble plumes have shown, perhaps surprisingly, that system rotation significantly alters plume behavior even at oceanographic Rossby numbers[1,2]. In the current study, we turn our attention to modelling liquid-liquid mixtures of water and oil allowing for weak slip of the oil phase relative to water. High-fidelity turbulence simulations employing high-order spectral-element methods (SEM) and a computational domain that includes fully turbulent effluent input from a resolved pipe, are used to study the evolving structure of

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the oil plumes in the presence of background stratification and rotation. The multiphase oil plume is modeled using a standard mixture model for the liquid phases in a Boussinesq, Eulerian-Eulerian framework while incorporating a non-linear model for the effective phase slip. We concentrate on the effects of varying both the Rossby number and slip speed on the overall level of sub-surface oil trapping of and on changing both the number and thickness of the multiple intrusion layers formed. In the future, the current line of enquiry will be extended to account for horizontal cross-flows.
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Hydrate Growth on Gas Bubble Interfaces in a Water Dominant System

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Hydrocarbon fluids are susceptible to hydrate formation in deep-water (high pressure, low temperature) environments. Hydrate growth on dispersed gas bubbles is an important consideration in blowout dispersion modelling [1]. Previous studies on suspended gas bubbles found that at gas concentrations above saturation, hydrate shells form and growth continues until all free gas is consumed [2]. Dissolved gas concentration in the bulk liquid phase also affected the morphology of hydrate shells suggesting an impact on gas-water diffusion mechanisms [1,2]. This work extends previous studies on hydrate shell growth on a *single* bubble, to the interaction of many entrained gas bubbles, using a High Pressure Water Tunnel (HPWT) and high-speed camera.

Hydrate formation experiments were performed using methane, fresh water, and a 3.5 wt% NaCl solution at bulk velocities of 2.6, 4.0 and 5.4 ft s^{-1}. The HPWT operated at 900 psia and 13.5 °F subcooling to reflect subsea conditions. Hydrate growth was measured through PVT relationships and gas consumption over time. An edge detection script was used to analyze high-speed videos of bubbles and obtain size distributions as hydrate growth progressed over time.

Experimental results suggest competing effects between interfacial area driven growth and gas diffusion into the bulk phase. Measured hydrate growth rates are slower than rates of gas dissolution due to the formation of a transport-limiting hydrate shell. Hydrate shells on large bubbles were observed to shed due to hydrodynamic instability. Without salt, the bubble size distribution shifted from larger (~ 3 mm) to smaller (~ 0.3 mm) mean diameters following hydrate formation. On the contrary, bubbles in 3.5 wt% NaCl solution were finely dispersed, remaining on the order of 0.3 mm throughout conversion. The experimental data from this study provides key insights into the effects of hydrate formation on dispersed gas bubbles for subsea hydrocarbon plume modelling.
References:
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Phenomena Affecting Breakup of Oil Patches by Plumes and Waves

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The presentation summaries the findings of several studies aimed at characterizing the breakup surface oil slicks and subsurface oil plumes along with mechanisms affecting the resulting droplet size distributions. In both cases, mixing the oil with dispersant drastically reduces the droplet sizes to the micron (and sub-micron) range in a phenomenon - tip streaming, that cannot be modeled based on turbulence-based length scales. This phenomenon also continues the breakup of entrained droplets under the influence of mild residual turbulence long after the wave breaking. In oil jets in cross flow, the boundaries of the jet and spatial distribution of droplets in it are affected by the droplet sizes, and consequently, the presence of dispersants. In vertical jets, high shear in the near field generates compound droplets that increase the oil-water interfacial area significantly.

Experimental Investigation and Prediction of Droplet Size Distributions in Turbulent Oil-in-Water Jets - Scale-Up from Lab to Large Scale

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A scientifically sound response in case of submarine oil blowouts like the Deepwater Horizon (DWH) accident and the development of mitigation strategies for future oil spills are important to avert major damage to people and the environment. The success of these measures hinges on the accuracy of the used oil fate models. The droplet size distribution (DSD) that ensues during a submarine oil spill is a crucial input parameter for these models. It is highly dependent of the blowout conditions, i.e. pipe diameter, exit velocity and turbulent mixing intensity. Moreover, physical properties like the densities of the involved phases and their interfacial tension (IFT) as well as the presence of a gaseous phase affect the DSD. Subsea application of chemical dispersants (SSDI) to the oil-gas-water mixture as applied during the DWH spill is supposed to bias the DSD towards smaller droplet sizes in order to keep most of the oil subsea. If the droplets are already small enough to stay dispersed in the deep sea due to turbulent dispersion alone, SSDI would be redundant and might cause further damage the ecosystem. Multiple experimental investigations on the DSD in free jets have been carried out in the past. Most of them use nozzles with diameters of a few mm only. Thus, the obtained correlations have to be extrapolated by multiple orders of magnitude to the field scale causing a high degree of uncertainty. Therefore, larger facilities are needed for the improvement of modeling accuracy. Two custom-made jet facilities (lab and pilot-plant scale) with direct optical access have been built at Hamburg University of Technology. High-speed PIV and an endoscopic DSD measurement technology are applied to investigate turbulence characteristics and the ensuing DSD of oil-in-water jets. Experimental results are presented in conjunction with appropriate scaling correlations. This research was made possible by a grant from the Gulf of Mexico Research Initiative (GoMRI), C-IMAGE II/III.

Detailed Characterization of the Breakup of Subsurface Turbulent Oil Jets: Formation of Compound Droplets and Their Morphological Statistics

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Subsurface crude oil discharge generates a buoyant turbulent oil jet and plume. Developing prediction capabilities of the transient phenomena involved requires the understanding of the droplet formation processes in the near-field. However, this domain is nearly optically opaque, limiting the type of data that could be obtained non-intrusively. To resolve this challenge, we inject refractive index-matched silicone oil into sugar water as surrogates for crude oil and water, respectively. The dynamic similarity is maintained by keeping the same interfacial tension as well as density and viscosity ratios. This approach enables unobstructed quantitative visualization by simultaneous application of planar laser-induced fluorescence by premixing the oil with dye, and particle image velocimetry, by seeding both phases with particles. Compound oil ligaments and droplets, which contain smaller water droplets, form regularly during fragmentation. Water layers entrained initially at the periphery of the jet subsequently breakup as they interact with oil ligaments 10-15 diameters downstream of the nozzle. The compound droplets maintain their multi-layer form for at least up to 30 nozzle diameters (range of the present data), well after the entire plume is fragmented to droplets. A random forest-based trainable model is applied to distinguish between phases within the droplets and to quantify the resulting volume fractions and interfacial areas. While rarely occurring in a low Reynolds number jet (Re=594), after 20 nozzle diameters, the fraction of compound droplet increases to 15%-17% for jet Reynolds number in the 1358-2122 range. The corresponding increase in the interfacial area is 12%, and the most probable diameter is 137 um. However, the distribution of areas increase is broad, reaching a maximum of 450% when a single oil droplet contains multiple water droplets. This distribution broadens further at 30 nozzle diameters, indicating that the formation process persists.

Experimental and Numerical Characterization of Multiphase Flow from Underwater Blowout: A Combined Particle Imaging Velocimetry and Computational Fluid Dynamics Approach

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Oil jet released from Deepwater Horizon Blowout (DWH) is accompanied by a large amount of gas. However, the role of gas phase plays in oil jet blowout was seldom investigated in the open literature. In the present study, the multiphase (air-water) bubbly and churn jets were measured experimentally in a laboratory scale by using Particle Imaging Velocimetry (PIV) to evaluate the influence of the gas phase on the jet hydrodynamics, especially at the near-to-orifice region. Meanwhile, Computational Fluid Dynamics (CFD) approach with Large Eddy Simulation (LES) was used to simulate the hydrodynamics of bubbly and churn jet in detail. The turbulent flow characteristics, including the velocity, turbulent intensity, turbulent kinetic energy, vorticity, and turbulence dissipation rate, are compared between the bubbly and churn jets both experimentally and numerically. The churn jet suggests a larger entrainment from the ambient environment compared to the bubbly one. The results indicate that the gas phase plays an important role in influencing the hydrodynamics for the underwater blowout and may affect the formation of the droplet at the initial stage, as well as the effectiveness of dispersant.

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Population Balance Modeling to Study Evolution of Jet with Polydisperse Oil Droplets in a Large Eddy Simulation Framework

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In the context of oil spills, knowledge of the dispersed phase droplet size distribution and its evolution is critical for accurate prediction of many macroscopic features of the oil plumes. In this study, we adopt a population dynamics model for polydisperse droplet size distributions and implement it in a Large Eddy Simulation framework. This allows us to study the evolution of the number density of droplets due to turbulent transport and droplet breakup. Modeling breakup based on turbulent fluctuations and droplet-eddy collisions is a popular method that has been adopted in the literature, in which the breakup occurs primarily due to the bombardment of droplets by turbulent eddies. Existing models assume the scale of droplet-eddy collision to be in the inertial scale of turbulence. In this work we extend the breakup kernels to the entire spectrum of turbulence using generalized structure functions. Our model includes a dimensionless model coefficient that is fitted by comparing the model predictions with a dataset obtained from an experiment performed by C. Li and Katz (2017). Moreover, we develop a new parameterization for the breakup frequency over a wide parameter range to reduce numerical computations in our LES. As a flow application for LES we consider a jet in crossflow with oil being released at the source of the jet. We model the number density fields of the polydisperse droplets using an Eulerian approach. We compare the droplet size distribution obtained from our simulations with published experimental data from Murphy *et al*. (2016), and obtained good agreement. This research was made possible by a grant from the Gulf of Mexico Research Initiative. Computational resources were provided by MARCC.

003: Analytical Advances in Chemical Analysis for Oil Spills: Recent Gains and Gaps in Knowledge Facilitated by GoMRI-Funded Research

Foundational Analytical Methodologies in Oil Spill Analyses

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Oil is a natural component of our marine environment and is composed primarily of a very complex mixture of reduced carbon compounds. Unfortunately, sometimes the mixture of many different types of hydrocarbon molecules is introduced in quantities sufficient to overwhelm natural degradation processes and this causes environmental damage. Oil's composition of many different compounds, with molecular weights ranging from 15 to well over a 1000, requires the application of many different analytical methods including those appropriate for hydrophobic as well as hydrophilic compounds, and appropriate for use with gases to liquids and solids. Some methods focus on detection of overall compositional responses, and others focus on detection of specific sentimental components of the spilled oil, it's residues and in remedial products. These analyses include: identifying the oil's composition when spilled and as it weathers; forensically linking spilled oil with its source; supporting remedial efforts to mitigate environmental damage; supporting the assessment of environmental damage; and provide data for the understanding the fates and effects of the spilled material in the

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environment, and in commercially important marine fishery resources. This presentation will outline the various types of analytical methodologies used during and following oil spills, and point out their appropriate uses and limitations in response and assessment. It will focus on the most widely used analytical methods, GC and GCMS, and outline their current capabilities and appropriate uses, as well as provide an overview of their methodological developments since the Argo Merchant and Amoco Cadiz spills of the late 70s through currently used instrumentation and capabilities.

The Usage of Comprehensive Two-Dimensional Gas Chromatography following the Deepwater Horizon Disaster

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Following the Deepwater Horizon disaster, the usage of comprehensive two-dimensional gas chromatography (GC×GC) coupled with flame ionization detection (FID), time of flight mass spectrometry (TOF-MS), and high-resolution time of flight mass spectrometry (HRT-MS) have provided invaluable insights into oil-spill science. In this talk, we will present an overview on the power of GC×GC by discussing published studies on: (a) detailed characterization of samples; (b) refined biodegradation indices; (c) more accurate biomarker ratios; (d) behavior in the water column; (e) more accurate alkene values; and (e) comparison of the Macondo well oil vs. the Ixtoc oil. Last, we will discuss how we have used the lessons learned from DWH on other spills.

Applications of High Resolution Mass Spectrometry in Oil Spill Science: Past, Present, and Future Opportunities

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Oil is a complex mixture of alkanes, cycloalkanes, aromatics, nitrogen / sulfur / oxygen-containing heterocycles, alcohols, ketones, carboxylic acids, porphyrins, and myriad possible combinations therein. Once introduced into the environment, some weathering processes reduce this complexity through evaporative losses (loss to atmosphere) and water washing of low ring number aromatics, N/S/O heterocycles, alcohols, ketones, and carboxylic acids (loss to seawater). However, GoMRI supported research to date has revealed that the contributions of these mechanisms are dwarfed by that of oxidative weathering processes (photo- and bio-oxidation), which increase compositional complexity. Because these oxidative processes increase the complexity of an already analytically challenging organic mixture and concurrently increase the boiling point of transformed species, conventional analytical techniques yield little insight into the identification of oil spill transformation products. Despite the challenge, recent advances in analytical science now allow molecular-level insight into these complex systems irrespective of initial (unaltered) or transformed-product boiling point; these advances were largely made possible by GoMRI supported research efforts. Here, we summarize the advances in the molecular-level understanding of oil over the past 8 years, in the context of oil spill science, by high resolution mass spectrometry and highlight potential opportunities for future research with an emphasis on current knowledge gaps that must be addressed for future

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spills. This research was made possible in part by a grant from The Gulf of Mexico Research Initiative, and in part by NSF DMR 11-57490, the Future Fuels Institute, and the State of Florida.

What Can Molecular-Level Analyses Tell Us About Biological and Chemical Dynamics of Oil- and Dispersant- Degradation?

E. Kujawinski
Woods Hole Oceanographic Institute, Falmouth, MA

During the Deepwater Horizon oil spill, complex mixtures of oil and dispersants were released into a complicated ocean environment where physical, chemical and biological processes affected components differently. This talk will synthesize recent studies examining molecular-level changes in oil and dispersant mixtures as a function of biological and chemical weathering, focusing on laboratory and field investigations that sought to identify reactive components within oil and dispersants and to track their fate in the oceans. Identification of molecular-level processes in the Deepwater Horizon will enhance the predictions of environmental impacts in future oil spills.

Linking Chemical Analyses with Genomics to Gain Insights into the Biochemical Underpinnings of Oil Degradation

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Analysis of Oil Photo-Products: Insights About Oil Weathering from New Analytical Methods

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Photo-oxidation of surface oil after the Deepwater Horizon spill led to the formation of large quantities of oxygenated oil products. However, it is currently challenging to comprehensively characterize this complex mixture of polar oil transformation products. Furthermore, many of these products are not accessible with traditional analytical methods used in oil spill science. This talk will summarize recent analytical developments and progress in the identification and quantification of such oil photo-products, and how this knowledge leads to new insights about oil weathering processes.

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004: Environmental Setting, Stressors, and Their Influence on Resilience of Benthic Fauna in the Gulf of Mexico

First Complete Profile of Marine Snow Abundance in the Orca Basin, Sea Surface to Sea Floor

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Here we present the first complete profile of marine snow abundance for the Orca Basin in the northern Gulf of Mexico. Data presented cover the water column from the sea surface, through the pycnocline to within 10 m above the seafloor at 2,400 m depth. Orca Basin is an interesting location for studying marine snow because of its unique geological and hydrographic setting: the deepest ~200 m of the basin are filled with anoxic hypersaline brine, reaching salinities of over 260 PSU. A typical deep ocean profile of marine snow distribution was observed from the sea surface to the depth of the pycnocline at 2,200 m, namely a surface maximum in particle concentration, a midwater minimum and a particle nepheloid layer. However, instead of the nepheloid layer being positioned above the seabed, in Orca Basin, this layer was positioned atop the brine. Total particle volume in the brine increased by a factor of 2 to 3, whereas the total number of particles decreased, indicating aggregation and accumulation of material within the brine. This observation infers increased residence time and retention of material within the brine and agrees well with data recorded using laboratory-generated marine snow, for which a 2.2 to 3.5 reduction in settling speed of below the brine-seawater interface was observed. Similarly, increased DOC concentration in the brine matched the measured CDOM curve at a ratio of 10:1, inversely following total particle volume in the water column at the pycnocline. These data indicate DOC release concomitant with loss in total particle volume and increase in total particle numbers at the brine-seawater interface.

Benthic Foraminifera as Recorders of Oil Impact in the Southern Gulf of Mexico

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The Campeche Bay (Southwestern Gulf of Mexico) has a history of oil impacts, both natural and anthropogenic, that have left an imprint in the benthic communities living in the ocean floor. One of the main constituents of the bottom sediments are benthic foraminifera (BF) which have been used as ecological indicators of oil spills around the world. Benthic foraminifera have also proven to be resilient after the DWH spill. With this in mind, there are still some questions to be answered including 1) are BF good indicators of the benthic environmental impact and subsequent recovery produced by an oil spill? What other considerations have to be taken into account? To answer these questions, we studied a variety of samples from areas under the direct influence of natural oil seeps and anthropogenic oil spill sites, as well as “unaffected” ones in the Campeche Bay. Overall, benthic foraminiferal populations around directly impacted areas (both natural and anthropogenic) are less abundant, less diverse and show more modifications in their shells than those without direct or no influence. A word of caution has to be raised before defining the environmental health of a given area or when constructing base lines for the future. The geomorphology of the Southern Gulf of Mexico is very complex and it is

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affected by a variety of natural and environmental stressors. At regional scales, sampling resolution (spatial) is of utmost importance. At low resolution, sampling approaches can overlook areas of greater impact (as depressions in between salt domes), and higher spatial sampling resolution, taking into account the geomorphology and bottom currents, is advisable. Benthic foraminifera respond to different stressors in distinct ways; therefore, there is high potential to identify the type of stressor in an area through the use of BF and more studies are need in order to correlate specific stressor responses in BF assemblages.

Deep Water Coral-Associated Microbial Communities in the Gulf of Mexico Differ Along Gradients of Natural Oil and Gas Inputs

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Coral communities occur throughout the Northern Gulf of Mexico including near cold seeps that release oil, gas, and hydrogen sulfide. This chemical environment may shape the microbial community associated with corals. Similar to their role in shallow water corals, microbes may provide specific functions to deep water corals ranging from disease resistance to nitrogen cycling. Understanding this role is important for coral communities that were acutely impacted by the Deepwater Horizon oil spill. To characterize the coral-associated microbial community in relation to active seepage, we collected over 30 species of corals and sediment from across the Northern Gulf of Mexico from the mesophotic zone to 2000 m and sequenced the 16S rRNA genes of the associated bacteria. Microbial communities were coral specific and differed from the sediment. Many related microbes were shared among coral species including taxa in the genera *Endozoicomonas*, *Alteromonas* and the *Apicomplexa*. Close relatives of two sulfide-oxidizing symbionts of *Bathymodiolus* spp. were found associated with corals from lease blocks with active seepage: members of a symbiotic clade of SUP05 were abundant in three species and epsilon-proteobacteria within a newly described family of mussel epibionts were found in two species. In *Paramuricea* sp. B3, the relative abundance of SUP05 correlated with acquisition of seep primary production as measured by coral tissue stable isotope values. *Callogorgia delta* was sampled extensively from three sites near and far from active seepage. In addition to hosting three potential sulfide-oxidizers, *C. delta* was dominated by an unknown bacterium that may represent a new family within Mollicutes. Finally, sequencing of metagenomes and metatranscriptomes of paired *C. delta*, water and sediment is underway to further determine the effect of seepage on microbial community composition and gene expression. These data suggest that microbes may play an important role in deep-sea coral physiology and may interact with seep chemistry.

Significantly Increasing our Understanding of Deep-Sea Ecosystems While Monitoring the Deep Gulf of Mexico for Anthropogenic Impacts

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In 2010 our team began an investigation of potential impact to deep-benthic coral ecosystems from the DWH spill. We first returned to coral communities where we had established long-term monitoring sites prior to the spill as part of a BOEM project. However, the gross majority of our imagery, from even the best documented sites, was in the form of down-looking photo mosaics. When we did discover a

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site that had been impacted by the spill it quickly became apparent that reliable detection and quantification of impact required high resolution imagery taken from within meters of coral colonies. We soon realized that planar octocorals, including species impacted by the spill, had five major advantages over most animals for visual detection of anthropogenic impact: 1) Most species of these corals are normally almost fully covered with living tissue and the presence of dead branches is rare. 2) All of the branches of many planar octocorals can be imaged cleanly from a single perspective. 3) Corals exchange gases across the thin layer of tissue covering their skeleton and so cannot avoid exposure to most toxins. 4) Deep-sea octocorals live 100's to 1,000's of years and death is a rare event. 5) Because they are attached, the corals provide a record of impact to a particular place that can be detected for many years. We have now followed over 400 octocorals in the deep Gulf of Mexico from 2011 through 2017. This presentation will provide updates on long term impact and the different site-specific recovery patterns from the spill, and what we have learned about coral's life history and interactions with other species. Establishing additional monitoring sites at other depths, in other locations, and with other species of deep-sea octocorals in the Gulf of Mexico, will not only provide an early warning and evidence gathering system for anthropogenic impacts to the deep Gulf, this would inevitably provide a wealth of new data on these poorly know organisms and ecosystems.

Exploring Population Connectivity of Deepwater Corals to Inform Restoration in the Northern Gulf of Mexico

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With continued anthropogenic threats in the Gulf of Mexico (GoM) there is an urgent need to make decisions that will lead to the effective management and conservation of marine ecosystems. Deepwater corals, living deeper than 50 m, play a foundational role in benthic ecosystems by generating three-dimensional habitats for diverse and valuable communities. As such, the Flower Garden Banks National Marine Sanctuary and the GoM Fishery Management Council are in the process of amending and expanding marine protected areas (MPAs) to encompass additional deepwater coral areas within their respective jurisdictions. The establishment of MPAs is a key restoration strategy for benthic communities impacted by catastrophes like the Deepwater Horizon oil spill (DWH) in the GoM. Understanding the factors that promote or impede the connectivity among populations of key foundation species over horizontal and vertical dimensions is essential to manage these MPAs.

We aim to understand the processes that shape connectivity patterns in habitat-forming deepwater corals from the northern GoM. We focus on four species, including three that were directly impacted by the DWH. Target coral species live at three depth ranges: mesophotic (70-150 m), upper continental slope (400-1100 m), and lower continental slope (1300-2400 m). We quantified population connectivity in these species through the integration of field sampling, population genomics and physical oceanographic modeling approaches. We will present results defining spatial scales of coral population genetic structure and differentiation at different depths, indicating directionality and relative rate of genetic exchange among coral populations. Outcomes from predictive models of larval dispersal integrated with genetic data to estimate dispersal distances and connectivity networks will also be presented. These results, produced in collaboration with resource managers, will inform management of MPAs and restoration efforts in the GoM.

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Exploring the Role of the Microbiome on the Health and Resiliency of Corals at the Flower Garden Banks National Marine Sanctuary after Severe Storms

A. Shore, J. Drummond, A. M. S. Correa
Rice University, Houston, TX

The Flower Garden Banks National Marine Sanctuary (FGBNMS), one of the few remaining coral-dominated reefs in the greater Caribbean, has recently experienced acute periods of reduced water quality following severe storms in the northwest Gulf of Mexico. In late July of 2016, benthic organisms on the East Flower Garden Bank experienced a Localized Mortality Event (LME) after exposure to storm-generated floodwaters during the Tax Day Flood. In October of 2017, Hurricane Harvey-generated runoff entered the FGBNMS, but no signs of an LME were observed. The coral microbiome plays a key role in coral defense against potentially stressful environmental changes (e.g., in salinity or temperature) and is useful in assessing changes in coral health/disease states. To understand 1) how coral-associated bacterial communities responded to flood-driven changes in water quality, and 2) the relationship of the microbiome to coral health status, we sampled FGB corals (*Orbicella faveolata* and *O. franksi*) during the 2016 LME, approximately one year after the LME, and during a period of reduced water quality following Hurricane Harvey. We characterized coral-associated bacterial communities using Illumina MiSeq sequencing of the V4 hypervariable region of the 16S rRNA gene. Preliminary results from 2016 show that bacterial community structure in lesion samples was shifted from that of healthy coral tissues at East and West FGBNMS during the LME. Comparison of LME samples to pre- and post-Hurricane Harvey samples will enhance understanding of coral-microbe interactions during and after acute flood-driven reductions in water quality in order to predict when and where future LMEs may occur.

A Bayesian Hierarchical Model for Spatial Analysis of Reef Habitat Data of the Gulf of Mexico

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Since the spatial distribution of many fish species relates to certain habitats and depth regimes, spatial data of habitat type can provide valuable information in the absence of detailed ecological data, to predict the occurrence and abundance of fish species. This presentation is focused on modeling the relationship between the spatial distribution of fish abundance and habitat type, and the roles that different habitat types play in the spatial distribution of species abundance. First, a Bayesian hierarchical model was introduced to handle the high-dimension spatial data. Since there is no closed form solution for this model, Markov chain Monte Carlo (MCMC) was applied to conduct the statistical inference. Second, we investigated the correlations among different habitat data and found some of them are highly correlated. Then, several variable selection techniques were implemented to provide a deep understanding on both the model and the roles of different habitat types. In sum, we provide a framework for the spatial analysis of data to understand the relationship between habitat and fish abundance.

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PAH Influence on Living Resources Resiliency

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Systematic studies conducted in the southern Gulf of Mexico (GoM) showed that PAH contents in the water column and sediment have multiple sources: river runoff, natural seeps, IXTOC I blowout and recent oil activities. Total PAH discharged by river runoff is one of the main contributors to the GoM ecosystem estimated between 2.2 $x10^{-08}$-0.10 metric tons/day. PAH Concentration showed a general decreasing pattern from coastal areas-offshore. Highest superficial sediment PAH levels were found in the oil infrastructure area with a maximum of 943.6 µg/kg, but usually PAH registers were in a range of 15.8-83.1 µg/kg. Analysis of cores in the SWGoM showed a high historical variability of PAH levels ranging from 25-107 µg/kg with the highest peaks not matching the Ixtoc I blowout time. Input of these hydrocarbons may be due to natural oil seeps that introduce systematically large quantities of hydrocarbons to the Gulf environment every year. Communities of crustacean, echinoderm and fishes seem to be adapted to live in this oiled environment; however episodic events, natural or man-made could disrupt this equilibrium. Exposure to episodic high levels of PAH concentration may have a direct impact in organismal health condition. Nonetheless, impact at the population and ecosystem level is not clear. Community structure and diversity variations are more related to environmental factors. Although there are no official fishery statistics in the Mexican GoM before 1975, available historical records showed a sustained increased trend up to 1994, suggesting healthy fishery stocks. After the 1990´s, overharvesting affected stock conditions. Living resources seem to have high resiliency to long term PAH variations and fishing effort looks like a more important stressor at population level.

Spatiotemporal Trends in PAH Baselines in Gulf of Mexico Fishes

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The Gulf of Mexico (GoM) is one of the most important regions for oil and gas reserves in the world. In addition to the extensive oil industry infrastructure and over 900 natural oil seeps, there have been more than 30 major oil spills in the GoM since the 1960's, all resulting in the ubiquitousness of oil and polycyclic aromatic hydrocarbons (PAHs) in the GoM. Yet surprisingly, baseline levels of PAHs in fish were relatively scarce prior 2010. Following one of the largest oil spills in the GoM history, the Deepwater Horizon oil spill, the C-IMAGE consortia conducted extensive demersal longline surveys from 2011-2017 in order to characterize Gulf-wide PAH exposures in a number of fish species. Biliary and tissue concentrations of PAHs in a number of fish species between pre-2000 and post-DWH data in the GoM demonstrate increasing trends. In general, mean biliary PAH concentrations for a number species collected in the northern GoM are continuing to decrease over time, however maximum concentrations have increased 90% since the 1990's. In contrast, liver concentrations of PAHs in fish demonstrate an increasing over time. Although, fish have a high metabolic capacity for PAHs, the increasing trend suggests their accumulation rates are greater than metabolic rates as a result of chronic exposures. The increasing demand for oil and the intensive exploitation with deeper drilling in

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conjunction with increasing trends in baseline levels should be cause for concern for the overall health of the Gulf ecosystem and its commercially important fish populations.

Will Coastal Shrimp Thrive in Areas of Louisiana Where Increased Inputs of Fresh Water Occur?

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Louisiana is experiencing substantial land loss, with an average loss rate of a football field every 100 minutes. One of the state's primary mitigation tactics is the building of diversions, manmade branches off of the main Mississippi river waterway, that redirect sediment deposition to create new land. However, these diversions will also increase fresh water input into these upper estuaries, reducing environmental salinity and resulting in potential negative consequences to the resident organisms there. One of the key species in these aquatic habitats is the daggerblade grass shrimp (*Palaemonetes pugio*). While grass shrimp can tolerate salinities from 1-55 ppt, their optimal salinity range is 4-16 ppt and it is not known how a shift towards lower salinities in coastal Louisiana will affect their survival and physiological fitness. In this study, we tested the lower salinity tolerance of grass shrimp by measuring mortality, feeding response time, respiration rate, and osmolality after exposure to low salinity (0, 3, 6, or 9 ppt) for seven days. Individuals at 0 ppt exhibited a 40% decrease in survival by the end of the treatment period and a significantly slower feeding response time. Further, the oxygen consumption rate in the 0 ppt group was approximately 61% lower than the 3, 6, and 9 ppt groups and osmolality was lower in all groups below 9 ppt. This indicates potential negative effects with freshening, especially as salinities approach 0 ppt. Additional studies describing species-specific physiological thresholds and the lower salinity tolerance of other estuarine taxa (including commercially targeted shrimp species) will allow coastal managers to implement proper regulatory measures for Mississippi River diversions.

Reproductive Impairment in Three Groundfish Species in and around the Northern Gulf of Mexico Hypoxic Zone

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Over the last few decades coastal hypoxia has emerged as a major seasonally chronic stressor on the northern Gulf of Mexico (GOMEX) benthic community. Coastal hypoxia has been shown to have a litany of negative consequences, at both the organismal and populations levels, for organisms impacted by it. A particularly profound consequence is reproductive impairment and ovarian masculinization. We detected varying degrees of ovarian masculinization in nearly all specimens examined of three groundfish species, captured in trawl samples by the RV Oregon II in waters in and around the area where hypoxia seasonally develops in the GOMEX during the 2016 SEAMAP Summer Groundfish survey. This phenomenon, which was previously documented in specimens of *Micropogonias undulatus* from the GOMEX hypoxic zone, was detected in much higher proportions of specimens of this species and also observed in *Leiostomus xanthurus* and *Prionotus longispinosus*. Masculinization was observed at both hypoxic and normoxic sites. Our finding of similar reproductive impairment at the order level demonstrates how widespread the impact of coastal hypoxia is on the northern GOMEX fish populations. This work builds on previous studies that have linked ovarian masculinization to

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hypoxia and shows that the scope of the reproductive impairment is more pervasive than previously thought.

005: Filling Long-Term Research and Monitoring Gaps across Multiple Taxa of Large Marine Vertebrates: Marine Mammals, Sea Turtles, Seabirds, and Beyond

Cetaceans as Sentinels of Ecosystem Health in the Gulf of Mexico

R. Wells (Invited)
Sarasota Dolphin Research Program, Chicago Zoological Society, Sarasota, FL

Cetaceans inhabit the full range of available habitats in the Gulf of Mexico, from shallow inshore waters to the deepest canyons. As top predators with decades-long life spans, their population dynamics, life history parameters, behavior, health, and body condition can reflect exposure to a broad variety of threats, depending on their ranging patterns, and diet. When ranges of management units have been well-defined, the possibility of relating specific localized threats to specific outcomes is facilitated. As an example, stocks of bottlenose dolphins exhibiting at least some level of residency occur in most bay, sound, and estuary habitats of the Gulf. In some places, such as Sarasota Bay, Florida, bottlenose dolphins are known to be multi-decadal, multi-generational, year-round residents to specific bay systems, and can include individuals up to 67 years of age and as many as five concurrent generations within a single lineage. Research initiated in 1970 in Sarasota and vicinity, including tagging and tracking, photographic identification, capture-release health assessments, biopsy dart sampling, and focal animal behavioral follows have provided detailed background knowledge of the resident dolphins, most of which are readily recognizable. Long-term, repeated observations and health assessments provide opportunities to define the range of variability for health and behavioral parameters, leading to the use of the Sarasota dolphins as a reference population for comparative studies to investigate more at-risk bottlenose dolphin populations. Concurrent environmental sampling and monitoring, including abiotic factors as well as prey fish surveys, harmful algal bloom cell counts, and human activity measures provide the basis for identifying population-level responses within the Sarasota community, such that these dolphins can serve as sentinels of ecosystem health.

When Gaps Aren't Voids: What We [Don't] Know about Marine Birds in the Gulf of Mexico

C. Haney (Invited)[1], Y. Satgé[2], J. R. Gleason[3], P. G. R. Jodice[2], R. Wilson[4]
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Compared to other apex predators and marine regions, astonishingly little is known about seabirds in the Gulf of Mexico. Data gaps persist despite the Gulf having among the densest, most extensive industrial footprint of any sea. Since 1942, about ~6,000 oil and gas structures have been constructed in the western and central Gulf, with ~3,500 structures still present, and ~3,200 of these currently active. Perceptions the Gulf lacked appreciable diversity or densities of marine birds had several origins. Prior to 2017, studies of marine birds in the Gulf were opportunistic, largely confined to a subset of continental shelf or slope waters. Formal study of marine birds in the eastern U.S. is still

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nascent relative to, e.g., the Pacific basin. Atlantic marine bird research has tended historically to be stove-piped among management and research entities, including federal natural resource agencies having regulatory authority over Gulf waters. Perceptions the Gulf was relatively impoverished of marine birds also stems in part from certain life history traits distinctive to these apex predators. Typical of subtropical and tropical marine avifauna, Gulf seabirds are patchy in space and highly variable through time, especially in their seasonal use of this region. Once complete (2017-2020), surveys from the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) should give the first near synoptic picture of marine bird distributions in the Gulf. Nevertheless, a number of profound gaps in our knowledge remain. Among these include identifying fundamental drivers to seabird trophic linkages in the Gulf, knowing which regional oceanographic and atmospheric conditions affect marine bird habitats, and how predominant natural (hurricanes) or anthropogenic perturbations (e.g., Deepwater Horizon) influence the marine bird community in Gulf ecosystems.

Aerial Seabird Surveys in Northern Gulf of Mexico: Design Considerations and Preliminary Results

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Despite the importance of the Gulf of Mexico for seabird species, there is limited information available to quantify species-use in the region. To bridge this gap, the U.S. Fish and Wildlife Service is working to identify a statistically sound sampling framework for aerial seabird surveys in the near-shore environment as part of the Bureau of Ocean Energy Management's Marine Assessment Program for Protected Species (GoMMAPPS). Low-level (200-foot) aerial surveys were conducted from the USA-Mexico border near Brownsville, TX to Key West, FL including the Dry Tortugas during February 2018 and July 2018 based on lessons learned in a pilot-effort off the Louisiana coast in July of 2017. Using the U.S. EPA Environmental Monitoring & Assessment Program's 40-square kilometer hexagon sampling grid and a generalized random tessellation stratified sampling technique, 180 hexagons were randomly selected. A random flight direction was selected for each hexagon, which defined two additional, adjacent hexagons thereby increasing the spatial coverage and creating a three-hexagon sampling unit. Each sampling unit consisted of three parallel ten mile transects spaced one mile apart, resulting in approximately 30 miles of transect per sampling unit. A double observer protocol was implemented with three observers collecting data: the pilot-biologist, and two biologists who rotated their seat position daily (from back to front, as well as behind the pilot). Preliminary results indicated no apparent detection bias based on observer or seat location, though flock size estimation differed between observers in the front and rear seats. In winter, detections were dominated by gulls and northern gannets offshore and waterfowl (e.g., mergansers and loons) nearshore whereas in summer several true pelagic species were observed near the outer continental shelf (e.g., shearwaters and storm-petrels) while gulls, terns, and pelicans dominated the nearshore environment.

Novel Insights on the Distribution and Abundance of seabirds from Vessel-Based Surveys in the Northern Gulf of Mexico

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Seabird surveys associated with the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) are uncovering previously unknown aspects of the distribution, abundance, and seasonality for these apex predators. From April 2017 - October 2018 we have conducted ~ 165 days of surveys on 13 NOAA cruises. Using standard, transect-based methodology we have amassed ~ 5,700 detections of 36 seabird species totaling ~ 25k seabirds. Preliminary results suggest a significant number of the continent's black terns *Chlidonias niger* use the Mississippi River delta as staging, migratory, and non-breeding habitat for up to eight months of the year. Although commonly associated with tropical coastal environments, GoMMAPPS surveys have observed the brown booby *Sula leucogaster* to be widespread in pelagic Gulf waters, even more so than the regionally-breeding masked booby *Sula dactylatra*. GoMMAPPS has also discovered that seasonal use of the Gulf by Macaronesian-breeding band-rumped storm-petrels *Oceanodroma castro* spans at least March to September, more than two months longer than recorded for this species elsewhere off the southeastern United States. Finally, GoMMAPPS has regularly detected black-capped petrel *Pterodroma hasitata* using the offshore Gulf, a finding most notable for the fact that this threatened species is currently petitioned for protection under the Endangered Species Act. These novel insights into the habitat use and distributions of the seabirds using the Gulf of Mexico provide an important ecological context for current regional activities and can inform the development of future activities.

Marine Mammal GoMMAPPS: Seasonal Line-Transect Surveys for the Development of Spatially and Seasonally-Explicit Density Models

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The Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) is a multi-agency program designed to improve information on abundance, distribution, and habitat use of protected species in the northern Gulf. The marine mammal component of GoMMAPPS consists of seasonal line-transect aerial and vessel surveys. Aerial surveys are conducted over continental shelf waters between the 20 and 200m isobaths and use visual observer teams to record cetacean sightings, consisting primarily of common bottlenose and Atlantic spotted dolphins. Vessel surveys are conducted over shelf and oceanic waters from the 100m isobath to the U.S. EEZ boundary and combine visual observations and passive acoustic sampling using a towed hydrophone array. The summer 2017 and winter 2018 aerial surveys resulted in 14,784km and 8,167km of track lines surveyed with 293 and 201 marine mammal sightings respectively. The summer 2017 vessel survey resulted in 7,289km of track line visually surveyed with 338 sightings and 545 acoustic detections. The winter 2018 vessel survey resulted in 5,814km of track line visually surveyed with 143 sightings and 198 acoustic detections. These surveys included sightings of more than 18 cetacean species including sperm and Gulf Bryde's whales. The third aerial and vessel surveys are ongoing and will be completed by December 2018. Ongoing analyses are integrating the GoMMAPPS survey data and historical survey data with *in-situ* and remotely-sensed oceanographic data, and topographic data to develop seasonal spatially-explicit density models for cetaceans. Resulting abundance estimates will be incorporated into NOAA Fisheries

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stock assessments and assist managers with important tasks such as decisions related to offshore energy development and evaluating future restoration projects. The results of GoMMAPPS will fill gaps in understanding the factors that influence cetacean distribution in the Gulf and support future marine mammal management, research, and restoration.

The Trophic Ecology and Habitat of the Gulf of Mexico Bryde's Whale (*Balaenoptera edeni*)

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The Gulf of Mexico Bryde's Whale (GoMex whale, *Balaenoptera edeni*) primarily occupies a discrete habitat near the shelf break in the Northeastern Gulf of Mexico. This is a small population (N = 33 [CV = 1.05]), and available data suggest that it is resident year-round. In this study, we examine the movements and trophic ecology of the GoMex whale to better understand the essential features of its limited habitat. Analyses of large vessel line-transect survey data demonstrate that GoMex whales occur within a restricted depth range between 178-408m and are observed most frequently near the 200m isobath. Data from animal borne telemetry tags indicate that during daylight hours, the whales dive to depths between 200-280m and execute feeding lunges near the bottom. Multi-frequency (18 kHz, 38 kHz, and 120 kHz) scientific echosounder (Simrad EK60) data collected in the GoMex whale habitat indicate a concentrated layer of organisms near the bottom during daylight hours. These organisms undertake diel vertical migration and are more dispersed in surface waters at night when the whales do not appear to actively feed. Mesoscale circulation patterns may contribute to this high concentration of prey as there is persistent along-shelf flow of water near the shelf edge from DeSoto Canyon along with an inner-shelf convergence zone in the Big Bend, Florida region that may entrain highly productive shelf water. The GoMex whale is the focus of an ongoing study supported by the NOAA RESTORE Act Science Program. This effort includes research cruises conducted during June 2018 and November 2018 and planned for June-July 2019 to deploy additional animal-borne tags, collect tissue samples for genetic and stable isotope analysis, sample potential prey aggregations, and collect acoustic backscatter data. These studies will further refine understanding of the trophic ecology of this small baleen whale population.

Juvenile Loggerhead Dispersal in the GoM, What Are the Controlling Circulation Processes and How Does This Compare to Other Global Nesting Sites?

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Loggerhead sea turtles have a poorly observed juvenile dispersal stage, moving from nesting beaches into the open ocean. During the first year mortality is high, and understanding oceanographic processes contributing to dispersal and survivability is critical for understanding how climate variability and human interactions affect these endangered populations. Here we report on a subset of findings from a global modeling study of loggerhead turtle dispersal in their first year (Sim Turtle), using a high-

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resolution Earth System model simulation with ocean biogeochemistry (CESM-BEC) and a particle tracking model (CMS). We use total plankton carbon biomass as a proxy for turtle forage, and track this, as well as temperature, along the turtle trajectories, allowing assessment of potential feeding success and freezing exposure. The two main nesting sites dispersing into the Gulf of Mexico (Western Florida and the Yucatan), have very disparate dispersal outcomes, largely controlled by the Loop Current and its variability. Juveniles from the Western Florida site are largely retained within the Florida shelf, while hatchlings from the Yucatan are dispersed either into the Gulf of Mexico or the North Atlantic, depending on the Loop Current state. Best-fed juveniles dispersed into the Gulf of Mexico have a high probability of encountering regions of heavy oil drilling. Comparisons with other global nesting sites will be made, highlighting the unique processes occurring in the Gulf of Mexico affecting turtle dispersal.

Combining Methods to Assess Exposure of the Northern Coastal Stock of Common Bottlenose Dolphins (*Tursiops truncatus*) to Multiple Environmental Stressors

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Common bottlenose dolphins in the northern Gulf of Mexico (nGoMx) are exposed to numerous environmental stressors, including harmful algal blooms, infectious disease, and anthropogenic impacts. Such stressors have caused four Unusual Mortality Events in the nGoMx over the past 2 decades. Three of these mortality events were attributed to harmful algal toxins while the fourth was linked to the Deepwater Horizon (DWH) oil spill. Based upon findings from the DWH Natural Resource Damage Assessment, 38% of the Northern Coastal Stock (NCS) of common bottlenose dolphins was killed as a result of DWH oiling. Unlike other restoration efforts initiated in the nGoMx, implementation of similar efforts for the NCS has been hampered by a near total lack of knowledge about the status, critical habitat, and movement patterns of this stock. This stock's boundaries cover approximately 700 km of coastline, creating numerous challenges for assessing threats across this extended geographic range. Thus, utilization of multiple tools is necessary to efficiently fill data gaps as this stock continues to be exposed to a wide variety of anthropogenic stressors. Long-term photographic-identification and short-term radio and satellite telemetry have been conducted on a subset of individuals in the nGoMx since the early 2000's; such efforts have provided some insight into habitat use and movement patterns of the NCS. Remote biopsy sampling in the nGoMx has also been used to assess contaminant exposure in this stock as well as adjacent estuarine stocks. Upcoming projects, including health assessments and satellite telemetry, will further increase our knowledge of the NCS and the threats facing nGoMx dolphins. The combination of these multiple tools provides a methodology that can be applied to other stocks and/or populations that have extended movements and encounter anthropogenic threats across a broad geographic scale.

Long-Term Regional Abundance Trends of Deep-Diving Marine Mammals near the Oil Spill Site

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Passive acoustic monitoring becomes a lead approach to study populations of deep diving marine mammals. To study the regional abundance variability and habitat use by endangered sperm and beaked whales in the Northern Gulf of Mexico (GoM), passive acoustic data were collected by the Littoral Acoustic Demonstration Center-Gulf Ecological Monitoring and Modeling (LADC-GEMM) consortium in the Mississippi Canyon area in the vicinity of the 2010 oil spill site between 2001 and 2017 through short-term and long-term studies. The regional abundances of the sperm and beaked whales were estimated by several methods using acoustic information collected on stationary and moving platforms. The results indicate the habitat preference shifted for sperm whale after the 2010 oil spill with activities higher at the sites further away from the spill site. The data processing results also show that two different species of beaked whales (Cuvier's and Gervais') were acoustically observed in the study area. The result suggests that Cuvier's beaked whales are predominantly vocal at the deeper sites (about 1500 m depth) persistently through observed years. Gervais' beaked whales mostly phonate at the shallower site (about 1000 m depth). The data corroborate the ecological niche hypothesis. These results provide important insights into the population structure and habitat use of different species of cetaceans in the northern Gulf of Mexico and indicate the importance of high spatial resolution acoustic observations in marine mammal population studies. [This research was made possible in part by a grant from The Gulf of Mexico Research Initiative, and in part by a grant from The National Science Foundation and Greenpeace support. Data are publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) at https://data.gulfresearchinitiative.org (doi:< 10.7266/N700005N >, <10.7266/N7V69GNZ >, < 10.7266/N7TM78RW>)]

Trends and Demographics of Sperm Whale Populations in the Gulf of Mexico: 2010-2017

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The Gulf of Mexico (GOM) is an important habitat for globally endangered sperm whales, which may use the region as a breeding or nursing ground. The short and long-term impacts of the Deepwater Horizon oil spill on GOM sperm whales have not been quantified. We analyzed nearly continuous passive acoustic recordings collected at three long-term monitoring sites in the GOM from 2010 to 2017 for sperm whale echolocation signals. Echolocation click detections were used to estimate sperm whale densities on seasonal and inter-annual scales. Sperm whales show strong sexual dimorphism in body size; therefore, population structure was determined using inter-click-interval and correlated with inter-pulse-interval times as a proxy for body size, and compared across sites and over time. No evidence of oil avoidance during the 2010 spill was found. Female sperm whales are present nearly continuously at northern GOM sites throughout the seven-year monitoring period with a decrease of presence during the summer months, with the occasional presence of males. At the southern-most GOM site, female sperm whales were primarily detected in summer months with a higher presence of males through the year. Encounter rates were highest at the site nearest to Mississippi Canyon with estimated average densities of 3.11 animals/1000km^2. Long-term declines were observed at northern GOM sites, with the highest change of -11%/year at Mississippi Canyon followed by Green Canyon with a -3%/year. In contrast, at the southern-most GOM site, an increase of 16%/year was observed in the last three years. A majority of detections consisted of small females and mid-sized animals, in contrast with observations in the broader Atlantic where a 3% of observations are of male sperm whales. This

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supports the prior hypotheses that the GOM may be an important location for sperm whale reproduction.

Genetic Data Suggest Sex-Biased Dispersal among Sperm Whales in the Gulf of Mexico

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In the Gulf of Mexico (GOMx), sperm whales are found predominantly in deep waters, most commonly over the continental slope in the north-central and western Gulf. However, more recently sperm whales have been documented north of the Dry Tortugas in the southeastern GOMx. Satellite-telemetry tagging studies indicate little connectivity between sperm whales in the northern and southeastern GOMx. These findings suggest that instead of a single panmictic population, sperm whales in the GOMx may partition themselves into separate populations. We analyzed two types of genetic markers, mitochondrial DNA (mtDNA) and nuclear DNA, to investigate whether multiple demographically-independent populations of sperm whales are present in the GOMx. MtDNA control region sequence data (955 base pairs) were collected from 78 sperm whales biopsied in the southeastern, north-central and western GOMx. In addition, to investigate connectivity with adjacent waters, we included 15 samples collected in the western North Atlantic. A subset of samples (n = 75) was also used to obtain nuclear DNA data in the form of thousands of single nucleotide polymorphisms (SNPs) generated through restriction-site associated DNA sequencing (RAD-Seq). Significant genetic differentiation was observed among the four geographic regions (Atlantic, southeastern, north-central and western GOMx) in the matrilinearly-inherited mtDNA data. In contrast, the nuclear SNP markers did not show evidence for significant differentiation across the four locations. This result is not surprising given the social structure of the species. Female and juvenile sperm whales exhibit year-round philopatry, while adult males migrate seasonally. Thus, population structure is driven by female matrilines and, because mtDNA is maternally inherited, it captures levels of female-mediated gene flow in this system. The results from the combined analysis provide evidence for female philopatry accompanied by sex-biased dispersal of males.

Recurrence of Bottlenose Dolphin Immune Function Changes Associated with the Deepwater Horizon Oil Spill in the Northern Gulf of Mexico

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The explosion of the Deepwater Horizon platform in 2010 resulted in an unprecedented release of oil in the Gulf of Mexico. Comprehensive health assessments were conducted on bottlenose dolphins in Barataria Bay, LA (BB), in 2011, 2013, 2014, 2016, 2017 and 2018, to assess potential health effects resulting from exposure to oil. Results were compared to those for Sarasota Bay, FL (SB), dolphins not exposed to oil (sampled in 2011, 2012, 2013, 2014 and 2018).We previously reported significant

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increases in T lymphocyte proliferation, as well as lower Th1 cytokines IL-2, IL-12 and IFNg, lower Th2 cytokines IL-5 and IL-13 but higher IL-4, and lower Treg cytokine IL-10, in BB 2011 compared to SB. These changes in immune functions were generally similar to those documented in other species when exposed to oil or PAHs, and consistent in time and space with exposure to oil from DWH. While measures of T cell proliferation and cytokines returned to "normal" values in 2013, 2014 and 2016, results in 2017 and 2018 were similar to those in 2011, with a recurrence of increased T cell proliferation and a cytokine balance tilt towards a Th2, rather than Th1 or Treg response. The recurrence of immune changes, along with a preliminary assessment that dolphins born after the spill appear to be driving those trends, suggest the possibility of transgenerational adverse effects. Our study highlights the need for assessing subtle, sub-clinical aspects of health to understand potential ongoing and future consequences of exposure to oil spills.

006: Science to Action: Building Partnerships and Developing Collaborations to Support Living Coastal and Marine Resource Management

The Development of Living Shoreline Suitability Models for Select Waterbodies within the Gulf of Mexico

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The current trend in the Gulf of Mexico is to install hard structures; such as, bulkheads, groins, or revetment on the shoreline to protect waterfront coastal property from erosion. In Alabama over 26% of the state's tidal shoreline has been armored, 40% of Tampa Bay's shoreline has been armored, and 20% of tidal marshes in Galveston Bay have been lost as a result of armoring. Hard structures are reducing critical habitat needed for wildlife, nutrient recycling, and sustainable fisheries. Based on discussions from the greater Gulf of Mexico scientific community more decision support tools need to be created to assist with the site suitability and to promote the use of "Living Shorelines." The presenters will discuss the creation and implementation of a Living Shorelines Suitability Model and an associated Living Shorelines Decision Support Tool for different waterbodies within the Gulf of Mexico to include coastal Alabama, Lake Pontchartrain, Louisiana, Galveston Bay, Texas, and Tampa Bay Florida that is being funded by the NOAA RESTORE Science Program. The presenters will discuss the data layers needed to run the site suitability model, the creation of water body specific Living Shorelines Advisory Boards, geographic challenges, potential use by resource managers, outreach needs, and shoreline management outputs generated by the model. The shoreline best management practices could include no action needed, maintain beach or offshore breakwaters with beach nourishment, maintain/enhance/create marsh, plant marsh with sill, revetment, and no recommendation due to highly modified area. The appropriate erosion control recommendations from the Advisory Boards have been considered in the Living Shorelines Suitability Model to help ensure that the model is being built based on local habitats, erosional forces, and regulatory compliance.

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Understanding the Role of Mangroves in Buffering Coastal Inundation during Tropical Cyclones and Rising Sea Level in Southwest Florida

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Southwest Florida, with the largest mangrove forest in GOM region, is experiencing increased coastal inundation during high tides and tropical cyclones. As part of the NOAA/NCCOS project "Adaptation of Coastal Urban and Natural Ecosystems (ACUNE)", researchers are working with local governments (Collier County, City of Naples, and Everglades City) and resource managers (Rookery Bay NERR, Ten Thousand Island National Refuge, and South Florida Water Management District) to develop quantitative understanding on the role of mangrove forests in protecting communities from coastal inundation. Using LiDAR topography data and vegetation data in the region and a 3D vegetation-resolving surge-wave modeling system, the ACUNE team found that the mangrove forest significantly reduced inundation during high tides in 2016-2017 and Hurricane Irma in 2017. Mangrove forest was found to reduce the 1% annual chance coastal inundation area in the region by 35%. First-year results were integrated into the ACUNE decision support system and communicated to local governments and resource managers, resulting in enhanced interests in mangrove restoration. 1% annual chance coastal inundation maps for mid and late 21st century are being produced, considering future storms predicted by CMIP5 climate models and sea level rise scenarios predicted by NOAA in 2017. It is noted that probabilistic coastal inundation in the mid and late 21st century is being simulated using a dynamic coastal modeling system (instead of a "bathtub model") which combines the effects of future storm ensemble and sea level simultaneously.

Identifying Priority Research Needs for Snapper-Grouper Fisheries of the West Florida Shelf through Participatory Fisheries System Modeling

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As NOAA Fisheries endeavors to develop more holistic ecosystem-based approaches to fisheries management, there is an increasing need to engage resource managers and users in identifying relevant ecosystem drivers, risks, and trade-offs. During a series of participatory fisheries system modeling workshops with resource managers and users in the West Florida Shelf region, many concerns were highlighted regarding the multifaceted impacts of severe red tide events. The impacts of red tides have already been incorporated in the stock assessment process, whereby red-tide induced fish mortality is estimated and advice can be given on the appropriate and sustainable levels of fishing mortality in light of these events. The participatory workshops brought to light a number of additional concerns beyond the immediate impacts of red tide on fish mortality; red tide events are also observed to affect habitat condition, commercial and for-hire fishing businesses, aquaculture, tourism, protected species, and human health. These additive or potentially synergistic red tide impacts have further implications for the stock assessment, the ecosystem, and fishing communities as a whole. By leveraging resources and collaborating with state and federal agencies, a red tide response plan was developed to better understand the 2018 severe red tide event and its impacts on the biological and human communities of the West Florida Shelf. We will discuss the strength of the participatory

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modeling approach for building partnerships and identifying information gaps, how the resulting response plan led to decision-relevant knowledge, and the prospects for improving upon this research effort in the future.

From Threat to Improved Practices: How Ecological Events Led to the Design of Monitoring Tools in Two Gulf of Mexico National Marine Sanctuaries

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In July 2016, the Flower Garden Banks National Marine Sanctuary experienced a localized but intense episode of coral and sponge mortality, which was attributed to locally low levels of oxygen. Observations showed that this event was associated with the large-scale export of brackish waters from the coasts over the northwestern Gulf of Mexico shelf, following exceptional precipitation in Texas and subsequent river runoff. The identification of factors conducive to offshore coral reef mortality led to the design of an automated online monitoring tool dedicated to the Flower Garden Banks. The tool provides, in real-time, maps of Chlorophyll-*a* (Chl-*a*) concentration derived from satellite ocean color images, sea surface temperature from satellite infrared sensors, and time series of discharge from rivers along the coast of the northeastern Gulf of Mexico from *in-situ* gauges. Chl-*a* and Chl-*a* anomalies with respect to climatology can be used as a tracer of coastal waters as they disperse into the deeper ocean. The time series of images of Chl-*a* and Chl-*a* anomalies show that coastal waters can reach the Flower Garden Banks Sanctuary. This effort inspired the development of a comparable tool for the Florida Keys National Marine Sanctuary. There, processes such as the recent Harmful Algae Bloom on the West Florida Shelf in the summer of 2018, the export of hypersaline waters from Florida Bay, and the presence of turbid waters are important to monitor as they have periodic and severe impacts on local coral reef communities.

We present both monitoring tools and case study results. The applications were designed based on specific requirements expressed by managers of each Sanctuary. The design requirements resulted from close collaboration with Sanctuary personnel as part of academic projects (NOAA RESTORE and the NOAA IOOS/NASA Marine Biology Observation Network or MBON). These decision-relevant knowledge tools for monitoring environmental conditions can potentially be used as decision-support tools. They are designed to serve as warning systems, and they can be programmed to issue alerts when identifying hotspots that exceed threshold values based on the analysis of historical ecological conditions.

Evaluating Ecological and Human Dimension Indicators for an Ecosystem Assessment of Barataria Basin

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In an effort to stem the rapid catastrophic land loss along coastal Louisiana, the State of Louisiana has proposed sediment diversions of the Mississippi River in order to restore deltaic processes to the adjacent receiving basins, which has poorly understood implications for the biological, social, and economic resources of the region. To better understand the potential consequences of this large-scale restoration activity, NOAA's Gulf of Mexico Integrated Ecosystem Assessment (IEA) program team with the help of local experts created a socio-ecological conceptual model of the Barataria Basin to identify relevant indicators to assess the baseline ecosystem condition. These ecological and human dimension indicators will be used in an ecosystem assessment of the Barataria Basin to evaluate the status, natural variability, and long term trends of the basin prior to the diversion construction and operation. All indicators (biophysical, ecological including habitats and species, and human dimensions) were selected from a large list of potential variables based on three criteria: (1) data availability, (2) responsiveness to change, and (3) utility to managers and stakeholders. First for each indicator, consistent, credible data need to be available in at least a long-term time series. Second, the indicator needs to be able to respond to or drive change in the ecosystem. Finally, the indicator needs to be understood by managers and a wide range of stakeholders to be considered relevant. More than sixty indicators were selected representing this complex socio-ecological system. We will present the preliminary results of the indicator analyses to assess the status and trends of ecosystem health of Barataria Basin, LA.

Facilitating Climate Adaptation in the South-Central U.S. Using Co-Produced Science: The Challenge of Too Much or Too Little Inertia

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The South Central Climate Adaptation Science Center (CASC), hosted at the University of Oklahoma, is one of eight regional CASCs that extend nationwide. Each CASC focuses on providing climate science information to natural and cultural resource managers in their region. To this end, the CASCs provide funding for and conduct research and training. Studies show that one of the most effective ways to generate science that meets a specific group's needs (such as those of resource managers) is to have them as active participants in the process (i.e., co-produced science). However, pairing researchers with resource managers has proven challenging in the current academic and governmental environments. Academic barriers include a reward system that prioritizes publications over relationships, time pressures (especially on early-career professionals), and the lack of incentives for co-production or even interdisciplinary research. Government barriers include the short-term nature of funding cycles, difficulty in hiring permanent employees, and fragile nature of working without a Fiscal Year budget for several months. We will discuss the innovative approaches taken by the South Central CASC to incentivize relationships between researchers and stakeholders, and recount example projects along the Gulf Coast.

Incorporating Manager Input into Ecosystem Modeling Efforts for the Gulf of Mexico

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In the Gulf of Mexico, dozens of ecosystem models have been developed for a variety of applications including fisheries management. However, ecosystem models have rarely been used in actual fisheries management decisions. This is largely due to data limitations, model uncertainties, absence of a formal review process, improper format of model outputs, and poor timing. In order for ecosystem models to be useful for managers, they must provide relevant information at the most appropriate point during the management process. Doing so requires careful planning and strong communication between the modeling team and managers. An ongoing study in the Gulf of Mexico seeks to incorporate input from federal and state management agencies into ecosystem modeling efforts. A Scoping Workshop was held with scientists, managers, and other stakeholders to identify and prioritize challenges that could be addressed using ecosystem models, and how best to incorporate those models into the existing fisheries assessment and management framework. Challenges identified were associated with uncertainty in stock assessments, environmental stressors, multi-species reference points, invasive species, habitat effects, spatial management, and forage fisheries. Short-term priorities included those that address critical assumptions in stock assessments and aim to inform imminent decision making, whereas long-term priorities were those associated with environmental stressors and novel management approaches. Having identified the most important questions, the modeling team must now work with fisheries managers to appropriately format and deliver model outputs that directly inform decision making.

Gulf of Mexico Avian Monitoring Network: A Monitoring Community of Practice

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Hundreds of bird species are supported by barrier islands, beaches, marshes, nearshore and offshore waters, and coastal forests found along the Gulf of Mexico. Although many avian monitoring projects have been implemented across the region, researchers and resource managers have historically lacked a forum by which to share information and identify cross-program/cross-agency needs at the scale of the northern Gulf of Mexico. To address this need, the Gulf of Mexico Avian Monitoring Network (GoMAMN) - a diverse group of conservation partners including state and federal agencies, NGOs, and academic institutions was formed to coalesce a community of practice and define a vision and process for framing the role of bird monitoring. Using the principles of decision theory, GoMAMN developed a set of fundamental objectives along with an explicit objectives hierarchy and associated value models to qualitatively and quantitatively define stakeholder values and goals. Collectively, development of this framework provides: (1) a structured forum by which stakeholders can coordinate and integrate monitoring efforts; (2) clearly articulated core-vales, data needs, and fundamental objectives underpinning bird monitoring efforts; (3) means to identify and implement cost-effective, yet scientifically robust regional monitoring efforts; and (4) a means to standardize data collection and data management efforts that support adaptive management. Additionally, GoMAMN has developed and published a number of products: (1) Strategic Avian Monitoring Plan; (2) Structured Decision Making and Optimal Bird Monitoring Technical Report; (3) Monitoring Optimization Decision Support Tool; (4) dedicated web site; (5) newsletter; and (6) variety of supplementary resources (e.g., birds of conservation concern, ecological systems) as a means to further advance collaborative bird conservation and monitoring efforts across a broad breadth of partners and stakeholders. Hence, GoMAMN provides a structured forum by which the bird monitoring community of practice can share information and collaborate on projects to advance restoration and decision making across the northern Gulf of Mexico.

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Maintaining Engagement with End-Users Throughout the Research Process to Strengthen Applied Science

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Despite efforts to link research outputs and their use in policy, a gap often exists separating the two. Engagement with end-users such as managers and decision makers throughout the research process can strengthen the applicability and use of results in an applied science framework. Engagement with stakeholders is often most effective when initiated during the research planning stage and when maintained throughout the entire research process. We will highlight a case study of an ongoing large-scale, Gulf of Mexico-wide project involving collaboration with an Expert Advisory Panel (EAP) of resource managers and other end-users to assess the habitat use and production of nekton in turtlegrass, a widespread sub-tropical seagrass species. This project is driven by management needs identified by end-users, and guidance provided by the EAP has refined the overall scope of the project and identified additional knowledge gaps impeding management. Through this case study, and others, we will discuss successes and lessons learned when maintaining engagement with end-users to bridge the gap between research outputs and their use to inform management and policy.

The Northern Gulf of Mexico Sentinel Site Cooperative: Connecting Research, Service, and Decision-Making

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Sea-level rise (SLR) is generating negative effects in the northern Gulf of Mexico across multiple interconnected sectors in coastal ecosystems and communities. Stakeholders and partners across the science to stewardship continuum are working to better understand and prepare for rising seas. Through the Northern Gulf of Mexico Sentinel Site Cooperative (Cooperative), researchers, non-profits, local, state, and federal officials and agencies, natural resource managers, tool developers and others are coming together to facilitate the integration of SLR into decision-making. This takes the form of many different projects and activities, with a common theme of building strong, two-way dialogue. The result is a robust partnership that provides access to SLR experts, communicators, tool developers, and decision-makers. In this presentation, the purpose, partnerships, and activities of the Cooperative will be reviewed. Additionally, opportunities and best practices for integrating science into decision-making by leveraging existing networks will be discussed.

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007: Organismal Responses to Oil Exposure: From Individuals to Ecosystems

The Long-Term Impacts of the Deepwater Horizon Oil Spill on Bottlenose Dolphins and the Development of Advanced Diagnostic Tools to Better Characterize Injury and Recovery

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In the aftermath of the Deepwater Horizon (DWH) catastrophe, impacts to bottlenose dolphins in heavily oiled coastal areas of the northern Gulf of Mexico were well documented.[1,2] Necropsies of recovered carcasses and studies of live dolphins within the DWH oil spill footprint confirmed lung injury and adrenal gland lesions consistent with known exposure effects from oil or petroleum-associated compounds.[3,4] In addition, a high incidence of reproductive failure was concluded from a lack of calves being observed during monitoring surveys of pregnant dolphins.[5,6] During the initial investigations, the exact mechanism of reproductive failure was undetermined due to limitations in protocols and techniques. Proposed causes of failure included poor maternal health, direct oil-related toxic effects to the reproductive system or fetus, complications related to adrenal system dysfunction, and/or immune system perturbations leading to an increased susceptibility to reproductive pathogens. More recently, health assessment data collected in 2016 from live dolphins in heavily impacted Barataria Bay showed that cardiac disease could be an emerging problem. Cardiac auscultation revealed an increased prevalence of systolic heart murmurs in Barataria Bay dolphins relative to dolphins living outside the oil spill footprint. However, little could be determined about overall cardiac health due to the lack of advanced cardiac diagnostic techniques in existing field protocols. To address the lingering reproductive failure rates, potential immune system compromise, and the possibility of an emerging cardiac health issue, we developed enhanced diagnostic techniques to evaluate fetal, placental, and maternal health of dolphins. Specifically, enhanced reproductive ultrasound protocols were developed and applied to detect subtle indicators of fetal and placental disease, which can help determine pregnancy outcome and etiology of reproductive failure. Additionally, improvements to the general medical assessment of maternal health were implemented including expanded immune system evaluations and monitoring of adrenal system function. To characterize dolphin heart health, in-water echocardiographic protocols and blood-based cardiac biomarkers tests were developed and applied to wild dolphins living inside and outside the DWH oil spill footprint. These technological and clinical advances are currently being utilized to better understand the long-term injury to northern Gulf of Mexico dolphins and will improve our evaluation of population recovery trajectories post spill.

Acknowledgments: We greatly appreciate the efforts of the multi-institutional field teams involved in the acquisition of data. This research was made possible by two grants from the Gulf of Mexico Research Initiative. Data will be made publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) at https://data.gulfresearchinitiative.org.

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What is the Mechanism of Stress Response Impairment of Toadfish Affected during DWH Oil Exposure?

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Exposure to the polycyclic aromatic hydrocarbons (PAHs) associated with the Deepwater Horizon (DWH) oil spill have been found to impair the release of the stress hormone, cortisol, in marine mammals found in areas contaminated by DWH oil and in teleost fish exposed to PAHs in the laboratory. With this impairment, organisms have a reduced ability to properly respond to natural environmental stressors - an effect that may result in a reduction in overall fitness. The mechanisms for this impairment remain unclear; the inhibition in cortisol secretion may be due to pituitary fatigue through over-stimulation of the hypothalamic-pituitary-interrenal (HPI) axis or could be via an inhibition of cortisol biosynthesis through interactions of PAHs and the aryl hydrocarbon receptor (AhR). Our work uses Gulf toadfish, *Opsanus beta*, a GoM resident, as a model species to understand the effects of DWH PAHs on the HPI axis and the potential for recovery. Using a flow-through system, toadfish are continuously exposed to control conditions or three environmentally relevant concentrations of PAHs from DWH high energy water accommodated fraction (HEWAF; $\sum$PAH = 0 - 10 $\mu g \cdot L^{-1}$) for 7 days followed by recovery. Preliminary data suggest that circulating cortisol and adrenocorticotropic hormone (ACTH) levels are not significantly different between control and DWH oil-exposed fish after 7 days of DWH oil exposure; however, potential impairment of the toadfish stress response, as measured by circulating cortisol levels following a simulated predation stress, may be evident. Combined, these data suggest that impairment is likely not at the level of HPI axis hyperactivation but may be via inhibition of cortisol biosynthesis. Follow-up experiments will investigate the mechanisms responsible for this impairment (differences in melanocortin 2 receptor (MC2R) mRNA expression and cAMP levels in stimulated interrenal tissue) as well as the potential implications on metabolism and the immune system (differences in plasma glucose, liver glycogen, hepatic-somatic index and differential white blood cell counts). CYP1A mRNA expression will be measured throughout HPI axis tissues and liver to measure potential involvement of the AhR.

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Impacts of Crude Oil Exposure on Ecological Performance in Fish

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It is well established that oil exposure causes reduced cardiorespiratory performance in fish. Yet, the downstream implications of impaired cardiorespiratory function for fish ecophysiological performance have rarely been experimentally validated. Oil induced reduction in cardiac performance leads to a reduced aerobic capacity that may impact an individual's success in competitions and predator evasion. We first sought to understand the effect of oil exposure on competitive ability using one-on-one (dyad) competitions between exposed and unexposed individuals. In dyad contests individuals exposed to oil concentrations as low as 5.7 ug l^{-1} ΣPAH had higher instances of social subordination compared to their unexposed conspecifics. We next sought to explore the long-term implications of these relationships using a grow out study design, whereby control and oil exposed groups would compete for resources under resource-rich or resource-limited conditions. After 8 weeks, both 25.3 ug l^{-1} ΣPAH and 53.4 ug l^{-1} ΣPAH oil exposed groups demonstrated reduced specific growth rates when in resource limited environments. This reduced specific growth rate was also accompanied by a reduction in standard metabolic rate, further reinforcing the reduced growth. A final experiment sought to understand the impacts that oil exposure has on predator evasion success, whereby groups of 10 fish were placed in mesocosm tanks in the presence of predators. Using time to 50% mortality as an indicator of predator evasion, oil exposed groups reached 50% mortality in 52.5 min compared to the unexposed groups that reached 50% mortality at 76.1 min. This combination of results supports the hypothesis that oil induced cardiac impairments will have implications on ecological performance of exposed fish.

Identifying Conserved Transcriptional Profiles among Different Fish Species following Exposure to Oil

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RNA-Seq is a high throughput next generation sequencing technology that has developed into a power tool for ecotoxicology research, as it allows for rapid, accurate quantification of the transcriptome of non-model fish species following exposure to anthropogenic and environmental stressors. Many studies have linked transcriptome changes with endpoints of ecological significance (survival and growth), but most of these are tightly focused on specific organisms, environmental conditions, and dose. While doing so is important to accurately anchor the observed responses to the chosen stressor combinations, analyzing the responses solely in the context of a given experiment necessarily limits the utility of the data. However, the increasing ubiquity of RNAseq datasets from multiple species offers researchers the ability to use the results from one species to infer the possible effects on other species. We analyzed RNAseq profiles from 6 different fish species exposed to oil under different circumstances and identified transcriptional patterns that were conserved across multiple taxa. Three pelagic species (red snapper, croaker, red drum), two estuarine species (sheepshead minnow and gulf killifish) and a benthic species (southern flounder) were compared to assess which transcriptional pathways were affected across species. We identified several pathways that are commonly affected across multiple species, including cardiotoxicity, protein synthesis, and cholesterol biosynthesis, as well as pathways

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that were specific to a particular species. Examining transcriptional responses in the context of different exposure conditions and species may allow identification of a generalized, rather than specific, understanding of how exposure to oil affects fish.

Lessons Learned from a Gulf-Wide Evaluation of Biomarker Expression in Red Snapper and Golden Tilefish

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From 2015 to 2017, golden tilefish (*Lopholatilus chamaeleonticeps*, n = 255) and red snapper (*Lutjanus campechanus*, n = 125) were sampled throughout the Gulf of Mexico continental shelf via demersal longline. After objective outlier removal, plasma samples from these fish were utilized to generate the first known reference intervals for oxidative stress, genotoxicity, and immune response biomarkers in these species. Relationships between biomarker response, biometrics, environmental parameters, and polycyclic aromatic hydrocarbon body burdens were evaluated, in order to determine the most useful biomarkers for health effects in field-caught fish. Finally, a transcriptome analysis of select golden tilefish was performed, which indicated differential gene expression of reproductive, immune, apoptosis-related and metabolic genes in stations impacted by the Deepwater Horizon oil spill, as compared to sites from Campeche Bay and the Yucatan Peninsula. This paper presents key findings from this study, with suggestions for future oil spill impact assessments in the Gulf of Mexico.

Exposure to Oil and Hypoxia Results in Alterations of Immune Transcriptional Patterns in Developing Sheepshead Minnows (*Cyprinodon variegatus*)

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The 2010 Deepwater Horizon oil spill occurred in an area subject to hypoxic conditions during a season when many fish species were spawning, thereby making the need for studies examining oil in conjunction with hypoxia in early life stages of fish crucial. Though critical to health, little research has targeted the effect of exposure of oil at early life stages on the developing immune system of fishes. To this end, we exposed sheepshead minnows (*Cyprinodon variegatus*) at three early life stages [embryonic, post-hatch (48 h after hatching), and post-larval (96 hours after hatching)] to either oil, hypoxia (<2 mg/L dissolved oxygen), or both for 48 hours. We performed RNA sequencing for each treatment group to understand how exposures alter expression of immune transcripts and regulation of immune pathways, and to examine when exposure had the greatest impact. Under control conditions, the first transition (embryo to post-hatch) had a greater number of significantly regulated immune pathways than the second transition (post-larval to post-hatch), indicating that the first transition may be more important for development of the immune system than the second transition. Exposure to oil and/or hypoxia had little effect on the first transition. In the second transition however, oil exposure had a unique signature (59 immune pathways were significantly altered), while hypoxia appeared to moderate some of these effects of oil exposure. These data suggest that exposure to oil has a greater effect on immune pathways in the second life stage transition than in the first life stage

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transition, and highlights the need to further investigate the impacts of oil on development of the immune system.

An Adverse Outcome Pathway Linking Oil Exposure to the Development of Vision in Fishes

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Polycyclic aromatic hydrocarbons (PAHs) have been shown to cause developmental malformation in fishes, with effects greater during early life stages. The establishment of adverse outcome pathways (AOPs) allows for anchoring of early molecular-level responses to physiological dysfunction. Here, we will present an adverse outcome pathway linking changes in gene expression to disruption of the visual system in fishes. We have observed downregulation of genes important in eye development and function in mahi-mahi and red drum in RNA-Seq studies conducted following exposure to Deepwater Horizon oil. These studies were consistent with changes in eye tissue determined histologically and decreased visual function observed as optomotor response. To examine a mechanistic link, we conducted further studies using a model organism (zebrafish). Similar changes in gene expression, tissue structure, and optokinetic response were observed in zebrafish and linked to a decline in neuronal structure of the retina. Taken together, these data suggest that oil exposure induces transcriptional responses in the developing eye that culminate with a loss of ability to transmit visual data to the brain.

Deepwater Horizon Oil Alters the Cholesterol Biosynthetic Pathway in Exposed Larval Fish

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In 2010, the Deepwater Horizon oil operation released over three million barrels of crude oil into the Gulf of Mexico. The timing of the spill coincided with the spawning of many marine species in the region including mahi-mahi (*Coryphaena hippurus*) and red drum (*Sciaenops ocellatus*). Numerous abnormalities due to crude oil exposure, including cardiotoxicity, have been documented in fish early life stages; however, the molecular mechanisms that cause these phenotypes are not well understood. Previously, RNA-sequencing was used to evaluate the transcriptomic profiles of oil-exposed red drum and mahi-mahi. Subsequent mRNA analysis not only identified cardiac development-related pathways, but also cholesterol biosynthesis as potential targets in both species. To determine the role of cholesterol biosynthesis in oil toxicity, mahi-mahi and red drum embryos were exposed to high energy water accommodated fractions (HEWAFs) prepared with oil from the surface (OFS) for 96 hours post-fertilization (hpf) and 72 hpf, respectively. Total cholesterol was quantified within exposed larvae using enzyme-linked absorbance assays and results demonstrated a significant decrease in cholesterol in mahi-mahi. Mahi-mahi larvae were pooled for qPCR-based quantification of transcripts involved in the cholesterol biosynthetic pathway. The results corroborate previous RNA-sequencing data, demonstrating upregulation of the cholesterol biosynthetic pathway with increasing oil exposure. Additionally, whole-mount immunohistochemistry was used in 72-hpf zebrafish embryos to visualize

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changes in cholesterol concentrations in the embryonic fish heart following PAH exposure. Understanding the mechanisms involved in producing the phenotypes associated with oil exposure will contribute to assessing the ecological risk of oil spills on fish populations. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

Understanding Bioaccumulation of PAHs in Deep-Pelagic Organisms: A Decadal Time-Series Assessment in Gulf of Mexico Mesopelagic Fishes

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Ecosystem-based management of the oceans strongly relies on continuous observations, essential for distinguishing natural variability from ecosystem change. However, a large portion of shallow to bathypelagic environments lacks such studies. For example, the Deepwater Horizon oil spill (DWHOS) highlighted the lack of baseline data for marine ecosystems in the Gulf of Mexico (GoM) and elsewhere. Several studies have indicated that the deep-pelagic habitat was most affected. Understanding the impact to the deep-pelagic habitat is important due to its diversity and size, role in the marine food web, and its role in carbon sequestration. Mesopelagic fish tissues were collected before the DWHOS oil spill (2007), immediately post-spill (2010), a year after the spill (2011), and five-six years post-spill (2015-2016) to assess if the mesopelagic ecosystem was exposed to, and retained, PAH compounds from the oil spill. Results indicated pre-spill tissues have PAH concentrations of 630 ± 236 ng/g, that increased in 2010-2011 (4972 ± 1477 ng/g) and decreased close to pre-spill values later in 2015-2016 (827 ± 138 ng/g). This temporal trend suggests an episodic contamination event in 2010 that continued through 2011. Also, bioaccumulation was driven by dietary intake and maternal transfer of PAHs, explaining the elevated PAH levels in unhatched eggs in 2015-2016. Results also indicated that a longer-term sink for oil in deep pelagic organisms occurs, potentially higher than in shallower counterparts. Overall, our findings demonstrated the importance of monitoring the persistence of organic contaminants in the deep pelagic GoM. However, trends and gaps in the datasets also emphasize the need for longer time scale ecosystem-based management efforts of the deep-pelagic ocean.

Chronic Developmental and Reproductive Effects in Estuarine Species Following Acute Larval Exposures to Thin Oil Sheens and Ultraviolet Light

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The toxicity of thin oil sheens to early life stages of aquatic species can be magnified by interaction of hydrocarbon compounds with ultraviolet (UV) light. Many early life stages congregate at the surface or in the upper mixing layer making them prone to UV light exposure and thin sheens of oil at the surface. Little is known about the long-term impacts of brief exposures to oil and UV light in combination. Laboratory testing was used to assess UV-oil sheen interactions with grass shrimp (*Palaemonetes pugio*) and sheepshead minnows (*Cyprinodon variegatus*), two common estuarine species. Newly hatched larvae were exposed to a 1 µm thick sheen of fresh Louisiana sweet crude oil for 24 h with or without UV light. The larvae were then moved to clean seawater and non-UV conditions. The grass

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shrimp test encompassed a full life-cycle, whereas a partial life-cycle test was completed using fish. Minimal mortality was observed after the initial exposure but larval development was significantly delayed in fish and shrimp exposed to the oil sheen under UV light. After reaching sexual maturity, shrimp were paired to evaluate effects on reproduction. Shrimp initially exposed to the oil sheen under UV light as larvae had a significant reduction in fecundity compared to controls. These results demonstrate the potential for acute exposures of early life stages to thin oil sheens and UV light to lead to long-term impacts in estuarine species.

The Effect of Oil Exposure on Reproduction and Development of Sheepshead Minnow (*Cyprinodon variegatus*) in Different Environmental Scenarios

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The release of over 640 million liters of crude oil into the Gulf of Mexico (GOM) following the Deepwater Horizon (DWH) oil spill affected more than 2,000 kilometers of shoreline, including estuaries that serve as important habitats and nurseries for aquatic species, such as *Cyprinodon variegatus* (sheepshead minnow; SHM). Importantly, these estuaries experience constant fluctuations in temperature, salinity, and dissolved oxygen, including seasonal hypoxia caused by runoff in the Mississippi River watershed. Polycyclic aromatic hydrocarbons (PAHs) are organic pollutants of particular concern in oil spills due to their toxicity and carcinogenicity to humans and wildlife. The purpose of this study was to determine the somatic, reproductive, and developmental effects on experimentally exposed adult SHM (F_0) following exposure to an environmentally relevant PAH mixture (tPAHs), the oil high-energy water accommodated fraction (HEWAF), with three different environmental scenarios: normoxic, hypoxic, and hypoxic low salinity. These scenarios were within the range of environmental conditions that SHM may have experienced in the GOM during potential oil exposure. F_0 SHM were exposed to no oil (control), low (1.7 µg/l tPAH) or high (17 µg/l tPAH) HEWAF for 14 days. High HEWAF reduced egg production compared to control SHM, and suboptimal (hypoxic and hypoxic low salinity) scenarios exacerbated this effect. Across scenarios, HEWAF exposure affected development of F_1 SHM, including reduced fertilization rates and impaired prey capture, and these effects did not appear to worsen in suboptimal scenarios. Correlations between tissue PAHs and observed endpoints provide additional evidence that the physiological effects observed were caused by hydrocarbon exposure. These data demonstrate that oil from the DWH oil spill was capable of causing significant physiological effects in exposed adult SHM, and that environmental conditions can exacerbate some of the effects of the oil on SHM.

Combined Exposure to Crude Oil and Hypoxia Leads to Transgenerational Epigenetic Inheritance in the Zebrafish

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Hypoxic conditions and exposure to crude oil may co-occur in the Gulf of Mexico, imposing selection pressures if not outright mortality in fish populations. Exposed parental populations exhibit phenotypic responses to these stressors influencing offspring survival. Commonly, experimental designs consider only a single factor at a time when studying the effects of these factors, and their interpretation

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embrace only the generation that has been directly exposed. Usually not investigated is how the all-important interactions between environmental stressors affect parental and offspring populations. A multi-scale approach employing the zebrafish (*Danio rerio*) was used to test the chronic responses over 5 weeks of exposure in four parental experimental groups: 1) Control (normoxia, control diet); 2) Hypoxia (60% DO, control diet); 3) Oil (normoxia, oil-loaded diet) and; 4) Hypoxia-Oil (~60% DO, oil-loaded diet). Offspring from each parental group was exposed to conditions similar to the parental exposures and their survival and performance were determined. Preliminary results indicate that survival (95%), growth rate, hypoxia resistance, and heart rate (240bpm) did not significantly differ among parental groups. However, global DNA methylation in adults was significantly decreased in heart tissue (P=0.05) but not in gonads. Offspring obtained from parents exposed to hypoxia+oil conditions exhibited higher survival (up to 50%) compared with the control group when raised in hypoxia+oil conditions. Regardless of parental exposure, F_1 exposed to oil and/or hypoxic conditions exhibited bradycardia in comparison with non-exposed larvae (110 and 180 bpm, respectively). In comparison with control and single-factor exposed parents, whole larvae global DNA methylation percentage was decreased in larvae derived from hypoxic-oil exposed parents. Although chronic exposure to environmental stressors in parental populations might not elicit phenotypic modifications, they do prompt signals to offspring populations via transgenerational epigenetic inheritance, likely helping offspring populations to survive while facing persistent environmental conditions. Responses to specific factors may compromise population performance and maintenance when more than one stressor is present.

008: RESTORE Act Centers of Excellence Research Grant Programs – Gulf Research to Inform Policy and Management

Using FLRACEP Funding to Meet Florida's Research Needs in the Eligible RESTORE Act Disciplines

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In the months after the initial the Deepwater Horizon settlements, the Florida RESTORE Act Centers of Excellence Program conducted public scoping and prioritized the eligible RESTORE Act disciplines dealing with marine science, monitoring, research, and community resilience based on this feedback. Without knowing if or when the larger claims against BP would be settled, the program funded ten Centers of Excellence projects that looked at a number of issues in the marine environment. While successful, informative, and impactful, the diversity of topical areas covered by these projects prompted the Program Management Team to consider developing a strategy that would guide and narrow the scope of future FLRACEP investments. Now that the full scale of the RESTORE Act contributions are set, programs like FLRACEP can develop strategic plans to align research projects with the needs of the state over the life of the program. In each of the five Gulf states, the relationship between research need and the Centers of Excellence it different, but perhaps nowhere is it more unique than in Florida. FLRACEP is not associated with any single state agency or institution, and is able to look broadly across agency priorities, resource types, scientific disciplines, and geographic regions for key science gaps to fill. In a state as large as Florida, the need far exceeds available funding, and the program will be considering a number of factors when developing long-term guidance documents. This

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presentation will provide an update on the development of a programmatic vision, mission, and strategy as well as our approach to understanding and prioritizing Florida's many research needs for funding.

Supporting Science and Restoration through the Mississippi Based RESTORE Act Center of Excellence (MBRACE)

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The Mississippi Based RESTORE Act Center of Excellence (MBRACE) was designated as Mississippi's Center of Excellence in September 2016. MBRACE is a consortium of Mississippi's four research universities (Jackson State University [JSU], Mississippi State University [MSU], University of Mississippi [UM], and The University of Southern Mississippi [USM]), with USM serving as the lead institution. The mission of MBRACE is to seek sound comprehensive science-and technology-based understanding of the chronic and acute stressors on the dynamic and productive waters and ecosystems of the northern Gulf of Mexico, and to facilitate sustainable use of the Gulf's important resources. MBRACE's Science Plan focuses on the State's directive toward sustainable coastal management through three major thrust areas: (1) monitoring and ocean observations, (2) modeling, and (3) process studies. The first awards funded by MBRACE in Fall 2017 under the Core Research Program focus on understanding oyster reefs and their sustainability. With these awards, researchers from JSU, MSU, UM, and USM are examining how ecological conditions relevant to oysters vary over time and between newly restored oyster reefs and adjacent unrestored oyster reefs in Mississippi Sound. Future funding opportunities will be made through a competitive award process on research topics detailed in the MBRACE Science Plan.

Texas OneGulf: Linking People and Environments for Resilient Coasts

K. Wowk
Texas One Gulf, Corpus Christi, TX

Texas OneGulf is working to advance research on natural and man-made disaster-related policy and planning, public health, and environmental and socioeconomic impacts to facilitate risk assessment-based processes that support science driven solutions. Researchers across nine institutions are strategizing to ensure Texas and Gulf communities can respond to and recover from recent disasters and prepare for anticipated future events.

LA-COE: Funding Applied Research to Support the Implementation of Louisiana's Coastal Master Plan

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The mission of the RESTORE Act Center of Excellence for Louisiana (LA-COE) is to support research that is directly relevant to implementing Louisiana's Coastal Master Plan by administering a competitive grants program. In doing so, the LA-COE provides the appropriate management, coordination and oversight to ensure that success metrics are tracked and achieved. The LA-COE is sponsored by the

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State of Louisiana's Coastal Protection and Restoration Authority (CPRA) and administered by The Water Institute of the Gulf. Thus far, one request for proposals (RFP1) was released and 13 research project awards were announced in June 2017 that totaled approximately $3 million. The funded research projects (two-year duration) are currently ongoing and include collaborative, research, and graduate studentship type awards and are associated with institutions from across the state of Louisiana, such as Louisiana State University, Nicholls State University, Tulane University, University of Louisiana at Lafayette, University of New Orleans, and Louisiana Tech University. The RFP1 funded research includes disciplines from the natural and social sciences, field observations and numerical modeling of coastal conditions and processes. Researchers provide updates to LA-COE on a quarterly basis through webinars and short reports and on an annual basis via an All Hands Meeting. The final report template will include a section regarding how these applied scientific research results can help CPRA implement the Coastal Master Plan.

Moving on Up: Observations on Adaptive Migration in South Louisiana

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In response to increasing coastal hazards and environmental change, households can continue to live as they have, take adaptive measures to safely stay in place, or adapt through migration. Nonstructural policies to strengthen resilience have focused heavily on interventions that help people stay in place, including flood proofing and home elevation. However, focusing on the mitigation of structures alone is not sufficient to meet the challenges of increasing flood risk and coastal climate adaptation. Increasingly, local officials in Louisiana and elsewhere are recognizing the need for relocation to reduce vulnerability. Helping property owners move out of areas of high flood risk is a key component of the nonstructural measures outlined in *Louisiana's Comprehensive Master Plan for a Sustainable Coast*. While local officials may understand the need for voluntary relocation strategies, and migration away from the coast has already started in Louisiana, surprisingly little is known about the factors that shape climate and hazard-induced migration decisions (McLeman & Hunter, 2010; Warner *et al*., 2010). Sophisticated tools can identify areas or structures most at risk but do not explain factors that determine when people decide to move (or accept a buyout), why they would choose to do so, or where they would likely go. Drawing on interviews with residents and local officials in Terrebonne Parish, Louisiana, this paper examines how a community is responding to increasing climate-related coastal hazards and offers suggestions on shaping equitable and effective relocation strategies that respond to long term change.

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Warner, K., Hamza, M., Oliver-Smith, A., Renaud, F., & Julca, A. (2010). Climate change, environmental degradation and migration. *Natural Hazards*, *55*(3), 689-715.

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An Evaluation of Faulting in Holocene Mississippi River Delta Strata through the Merger of Deep 3-D and 2-D Seismic Data with Near Surface Imaging and Measurements of Vertical Motion

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This work focuses on mapping the geographic extent and late Quaternary history of displacement on Cenozoic faults that underlie the Holocene Mississippi River delta plain. The study areas are located in Terrebonne-Timbalier Bay, along Bayou Lafourche, and Lakes Pontchartrain and Borgne. Current work being done by the team, as well as previous studies, has documented deep-seated (>~ 100 m depth) faults that may have contributed to fault-induced subsidence of recently (~last 10 ka) deposited strata, and the modern delta plain surface. The success of Louisiana Coastal Master Plan efforts rely upon an understanding of vertical elevation changes. The three Louisiana university investigators engaged in this project hold license agreements with companies, who have provided access to high-quality, industry-standard seismic reflection data that images Cenozoic strata in the study areas. These data allow for an assessment of whether deep-seated faults are present in these areas, and if these faults extend upward into younger, overlying strata. Seismic data of this kind are essential for the success of any study attempting to document the potential impact of faults on geomorphology, morphodynamics, deltaic geology, or the stability of Holocene sedimentary units. This work is unique from all earlier late Quaternary fault research of the delta plain inasmuch that it unites industry seismic reflection data (3-D, 2-D) with shallow, high-resolution seismic, shallow cores, shallow geochronology, quantification of surface sediment accumulation rates, and elevation surveys. These multi-disciplinary sub-surface and surface data sets are being used to assess whether there has been recent displacement and/or deformation across the study areas fault systems. The project goals are well-aligned with the Center of Excellence (COE) Research Strategy, and the project is designed to produce data and results essential to understanding fundamental geologic processes operating in coastal Louisiana, with clear relevance to current and future Louisiana Coastal Master Plan objectives.

Research Relevant to Implementation of Louisiana's Coastal Master Plan

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Louisiana's coastal environments are important to the identity of the state's coastal communities, the ecology of the Gulf of Mexico, and the vibrancy of the nation's economy. However, an estimated quarter of this productive landscape has been lost over the past century, with greater losses predicted in the future. The Louisiana Coastal Protection and Restoration Authority (CPRA) is responsible for developing and implementing Louisiana's Coastal Master Plan - a comprehensive 50 year, $50 billion plan for the protection and restoration of our coast. The Coastal Master Plan is designed using the best available science and engineering to prioritize and sequence projects for implementation, and emphasizes the need to track performance and to advance scientific understanding so that projects and programs can be adaptively managed. The RESTORE Act Center of Excellence Grants Program provides a funding stream to support research relevant to Coastal Master Plan implementation. One of the success metrics of the Center of Excellence is the number of Coastal Master Plan projects and programs that directly utilize research finding within one year of project completion. Efforts

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undertaken to facilitate the translation of the research, and increase CPRA's utilization for better program and project decision making, will be discussed.

009: Human Risk Assessment Associated with Oil Spill Chemicals: Approaches and Analyses

Introduction

K. Mena (Invited)
University of Texas Health Science Center School of Public Health

Tracking Toxic Oil Compounds Using Fractionation and Bioassays

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Crude oil consists of a mixture of chemicals, many of which have little toxicological characterization. We implemented a strategy of oil fractionation coupled with *in vitro* toxicity testing to characterize the lesser-studied chemicals in crude oil. These *in vitro* toxicity tests utilize human receptors and cells to infer relevance to human health endpoints and general toxicity. This approach identified four ringed aromatic compounds with variable methylation as potent agents in crude oil. Of the methylated polycyclic aromatic hydrocarbons found in oil that were commercially available, the methylchrysenes had the greatest activity. Monomethylated chrysenes were reasonably similar to unsubstituted chrysene in aryl hydrocarbon receptor signaling assays. Monomethylated chrysenes were also comparable to chrysene in cytotoxicity, mRNA, and protein expression assays conducted in human HepG2 cells that serve as a hepatotoxicity model system. Ongoing complementary studies with primary sinonasal cells may relate pulmonary risks of oil exposure.

Transcriptional Responses to Polycyclic Aromatic Hydrocarbons Found in Crude Oil in Murine Lung and Liver Cell Lines

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Polycyclic aromatic hydrocarbons (PAHs) are chemicals that are abundant in the environment, can be generated through the process of incomplete combustion, and are common hydrocarbons in crude oil. Some PAHs are known to be hazardous to human health due to their environmental ubiquity and carcinogenic properties. Although there are many types of PAHs, individual PAHs may produce different biochemical and toxicological responses in biological systems depending on their chemical structures. Current regulatory assessments are based on a few, unsubstituted PAHs that have been widely used for toxicity testing, but there has been comparatively little research on substituted PAHs such as those with one or more alkyl side groups. In order to determine if selected alkylated PAHs elicit transcriptional responses, perhaps to varying degrees, compared to their unsubstituted parent compounds, we are treating metabolically competent murine lung and liver cells with specific PAHs

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found in Deepwater Horizon MC252 oil. Parent PAHs are being used as positive reference PAHs, and phenanthrene is being used as a negative reference PAH. Cytotoxicity is being evaluated using the SRB assay. *Cyp1a1*, *Cyp1a2*, *Cyp1b1*, *Gclc, Nqo1*, and *Hmox1* are being assessed for changes in gene expression and treatment-dependent responses at the molecular level of transcription.

Characterization of the Heavier PAH Especially Chrysene and Its Isomers in the Weathered MC 252 Oil and Their Response to Aryl Hydrocarbon Receptors

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Polycyclic aromatic hydrocarbons PAH(s) are potent environment pollutants that comprise of two to seven membered (fused) benzene rings with dense cloud of pi-electrons on both sides of the ring, making them resistant to nucleophilic attack. The solubility of these PAH compounds in aqueous medium decreases with increasing molecular weight which makes the bigger PAH(s) more susceptible to remain in the environment for a longer period of time as it more likely to be absorbed to soil organic matter. There are a lot research in the fate of the weathered oil after the spill. According to these studies, heavier PAH(s) four especially chrysene and its methyl homologs are known to degrade at very slow rate and has shown toxic properties to the living organisms. Chrysene is a four membered fused polycyclic ring with a molecular weight of 228 g/mol and has four different isomers benzo[a] anthracene, benzo[b]anthracene or pentacene and triphenylene. In this presentation, we will focus in the characterization and response of bigger PAH(s) especially chrysene and its isomers to Aryl Hydrocarbon Receptor (AhR) assays. We have discovered that triphenylene which has similar spectroscopic properties as chrysene is being mistakenly characterized as chrysene and happens to be present in the environment for a long time and shows less toxic properties compared to chrysene.

In vitro Oily Marine Aerosol Exposure Alters Human Airway Epithelial Function

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Johns Hopkins University, Baltimore, MD

The 2010 Deepwater Horizon was the largest accidental marine oil spill to date leading to 4.9 million oil barrels and 1.9 million gallons of dispersant in the Gulf of Mexico (Gray *et al*. 2014). Excess oil and oil with dispersant that is not removed forms oil slicks on the ocean surface. Crashing waves aerosolize oil slicks, creating nano to micron sized oil droplets capable of entering human airways. An evaluation of oil spill research from 1968 to 2015 revealed less than 1% of the selected publications investigated how oil spills effect humans (Murphy *et al*. 2016). Our research adds to this deficiency by understanding how aerosolized oil effects the human bronchial epithelium at the cellular level. Utilizing the novel *in vitro* Oily Aerosol Exposure and Microscopy System (IOAEMS) we expose differentiated patient derived primary Human Bronchial Epithelial (NHBE) cells to aerosolized clinically relevant oil concentrations and/or oil with dispersant and assess airway epithelial function. Specifically, our data shows a significant increase in ciliary beat frequency following exposure to oil with dispersant although in oil only and dispersant only conditions there is no change in ciliary beat frequency. This indicates oil with dispersant alters mucociliary clearance-a function critical to basic monolayer physiology. Additional airway epithelial functional assessments such as epithelial protein abundance, barrier function, monolayer polarity are being investigated. Determining further how these exposures influence airway

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epithelial function will allow us to both elucidate potential therapeutic strategies to address this, and guide policy in response to oil spills.

Integrating the Results from a Fate and Transport Model in the Interpretation of Oil Spill Chemicals Concentration Distributions within Nearshore Environmental Samples

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Marine oil spills will frequently affect coast lines worldwide but risks to human health resulting from oil spill chemicals (OSCs) are not yet fully understood. Crude oil contains thousands of different compounds which can impact human health in different ways. Predicting OSCs distributions in human health exposure-zones (beach sand, water and air) remains a challenge due to inherent difficulties presented by oil composition and varying factors in fate and transport. The objective of this study was to evaluate the concentration distributions of the many OSCs along the Gulf Coast with the aim of improving estimates of uncertainty in children's exposures and risks to OSCs. Data generated by a validated oil spill fate and transport model in conjunction with data from environmental sampling along the Gulf Coast conducted by the U.S. EPA immediately after the DWH oil spill were processed with GIS software and Python to develop time-space specific distributions of OSCs along three matrices: weathered oil, water and sand. The concentration distributions for each matrix included two categories that corresponded to samples collected prior to and subsequent to impact by oil as predicted by the model's surface oil trajectories, sampling date and location. A third category corresponded to OSC distributions for samples collected from zones estimated not impacted by the oil spill. The frequency of oiling (days) for each sampling location was also estimated. This analysis showed that the majority (but not all) of the mean concentrations were statistically higher for impacted sites in comparison to those that were never impacted. This study may be used for developing algorithms to predict concentration distributions in future oil spills. Results will be integrated into a risk assessment that considers cumulative and aggregate risks to children's health. The all-encompassing goal is to help guide policies for the protection of public health in the event of an oil spill.

Exposures of Responders to Dispersants During the Deepwater Horizon Oil Spill: Were Response Workers Really at Risk?

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We seek to test the assertion in recent retrospective studies that a significant number of responders to the Deepwater Horizon (DH) incident with reported health effects were exposed to dispersants with minimal protective equipment or monitoring of exposure. The potential risk of oil dispersants to human health depends on the intrinsic hazard of the dispersants and the potential for human exposure. Most dispersant components are generally regarded as safe or are acceptable for food contact, and their potential toxicities are well understood. Furthermore, these components are found in consumer and industrial products often used in daily life. Corexit 9500, the most commonly used dispersant during the DH response, is approximately as acutely toxic as ethanol if consumed. However, there are concerns that prolonged exposure to the liquid may be irritating to skin and that exposure to

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dispersant aerosols may have transient effects on cardiovascular and peripheral vascular functions and on olfactory and other neurological functions. During the DH response, industrial hygienists representing the Unified Command mandated protective equipment for workers loading dispersant planes and enacted 2-5 nautical mile exclusion zones for aerial dispersant applications. Vessel workers assigned to contain and recover oil on water did not handle dispersants. Once dispersants contact oil slicks or water, the mixture becomes entrained in the sea and is quickly biodegraded. Thus, it is unlikely that vessel or shoreline workers could have been exposed to dispersants. Extensive personal sampling for dispersant chemicals conducted while dispersants were being used revealed no significant exposures to the response workforce. We conclude that the intrinsic hazard of dispersants is minimal, that the risks associated with exposure to dispersants are small, and that the origin of reported health impacts to workers involved in the DH response cannot be scientifically linked to dispersant exposures.

Protocol for Collecting Child Activity Data at Beach Sites

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Data are limited that document children's activities in beach settings. The objective of the current study was to develop a protocol by which to document child activities. The protocol was designed to gather child demographics, beach sand adherence, macro-scale beach patterns through a beach use survey, and to document play activities through a video-recording technology. Beach study sites (two in Miami, FL and two in Galveston, TX) were chosen based upon characteristics that would be considered to impact child activities. Initial efforts focused on seeking IRB approval for human subject's research and permission from the beach managers. Beach managers were very specific about how and when beach sites could be used. Upon agreeing upon the dates, recruitment commenced immediately at local daycare settings, pediatrician offices, and through social media. Upon recruitment families were sent copies of the consent form, beach use survey, parent beach instructions, and directions to the beach sites. A telephone interview was set to explain the protocol to the parents, to get verbal consent for their child's participation, and to then schedule an appointment time at the beach. Each child was scheduled into a two-hour time block which was designed to take the child through a total of seven stations. These stations included: written informed consent (1), child demographics (2), hand presses (3), beach use survey (4), video-taping (5), sand rinses (6), and check out (7). All stations were set up near the beach parking area with the exception of stations 5 and 6 which were set up near the beach intertidal zone. The number of children processed per field day was variable. With two video-camera teams running concurrently, the maximum number of children that could be processed per day was 10. Recruitment required a team of about 4 individuals. Field work required a team of 10 to 16 individuals. A total of 119 children completed the process through all 7 stations.

Beach Survey Results to Look at Macro-Activities for Children Exposures to OSCs

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Over 400 parental surveys were collected at two beaches in Miami and two beaches in Texas to evaluate children exposure related activities as a part of the overall BEACHES study. Approximately 120 of these surveys were collected from parents whose children (aged 7 years and under) also participated in videotaping and soil adherence experiments at these beaches. Surveys did not take longer than 30 minutes to complete and each participant was paid 25 dollars for completion. Surveys were identified with alphanumerical codes and consisted of three general sections: demographics, exposure and risk perception. The demographics sections consisted of 7 questions (with some sub sections). The exposure section consisted of 29 questions and the risk perception section consisted of 15 questions, again both with sub-sections. The survey also contained some qualifying questions and some family demographic questions (e.g., number of children in family). Surveys were entered in the RedCap Platform and analyzed in RedCap and SAS to evaluate demographic and regional differences on activities related to beach behavior (e.g., how much time spent on beach, cleaning habits following beach activities). Univariate associations between the outcomes (e.g., time spent on beach), and the independent variables (demographic variables such as age and race, regional characteristics), were tested using chi-square test, two sample t-test, and simple regression and correlation. Finally, to examine the associations in the multivariable setting we applied linear and logistic regression respectively, depending on the outcome scale. All of the associations were considered significant at the alpha level of 0.05. Discussed are also survey limitation in terms of collection, representation and interpretation.

Video-Translation Data to Look at Micro-Activities for Children During Beach Play

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Video-footage was collected for 118 children at two beaches in Miami and two beaches in Texas to evaluate children's exposure-related activities as a part of the BEACHES study. Participating children were aged up to 7 years with the youngest at 9 months. Parents were instructed to engage in normal play at the beach for one hour as a team of two videographers focused the camera from tens of meters away on the child. A video-translation software program called VideoTraq was used to code for the activities of the children and convert video-footage data to lines of activity data in second details. Video-translaters first coded for the micro-locations visited (e.g., seawater, foreshore, berm and backshore) and the activities the children engaged (e.g., running, swimming, wading, sitting). Univariate associations among the outcomes (e.g., time spent in various micro-locations and time spent engaged in various activities), and the independent variables (demographic variables such as age and race, regional characteristics, beach profiles) were determined. Associations were tested using chi-square test, two sample t-test, and simple regression and correlation. Finally, to examine the associations in the multivariable setting, linear and logistic regression were applied, respectively, depending on the outcome scale. All of the associations were considered significant at the alpha level of 0.05. Video-translaters will code for the objects and surface contacted (e.g., seaweed, sand, play toys, shells) by the children for the right_hand, left_hand, and mouth at a later date. Statistical work

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will therefore overlap locations, activities and objects/surfaces to evaluate associations among all three and other independent variables for the BEACHES study. These micro-activities allow researchers to estimate dermal, inhalation and ingestion exposures to oil spill chemicals found at beaches, where detailed contact and time-spent activities improve the accuracy of estimates.

Human Health Risk Assessment for Children Playing at Beaches Following an Oil Spill

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Contamination of shorelines from oil spills can have lasting health and ecological impacts for communities and ecosystems. Although current research has characterized the health impacts associated with exposure to oil spill contaminants (OSCs) by adults, there is little evidence to describe the health impacts on children. The primary objective of the Beach Exposure And Child HEalth Study (BEACHES) is to assess the potential adverse health risks among young children (walking to under seven years of age) to OSCs after normal beach play following an oil spill event. The National Research Council (NRC) risk assessment framework will be modified to integrate data gathered from beach play behavior from 122 children from two beaches each in Miami, FL and Galveston, TX, as well as existing concentration and distribution data for various OSCs (such as polycyclic aromatic hydrocarbons, metals, dispersants, and alkanes). In addition, the framework will include information from qualitative surveys, child hand and body sand adherence tests, and existing peer-reviewed literature. Exposure scenarios will be developed that represent child activity patterns along shorelines, and will consider ingestion (non-dietary), dermal, and inhalation transmission of OSC levels. Exposures that account for child-specific activities and differences in child play at beaches with various physical characteristics will be considered, as well as nonspecific beach factors such as transdermal uptake, absorption across gut barrier, and dose-response from toxicity data. Further, computed risks will be aggregated to estimate cumulative risk. Both cancer and non-cancer health risks will be estimated. Uncertainty and variability will be addressed through the use of Monte Carlo approaches that will incorporate observed or assumed distributions. A sensitivity analysis will also be conducted to evaluate the different distributional assumptions for each model input, and provide information on data gaps where further research would provide the greatest benefit.

010: Progressive Visualization Techniques for Optimized Data Synthesis and Effective Graphic Communication

Conveying Big, Complicated Ideas... Even on Small Screens

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The Deepwater Horizon event, and its subsequent research efforts, provide a platform to communicate about the Gulf of Mexico environment. The skills used for effective public outreach - such as simplifying complex concepts and creating intuitive representations of data - can also be used to facilitate

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collaboration among professionals in different scientific disciplines. Why is this necessary? Each scientific community has its own terminology and data visualization types, which are used to efficiently convey concepts to one another. However, out-of-discipline experts may be unacquainted with some jargon or not immediately able to interpret unfamiliar data graphs. Overcoming such informational roadblocks is an important component to fostering Interdisciplinary collaboration. How might these types of obstacles be removed? A key step is examining knowledge in a hierarchical way: from overarching themes to concepts to specific facts. This type of exercise can help individuals or groups identify how their own work contributes to bigger ideas that resonate with target audiences (e.g., public, policy makers). Distilling science into discrete components has the added benefit of potentially seeing new societal connections or identifying research gaps. Actively participating in this type of deconstruction - e.g., creating more "digestible" content and honing take-home messages - is vitally important given today's reduced attention spans (and screen sizes). Strategies, tools, and concrete examples of effective communication and visualization techniques will be presented. Also, an overview of NASA's next generation of ocean sensors will be provided, including ways these missions' unprecedented data from the Gulf of Mexico will be broadly communicated.

Data Acquisition, Analysis, and Visualization of an Oysters' Gape Measurement System

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In this work we describe software and hardware techniques used to acquire gape data from bivalves in the field. The ways this data is stored, manipulated and analyzed is also explained. Finally, ways that this data may be correlated with other streams of data to serve as a gauge of the environmental health, or even a predictor of such, are discussed. Power consumption and bandwidth usage restrictions are the major challenges for our field sensor systems. When these data acquisition systems are located in the field, they are limited by the power that is generated naturally, such as solar power, and the visible communication hubs, or towers from the system’s location. This places a limit to the rate at which data is collected and transmitted. Although higher data sampling rates allow for the capture of higher frequency information, it will increase the power needs of the system, and quickly deplete the battery. Also, continuous transmission allows for the instantaneous observation of the field data, however, it will push the power consumption and bandwidth usage beyond what is available. To reach a balance, many software and hardware optimization techniques have been used to make possible the transmission of rich data within the limited power and bandwidth budget. These techniques are discussed and evaluated in this work.

We then examine the visualization and data analysis techniques. These range from a smart device application that can allow the user to see the incoming data stream instantly and at any location, to the use of large display walls that can be used to look at vast amounts of data all at once, to cloud based data visualization packages. Finally, we will examine the use of data classifiers and other machine intelligence techniques that may be used to create environment predictors.

Event-Based Climatology of Tropical Cyclone Rainfall in Houston, Texas and Miami, Florida

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*Student Presenter

Tropical cyclone (TC) rainfall amounts are compared from 1950-2017 for Houston, Texas and Miami, Florida to estimate the risk of TC rain in both cities. Following the wake of Hurricanes Harvey and Irma in 2017, concern has risen over the future of raininess in these locations. Per-event rainfall amounts are aggregated using tracks taken from HURDAT, time-of-rain gathered from National Weather Service daily weather maps, and rainfall totals taken from airport monitoring stations. Risk analysis tools include descriptive statistics, time series, and return frequencies for Houston and Miami, and spatially interpolated surfaces for Hurricanes Harvey and Irma. The season duration is longer in Miami than in Houston. The uppermost rainfall events in the distribution for Houston show a significant increase through time, suggesting the most intense rainfall events are becoming worse for Houston. The expected return frequency for a Harvey-like event (940 mm) in Houston is every 230 years, on average, and the 90th percentile rain of 286 mm is expected once every 17 years (11-29; 90% significance). The expected return frequency for an Irene-like event (261 mm-maximum for location) in Miami is every 173 years, on average, and the 90th percentile rain of 167 mm is expected once every 11 years (7-17; 90% significance). Results show a substantial difference between Houston and Miami TC rainfall climatologies similar to the differences of Hurricanes Harvey and Irma. Though emergency management must be tailored for each TC, management for inland TC rainfall may be more applicable in Houston than in Miami.

Advances in Visualization of Deep-Sea Blowout Using Numerical Modeling and Observations

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Accurately generating quantitative data is the final objective of oil model output and analysis. However, it is often difficult to compare the modeling output with punctuate observations and to identify the processes controlling the blowout. Here we present novel visualization techniques to trace the evolution of blowouts and optimize evaluation with observations. Four-dimensional visualization of iso-surfaces of oil concentrations are used to investigate dynamically the impact of specific toxicity thresholds on a series of organisms, from plankton to whales. The availability of model and observation data in GRIIDC facilitates the explorative aspect of data mining and visualization, showing that these hindcast methods are essential to facilitate the forecast estimation of water column exposure through time and first response.

Visualization Techniques for Big Data Storytelling: A C-IMAGE Task Group Exemplar

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GoMRI has supported the evolution of large research groups like the C-IMAGE Consortium, which has generated terabytes of data. How do we address the vast amount of data generated within any one research (task) group? How do we draw linkages between task groups within the C-IMAGE and/or between multiple consortia? What about the data generated between all of the GoMRI consortia and the individual investigator projects, that all of the other work, (state, federal, industry) done in the Gulf since DWH? How do we answer the question, “What are the threads that connect my data, results and interpretations, to other’s work?” Making these connections is imperative so that we prioritize areas of

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uncertainty, identify and close gaps both in data and knowledge, avoid duplication of efforts, and guide research to inform management decisions. The ultimate motivation for all of these efforts should be to produce a product for responders, resource managers, restoration planners and the community at large which utilizes these invaluable data to their greatest extent. But while we can generate Big Data and we know that we want these terabytes of information and more, they can become a liability if you can't understand them. The data visualization technique is like using the Rosetta Stone to unlock patterns, trends and correlations in your data, by having your analytics presented visually, and artfully. The ability to take data—to be able to understand it, process it, to extract value from it, to visualize it, to communicate it—that's going to be a hugely important skill in the next decades. This presentation will discuss the concept and merit of visualization techniques for data storytelling and highlight an interactive visualization map for data, results and connections of our three-year, complex multi-species, multiple pathway exposure and sublethal impact study on oil exposed GoM fish and will show how strong links can be made to data from other task/research groups.

Integration and Visualization of Oil in the Environment Using Remote Sensing and Modeling Results in ERMA

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NOAA's Environmental Response Management Application (ERMA) is a web-based mapping application that has been designated as the USCG's "Common-Operational Picture" or "COP" for oil spill and disaster responses. The same qualities that make ERMA an excellent COP during disasters are leveraged for managing and sharing cutting edge scientific efforts to improve our ability to analyze, interpret and communicate potential impacts from spilled oil in the coastal environment. Over the past several years, NOAA and project partners have been at the forefront of marshalling remote sensing technology and field measurements to improve our ability to delineate the extent and character of oil on water. The ERMA application is used as an environment to display remotely sensed images collected from satellite, fixed wing and remote operator platforms, and integrate these raw and interpreted images with field measurements, field samples, and laboratory results collected in the same space. By integrating these datasets in a single mapping environment, we are able to support spatial analysis to validate and improve modeling and tell a complex story.

Visualization for Synthesis of Large Data Sets from the CARTHE LASER Experiment

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CARTHE's LASER field campaign produced enormous amounts of disparate but coincident data, including drifter trajectories, velocity fields from x-band radar, aerial sea surface temperature surveys, and CTD measurements. While each type of data is valuable on its own, only analysis of combined data sets can provide insight into the interaction of processes acting across many time and space scales. Effective visualization of multiple data types spanning a large spectrum of space and time is therefore necessary to identify critical connections. Here we demonstrate preliminary results from our efforts to tackle this challenge.

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Visualized Genomics: Making Connections Between Organismal and Population Response to Toxicant Exposure

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Elucidating the impacts of toxicant exposure on wild populations of marine organisms requires that connections be made between individual-level and population-level effects. Genomics has become an important tool for this purpose because it provides a way to characterize response across multiple time scales from immediate changes in gene expression in individuals to generational changes in gene frequencies across populations. Understanding impacts at multiple scales requires a suite of research efforts including laboratory-based exposure experiments and real-world observations, each generating large genomic and non-genomic data sets. While individually these studies provide important information about specific aspects of biological responses to exposure, it is the connections between studies that provide a complete view of the consequences of exposure and may provide guidance for future response. Data visualization is a method for identifying and characterizing connections in complicated system and is particularly useful for Big Data applications, like genomics. Here we present a visualization of genomics data collected after the DWH spill highlighting how this technique can be used to better understand links between independent but related studies.

Using Ensemble Modeling Approach for Probabilistic Estimates of Water Pollution from Oil Spills

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A multitude of numerical models of oil transport and fate have been developed by different groups in order to prepare for the potential oil spill incident and response. These models could be based on diverse approaches, may account for a variety of the processes involved in oil transport and weathering, and could otherwise differ. Nonetheless, for the purpose of assistance to oil spill response and mitigation efforts or for assessment of the damage to the environment, final modeling results are expected to provide some practical equivalents of oil pollution prediction in terms of oil concentrations, oil mass, etc. Pollution estimates are likely to vary notably between the models, though all of them having their rationale for the prediction. Ensemble approach for a set of model runs consisting of different oil transport models or different model scenarios, could be further done for statistical evaluation of the potential threat. When different models are considered, individual model's contribution to a probabilistic forecast could vary depending on some pre-determined model skill rank or other performance assessment criteria, and then used construct the probabilistic maps of numerical pollution estimates reaching a certain threshold. The probabilities might indicate there is a chance of certain values of oil concentrations to occur in a given area. High probabilities may call for rapid response or assessment measures, while relatively small probabilities may warrant unnecessary precautions, e.g., unnecessary fishery closures, or other response measures. A single model, oil application of Connectivity Modeling System, is used to model the Deepwater Horizon 2010 blowout scenario. In addition to the control case scenario case started on 20 April 2010, several scenarios were considered with modified environmental conditions, which enabled the model spread. An example of probabilistic approach to surface oil concentration thresholds is presented.

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011: Bridging Field and Laboratory Observations of the Fate and Effects of Weathered Oil to Inform Oil Spill Risk Assessment, Planning, and Response

Challenges of Translating Findings from Lab-Based Oil Fate & Effects Studies to Conclusions Relevant to the Real World

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Most studies evaluating the fate and effects of an oil spill are based on lab-based mesocosm studies. This requires translating findings from a closed system (lab flasks) to an open system (the open sea). Oil spilled on the open sea has the opportunity for infinite spreading on the water surface and dilution in the water column. Oil placed in a flask in the lab does not. A better understanding of the limitations of representing the real-world in a flask will support more representative lab-based study design and more relevant translation of findings to the real world. Coolbaugh *et al*. (2017) reviewed dispersant-related literature post Deepwater Horizon and identified areas of concern. These included research that simulated spill scenarios where dispersant aren't used, tests performed under extreme dispersant / dispersed oil exposure conditions, preparation of exposure media resulting in unrepresentative conditions, and failing to characterize exposure conditions. One poorly understood issue with closed system study is that dispersed and dissolved oil components will come to equilibrium. This equilibrium likely causes dissolved phase concentrations of oil that are far higher than the non-equilibrium conditions that occur for oil dispersed at sea. This makes dispersed oil appear more toxic in the lab than the same concentration of oil at sea because dissolved oil drives toxicity. A second issue is that oil placed in a beaker doesn't spread as it would on the open sea. The beaker walls minimize potential spreading but spreading is also inhibited by surfactants from dispersants. This limited spreading can reduce the amount of dispersion seen in dispersant-effectiveness tests. A third issue is that biodegradation studies reported in the literature use protocols that don't compare biodegradation of oil dispersed into the water column to a surface slick. Rather, they compare chemically dispersed oil to mechanically dispersed oil. A decision not to use dispersants means that much oil from a spill will remain on the water surface whereas the effective use of dispersants places oil in the water column.

Models, Lab Tests, and Empirical Field Observations and Data: Coexistence and Optimization

P. D. Boehm
Exponent - Environmental, Maynard, MA

Oil spills are complex events of multidisciplinary interest, requiring the application of a blend of established, generally accepted, as well as innovative approaches to answer the many scientific and questions arising. The needs for data and actionable information arise quickly during the emergency response and these data and information not only support early phases of a spill, but also help to design further data collection efforts to answer longer term questions related to ecological recovery trajectories and damage assessment. Many challenges exist in applying scientific strategies and methodologies to studying oil spills, but central to many issues are questions on the needs and the feasibility of collecting representative, adequate field data vs (or more productively in concert with) the

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application of spill models. “Models” here include: 1) spill fate - transport models, 2) oil spill impact models, as well as 3) laboratory tests relating to chemical/exposure (e.g., weathering, partitioning), and 4) toxicity. All are “models” aimed at representing the “real world”, but are essentially only representations, arguably simplifications, of complex processes that may or may not occur only at limited times and/or over highly variable spatial scales during and after the actual incident. Challenges include a consideration the degree to which the processes and ambient measures in a new spill can be represented by extrapolations of data and information from prior spills. These extrapolations are very tempting, but can be very limited and/or downright wrongheaded depending on the situation. However, those who advocate for a complete empirical data collection to represent the real world are neither practical nor constructive. So what is the balance to be struck between empirical data needs and models/extrapolation? How can this blend be optimized in different types of spills, of differing sizes, at differing locations, of differing ecological and political sensitivity? Through a discussion of several cases studies - Exxon Valdez, Ixtoc 1, and Deepwater Horizon - this presentation will offer insights and suggestions from personal experiences, largely from a scientific perspective, but with a solid focus on the uses and users of scientific data in response actions, study designs, and regulatory/legal proceedings.

Marriage of Microcosm and Field Results: Molecular Understanding of the Weathering Processes and Fate of Macondo Well Oil by FT-ICR Mass Spectrometry

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Previous studies report rapid degradation of the Macondo well oil (MWO) in Louisiana salt marsh sediments after the 2010 Deepwater Horizon Spill. Rapid oxidative transformation increased the molecular complexity of MWO, and thus requires Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS) to identify compositional changes at the molecular level.[1] However, the relative contribution of the two main weathering processes, photochemical and biochemical oxidation, remains poorly understood. Controlled laboratory microcosm experiments (bio- vs. photo-transformation) facilitate comparison to field samples to identify dominant degradation pathways of MWO. Here, we compare the molecular transformations of oil in laboratory microcosms to identify photo- and bio-oxidation products. The products are compared to those identified in oil contaminated saltmarsh sediments collected from Barataria Bay between 2010 and 2017. Electrospray Ionization FT-ICR MS provides the molecular-level characterization of the transformation products and exposes the subsequent chemical evolution / degradation pathway similarities between Macondo Crude oil (MC252, NIST 2779) under controlled, oxidation-specific, laboratory conditions to that of field samples. The mass spectral analysis identified tens of thousands of photo- and bio-oxidation transformation products. Both pathways display distinctive oxidation signatures, which match the molecular composition of Deepwater Horizon field samples. Thus, the results from controlled microcosm experiments provide insight into the relative contribution of each oxidative process to field observations and help understand the fate and long-term impact of oil released into the environment. Work supported by NSF Division of Materials Research through DMR-11-57490, a grant from the Gulf

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of Mexico Research Initiative, and the State of Florida. **References**: 1. Chen H., *et al*., *Environmental Science and Technology* (2016), 50(17).

Dispersant Effectiveness Testing of Aged Oil Conducted at Ohmsett

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Recently, concerns have been raised regarding the ability of dispersants to effectively disperse photo-oxidized crude oil. Dispersants are an important tool in the oil spill response inventory and any phenomenon that could limit their effectiveness must be addressed and properly understood. In the past, photo-oxidation has been considered to have only secondary or tertiary impacts on dispersant effectiveness relative to oil evaporation and emulsification. We investigated the effect of photo-oxidation on light Gulf-of-Mexico crude oil (API Gravity 34) by aging it as thin films in 20 m x 20 m square boom enclosures on the wave tank at Ohmsett for durations of one, three, and five days prior to conducting dispersant effectiveness tests. The oil would have an average thickness of about 400 µm assuming even spreading; however, because of the open nature of the wave tank, wind drove the oil into thicker films and sheening into thinner films that varied throughout the aging periods. Oil samples were taken twice per day while aging to determine the amount of photo-oxidation, as well as changes to other oil properties. Dispersant tests using Corexit 9500 for oils aged one, three, and five days were conducted using both the large wave tank and the EPA recommended baffled flask test. This presentation will describe the results of this study.

Improving Oil Toxicity Test Methods for Aquatic Organisms

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A critical review of published laboratory studies assessing the toxicity of oil products to fish revealed a diversity in methods for preparing test solutions and for characterizing oil, test solutions, exposure regimes, and test outcomes. This variability in methodology may affect the composition of test solutions and toxicity assessments, thus limiting comparisons among studies and their application in oil spill risk assessments. Chemical characterization of oil and test solutions can partially enable comparisons of oil toxicity data generated with different methods. Standardized test methods are needed to reduce uncertainty in estimated toxicity and to facilitate comparisons of toxicity among studies and among various oil types and weathering states. Owing to the need to assess oil toxicity under site-specific conditions and because standard test methods cannot accommodate all environmental scenarios, we recommend that standard tests be conducted in tandem with tests conducted under site-specific conditions. Applying standard tests as controls will demonstrate how test variables affect test outcomes and increase the capacity to apply existing toxicity data to novel site-specific risk assessments. This presentation will review methods to assess oil toxicity, identify research needs, and provide recommendations for development of standardized methods for various oil types and weathering states to inform oil spill risk assessment, planning, and response.

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Dispersant Effectiveness Observations Relating to Oils that may be Perceived to be Non-Dispersible: Laboratory and Field-Based Experiences

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There are a number of "rules of thumb" relating to the ability to effectively disperse oil into an aquatic environment including maximum viscosity limitations, degree of emulsification or other weathering, and mixing energy. A goal of many lab-based studies is often to understand the effectiveness of dispersing oil into an open ocean environment and to provide supporting information to the decision-making process. However, experience has shown that laboratory experiments performed in small-scale glassware, bench-scale equipment or larger test tanks, as useful as they are for studying a wide range of parameters in a controlled setting, may over-estimate the manner in which these factors influence and potentially limit the effectiveness of dispersant treatment. In particular, there are a number of lab-based reports that suggest that there are limits to oil viscosity, entrained water content, extent of weathering, and calmness of sea state that severely limit dispersant effectiveness.

Observations in the field, including studies performed during and after the Macondo spill response, and large scale test tanks are sometimes at odds with smaller-scale lab-based conclusions. Without considering how laboratory results may or may not accurately translate to real world conditions, they may influence the decision-making process and limit the potential use of all tools in the oil spill response tool box. The proposed presentation will discuss real world and laboratory experiences with a focus on the potential cause and effects of disconnects that may occur between the two.

Biodegradation Testing Protocols

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Oil spill responders need all the help they can get, especially in understanding the natural phenomena that aid or compete with their response efforts. Although biodegradation is the principal process that removes oil from the biosphere, it does not play much of a role with floating oil. Nevertheless, biodegradation is rapid once oil is dispersed either physically or with the aid of dispersants. Birds, mammals and shorelines are at risk from floating oil, while planktonic organisms are at risk when oil becomes dispersed, albeit transiently as the dispersed oil dilutes. These phenomena need to be balanced by responders as they attempt to mitigate the environmental consequences of a spill. Field data are rare, so most of our knowledge about the processes that control the fate of spilled oil must come from laboratory simulations. It is essential that such experiments do indeed provide relevant information, and that appropriate analyses ensure that oil losses are due to the phenomenon under study. We know that biodegradation of dispersed oil takes place at <ppm levels with indigenous bacteria and nutrients, while the biodegradation of beached oil takes place at <% levels and is likely nutrient- and perhaps oxygen-limited. The microbes responsible for oil biodegradation are a complex community, and experiments are best done with natural seawater and the indigenous microbes rather than with artificial seawater and laboratory strains of microorganisms. It seems meaningless to use terrestrial organisms or excessive nutrients in marine simulations, or to work at temperatures or pressures outside those that these communities might experience during a year. Since dispersed oil rapidly dilutes to <ppm, there is little point in experiments at substantially higher concentrations. This

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talk will cover improvements in our understanding of how best to conduct laboratory experiments that WILL provide useful information to responders.

012: Towards Understanding the Physical, Photochemical, and Biological Processes that Determined the Fate and Effect of Oil and Oil-Dispersant Mixtures During the Deepwater Horizon Oil Spill

Towards Understanding the Fate of the DWH Spilled Oil: Multidisciplinary Scientists Need to Speak a Common Language

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Oil spills are tragic events, and fully understanding their impacts on the natural environment and humans require study of many scientific disciplines. Each of these disciplines see oil, its environmental movement, its weathering, and its impacts on the natural living and non-living resources through the lens of their respective scientific field. These disciplinary lens and associated disciplinary vocabulary represent challenges when trying to understand and communicate overall oils fates and effects. We propose a series of visual models (figures) with associated glossary of terms that will represent the various fates of hydrocarbon type molecules that entered the environment during the DWH oil spill and allow understand of effects from this spill. This concept encourages all scientists studying the spill to use common terms, and have a common understanding of these and their associated descriptions when describing the fates and effects of oil from this spill. Our proposed model concept is intended to be a living document, modified as appropriate by scientific studies, and is not intended to be a restrictive description of oil fates. However, without some discipline in our various understandings of spill events and their implications towards fates and effects, overall synthesis of findings will certainly be diminished.

Lessons on Weathering and Partitioning of Aliphatic, Monocyclic, and Polycyclic Aromatic Hydrocarbons from the IXTOC I and Deepwater Horizon Blowouts

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During both the IXTOC I and Deepwater Horizon (DWH) blowout events, dissolution of water-soluble hydrocarbons was measured in oil and water-column samples as a function of depth, time, and distance from the subsurface oil releases. With the IXTOC I release at ~50 m, subsurface oil was tracked 20-45 km in the upper 20 m of the water column as it was laterally advected and diffused by prevailing currents. In contrast, during the DWH release at ~1,500 m, the larger (mm to cm) oil droplets ascended to form a surface slick within a few km of the wellhead; however, a subset of smaller (<200 µm) physically and chemically dispersed, near-neutrally-buoyant droplets plus dissolved hydrocarbons and dispersant components also became entrained around a depth of 1,000 m. Using forensic chemistry,

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video and photographic evidence, conductivity, temperature and depth (CTD), dissolved oxygen (DO), and fluorometry profiles, this subsurface plume was tracked for 412 km (250 miles) SW of the wellhead. Surface oil was subject to evaporation, photooxidation (of alkylated chrysenes and triaromatic steroids), limited microbial degradation, reentrainment, water-in-oil emulsification (mousse formation), advection by winds and currents, and eventual stranding on shorelines. Subsurface oil during both incidents showed dissolution and microbial degradation. Enhanced dissolution of selected PAH was also observed in dispersant-treated DWH oil. Subsurface DWH oil droplets were observed and photographed in mucus flocs from microbial exudation products. The flocs formed into marine snow, and to differing degrees, interacted with inorganic suspended particulate material (SPM) or decaying planktonic/microbial biomass that further aggregated and sank, eventually incorporating into marine sediments. *In-situ* burning of DWH surface oil also created air-borne soot that, to some extent, settled back to the sea surface and, along with expected burn residues, eventually sank to the sea floor.

Synthesis of Photochemical Transformations of Oil in Marine Waters

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Oxidation by sunlight is an important environmental process that impacts the physical and chemical properties, and, in turn, the short- and long-term fate of petroleum released accidentally into marine waters. With a focus on results from GoMRI-funded research since the 2010 Deepwater Horizon oil spill, this presentation will synthesize the current understanding of sunlight-mediated processes and their impact on petroleum fate and transport in marine waters. Core principles of aquatic photochemistry as well as the challenges of scaling from the laboratory to the field will be discussed. Moving beyond GoMRI funded research, critical knowledge gaps for the petroleum photochemistry discipline will be identified and discussed.

How Toxic is Weathered Oil? The Potential Effects of Oil Photo-Products on Oil Toxicity

C. Aeppli
Bigelow Laboratory for Ocean Sciences, East Boothbay, ME

Since oil weathering generally decreases the content of polycyclic aromatic hydrocarbons (PAHs) in the remaining oil, it is often assumed that weathering processes make oil less toxic. However, relatively recalcitrant oil photo-products formed during weathering of surface oil likely contribute to the effects of oil residues. This talk will give an overview of the current knowledge of the impact of these oil photo-products on the overall toxicity of oil residues with a focus on the Deepwater Horizon oil spill.

Impact of Sunlight on Emulsification of Oil from the Deepwater Horizon Spill

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Following release of oil into aquatic environments, emulsification is frequently observed. Formation of water in oil emulsions dramatically changes the fate and transport of oil as well as its bioavailability. Mitigation efforts, including dispersion, *in-situ* burning, biodegradation, and skimming can all be inhibited by mousse formation. While some oils emulsify upon evaporation, not every oil has sufficient amounts of emulsifying agents to do so. Numerous studies have demonstrated that exposure of oil to

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sunlight results in oxygenated products. These photogenerated species are more polar than the original oil molecules and distribute into the aqueous phase and the oil-water interface. Because these compounds have both polar and non-polar functionalities, they are potential emulsifying agents. We exposed neat oil from the Macondo well and surrogate oil, both light sweet crudes, to simulated sunlight and assessed the mass loss and the ability to emulsify. A commonly used emulsification bottle test was applied to dark and irradiated samples (times ranging from 1-24 hours, equivalent to approximately ¼ day to 6 days of average solar exposure in the Northern Gulf of Mexico). Some dark controls were heated at 50 °C for up to 24 hours to assess evaporative effects. Dark controls, heated or not, showed no emulsification. By contrast, irradiated samples showed emulsification after one hour of exposure, and the degree of emulsification increased with exposure time. The Macondo and surrogate oils did not behave identically, but both showed substantial emulsification after irradiation. The results of this study clearly demonstrate that solar exposure leads to emulsification of oil. The impact of solar exposure on the fate and transport of spilled oil is significant on time scales potentially as short as less than a day, and modeling of oil spills must accurately account for these effects. This research was made possible by a grant from the Gulf of Mexico Research Initiative.

An Investigation into the Effects of Biodegradation vs. Photodegradation During Mesocosm Experiments

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Following the Deepwater Horizon oil spill, a significant flux of marine snow consisting of plankton/bacteria, their exopolymeric polysaccharide substances (EPS), and the aggregated oil was observed. These marine oil snow sedimentation and flocculation accumulation (MOSSFA) events are understood to have been a quantitatively important fate of the spilled oil. An understanding of how microbes interact with both oil and the dispersant Corexit to facilitate the removal of oil from the water column and subsequently transport it to sediments is needed to determine conditions that promote such MOSSFA events. Mesocosm experiments conducted by the ADDOMEx research consortium have emerged as an effective way to study MOSSFA events. Initial mesocosm experiments demonstrated the association of oil with marine snow, and allowed for the characterization of oil components associated with marine oil snow. Fourier transform ion cyclotron resonance mass spectrometry (FTICR-MS) is able to provide molecular level insight into the alteration of oil resulting from its interaction with marine snow and dispersants over the course of the experiments. Data from several mesocosm experiments suggests that degradation of marine snow associated oil occurs rapidly, and experimental conditions suggest microbial processes to be important. Photochemical processes are also known to be key degradation agents for oil components at the sea surface exposed to UV radiation. Using FTICR-MS, the transformation products resulting from the photodegradation of oil are compared to those from microbial degradation in an attempt to elucidate the primary mechanism of alteration for oil associated with marine snow.

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Detailed Identification and Molecular Characterization of Oxygen Compounds in Field Samples

A. M. McKenna[1], H. Chen[1], S. F. Niles[1], M. L. Chacon-Patino[1], C. C. Davis[1], R. P. Rodgers[1], Q. Lin[2], A. Hou[3]
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Once released into the environment, petrogenic species undergo oxidative transformation that further increases compositional complexity in the crude oil matrix by at least an order of magnitude. The molecular transformation drastically alters native petroleum chemistry through incorporation of oxygen functional groups that affect toxicity, solubility, aggregation, tendency for emulsion/mousse formation, and ultimately, bioavailability. Despite the challenge, recent advances in analytical methodology and mass spectral instrumentation now provide molecular-level insight into these complex systems regardless of initial or transformed-product boiling point. Specifically, 21 tesla FT-ICR mass spectrometry coupled to novel fractionation techniques provides unparalleled insight into the compositional complexity of field samples.[1] We combine three techniques to selectively target oxygen compounds formed through oil degradation and apply these methodologies to field samples, and identify specific oxygen chemistries that form the oil/water interface (interfacial material). These compounds remain undetected and thus unidentified in coastal sediments and shorelines due to polarity. Acidic incorporation onto hydrocarbon compounds occurs through various degradation pathways after environmental exposure. However, subsequent characterization by negative-ion ESI FT-ICR MS on whole oil samples highlights the preferential ionization of low molecular weight carboxylic acids that masks the presence of higher molecular weight acidic species.[2] Based on isolation, derivatization and mass spectral characterization, ketones and acids compounds are selectively ionized and unambiguously identified in weathered field samples. The work presented herein provides a more complete characterization of the contribution of specific chemical functionalities to tens of thousands of oxidized transformation products detected in field samples. Work supported by NSF CHE through DMR 16-44779.

The Fate of Aromatic Hydrocarbons in Light Louisiana Sweet Crude Oil after Exposure to Natural Sunlight in Gulf of Mexico

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Photooxidation was a dominant weathering process for surface oil after the Deepwater Horizon (DWH) oil spill, leading to the rapid formation of polar or oxygenated hydrocarbons along contaminated coasts. Despite the much research effort, little is known about the mechanistic processes of the formation of polar hydrocarbons by photooxidation, including the quantitative fates of aromatic hydrocarbons and structural detail of polar hydrocarbons. To address these questions, we traced the fates of ^{13}C-labeled phenanthrene that was amended to crude oil during photooxidation through a 44-day natural light exposure experiment, including the conversion of the ^{13}C-phenanthrene among the pools of saturate, aromatic, resin, asphaltene and dissolved inorganic carbon (DIC). Our results showed that of the ^{13}C-phenanthrene being photo-transformed, 57% remained in the aromatic fraction, and 19%, 14%, 10% converted to asphaltene, resin and DIC pools, respectively. This is the first quantitative

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data on the specific fates of aromatic hydrocarbons by photooxidation, which offers important insights into the overall budget of the DWH oil. Using thermal slicing ramped pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) and nuclear magnetic resonance (NMR) techniques, we revealed that the photo-generated asphaltenes have bridged-island structures with relatively smaller aromatic cores and longer alkyl tails in each island, different from "native" petrogenic asphaltenes in crude oil, a result that can help evaluate bioavailability and toxicity of the oxygenated or polar hydrocarbons after photooxidation.

Bacterial Responses to Different Crude Oils Under Varying Solar Exposure

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Investigations of the relationships between crude oil and bacterioplankton have unfolded clues into how crude oil constituents are degraded, and how anthropogenic spills affect system nutrient cycling and food webs. Some studies have indicated that this relationship changes when crude oil is exposed to natural weather patterns such as wind shear, ocean mixing, and solar irradiance. Oils are complex mixtures of hydrocarbons and other elements—no two wells yield the exact same oil composition, yet there is minimal information regarding a direct comparison of different crude oils under varying solar exposure and corresponding biological responses.

We investigated the biological effects of solar exposure on five Gulf of Mexico-derived oils and one terrestrial-derived oil from Wisconsin. Seawater microcosms were amended with irradiated and non-irradiated water accommodated fractions (WAFs) of crude oil. These microcosms were analyzed for acute and long-term effects on bacterial production, cell counts, and microbial diversity.

The oil sample from the Wisconsin well yielded significant differences from the Gulf of Mexico-derived treatments in all aspects of our study. Two of the Gulf of Mexico oils showed greater acute toxicity when irradiated under photosynthetically active radiation (PAR) than under full sun (UV) conditions. All oils presented greater acute toxicity from solar-exposed WAF treatments versus dark counterparts. In microcosms containing solar-exposed oils, 16S rRNA gene Illumina MiSeq sequencing analysis indicated strong selections for Rhodobateriaceae and Alteromonodaceae in solar-exposed treatments. These results and preliminary statistical analyses indicate that microbial responses to oil spills are dependent on both the source of the oil and the environmental (solar) conditions at the time and location of the spill. Further experiments include determining the dependency of microbial diversity on hydrocarbon and elemental constituents within each treatment.

Modeling Deepwater Horizon Oil Compositional Changes from Weathering and Dispersant Use - Implications for Water Column Exposure and Toxicity

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Weathering and fate processes (evaporation, photo-oxidation, dispersion by turbulence and dispersant use, dissolution, biodegradation, sedimentation) modify the chemical composition of oil, affecting exposure and toxicity. Modeling the Deepwater Horizon spill illustrates the relative importance of weathering and fate processes in determining exposure and toxicity. In April 2010, oil was released

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from a large orifice at the end of the fallen riser as >1 mm droplets that rapidly surfaced with little weathering and minimal deepwater exposure. In May, six holes developed at a kink in the riser pipe, which dispersed oil as small droplets at depth. Injection of dispersants into the blowout plume also produced small droplets. The higher surface area and residence time of the small droplets increased dissolution, biodegradation and sedimentation, greatly increasing exposure of deep water biota. Pre-weathering of the oil reduced evaporative flux and exposure of wildlife and responders to atmospheric volatiles. For oil surfacing during periods of calm winds, evaporation quickly removed remaining volatiles and semi-volatiles, leading to little water column exposure and toxicity. However, during windy periods much of the oil was entrained, increasing dissolution and exposure of surface water biota to PAHs and other semi-volatile and semi-soluble compounds. Photo-oxidation changed the composition of the surfaced oil, creating polar products that dissolved more readily than their precursors during these entrainment events. This implies that photo-oxidation increased the effects of the oil on surface water biota. However, the balance of the rates of the various physical dispersion and weathering processes determines the degree of exposure and effects on biota. Modeling analyses using pseudo-components representing the various hydrocarbon groups and oxidation products demonstrate the relative importance of these processes in contributing to exposure and toxicity.

Toward a Predictive Understanding of Biodegradation and Its Impacts on the Fate of Oil Deposited on the Northern Gulf of Mexico Coast

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Benthic ecosystems often act as a repository for oil contamination that washes ashore or is deposited onto sediments following a major oil spill. Sedimentary microorganisms mediate central ecosystem services on the coast, such as oil degradation along with natural carbon and nutrient cycling. Thus, during the response to the Deepwater Horizon (DWH) oil discharge, considerable effort went into characterizing the response of benthic microbial communities to oil deposition on shorelines of the northern Gulf. Metagenomic approaches, which were not available during previous large oil spills, have revolutionized the field of microbiology, providing new insights into the microbial response to oiling. This synthesis effort will center on a case study of the fate of oil contamination in Pensacola Beach sands, which sheds light on the rates and mechanisms of microbially-mediated hydrocarbon degradation along with the impacts of oiling to ecosystem functions. Research shows that benthic microbial communities contain a high potential for petroleum hydrocarbon biodegradation. Moreover, our results indicate that even when small oil particles (< 1 cm) are buried in the coastal zone, biodegradation by indigenous microbial communities is sufficient for the rapid mitigation of oil contamination after a major spill, in the presence of sufficient levels of oxygen and nutrients. In contrast, larger sand-oil-aggregates take longer to completely degrade because of their unfavorable surface to volume ratio. Oiling had pronounced impacts on the microbial nitrogen cycle; nitrification was shut down while nitrogen fixation was stimulated. Microbial groups such as chemolithoautotrophic nitrifiers show promise as bioindicators of oil contamination. Further, research during future disasters would be greatly facilitated by improved coordination between the emergency responders directing mitigation efforts and scientists investigating the success of those efforts.

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Marine Oil Snow

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First described about 40 years ago, marine oil snow (MOS) was first identified during the Deepwater Horizon spill as a significant pathway for oil transport to depth below 1000 m. Understanding the conditions leading to the formation of MOS, and the fate of oil incorporated in marine snow (MS), is a pre-requisite for the development of predictive models that can aid decision makers during response to future spills. This talk will review what we have learned about the formation of MOS, and its fate: The incorporation of oil into MS in any one water parcel is a function of oil properties, concentration, and dispersion, as well as, of MS properties and concentrations. In general, the presence of oil compounds may increase aggregation rates of marine particles. Oil compounds, depending on their chemical properties, may be incorporated into MOS via sorption to surfaces of aggregating particles, or as droplets trapped in the MOS matrix. Although counterintuitive, size-normalized sinking velocities of MOS are similar, or higher than those of MS, likely because the presence of oil compounds results in tighter packaging of MOS compared to MS. Potentially oil compounds within MOS, make it more cohesive, resulting in a decreased fragmentation potential compared to MS without oil. While the addition of the dispersant COREXIT increases concentrations of dispersed oil droplets, therewith increasing the potential of oil to be incorporated into MS, COREXIT also may hinder MS formation by dispersing the exudates that form the matrix of MS. The net effect of COREXIT addition on the amount of oil incorporated into sinking MOS depends on the relative strength of these opposing processes. Moreover, COREXIT increases the solubility of certain oil compounds, resulting in potentially more toxic compounds accumulating in MOS. Settling of oil compounds to depth, as observed during and after the DwH spill, may be modeled using coagulation models and physical dispersion models taking lateral and vertical movements into account.

MOSSFA: Understanding Ecosystem Impacts and Predictive Modeling

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MOSSFA (Marine Oil Snow Sedimentation and Flocculent Accumulation) is now widely accepted by the oil spill community as a mechanism capable of transporting significant amounts of crude oil and other surface water constituents (i.e., pyrogenic hydrocarbons, physical tracers and biomarkers of primary producers/consumers, clay-sized minerals components and dispersant derivatives) to the sea-floor. Continuing studies have revealed a wide-array of organic and inorganic constituents associated with the formation and sinking of marine oil snow (MOS) aggregates. Sediment studies have further revealed that MOSSFA events are enhanced by the application of traditional surface-oil remediation techniques (oil burning, freshwater discharge, surface dispersant application) leading to significant impacts to the benthic habitat and long-term consequences for benthic community structure and function. Numerical models of MOS formation can reproduce observed MOS size spectra in the water column and predict the amounts of oil arriving at the sea floor in MOSSFA events. Coupling these models to transport models, sediment diagenesis models and oil degradation rates provides the potential for predicting the spatial and temporal occurrence of MOSSFA events and their impacts, consequences, and recovery rates of benthic biological communities. The ability to predict the occurrence and magnitude of MOSSFA events provides first-responders with the information needed

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to make more accurate assessments of the amount of oil in surface waters and inform decision makers on the application of specific surface oil remediation techniques. This synthesis group will bring together that state-of-art knowledge in this rapidly evolving and important field of study.

Fragmentation of Marine Oil Snow Due to Small-Scale Turbulence

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Fragmentation of marine oil snow (MOS) due to small-scale turbulence is an important mechanism by which oil and associated contaminants are released back into the water column. We conducted laboratory experiments to determine whether the presence of oil affects fragmentation of diatom aggregates formed in roller tanks containing a senescent diatom culture (*Skeletonema grethae*) and Macondo oil. For this, individual aggregates were transferred from roller tanks into a cylindrical acrylic tank (2 L total volume) equipped with a circular grid that oscillates at specific frequencies in the lower part of the tank (between 20 and 70 mm above the bottom), generating small-scale turbulence. When sinking aggregates approached the bottom part of the tank where the grid was oscillating, the grid was turned off to avoid physical contact with the aggregates. Once the aggregate entered the area of turbulent mixing, it stayed either intact and sank to the bottom of the tank or fragmented into daughter particles. Prior to and after the transit through the turbulence zone, aggregates or their daughter particles, were sized microscopically and then collected on pre-combusted GF/F filters to determine their organic carbon content. Additionally, we determined the concentration of microscopic particles (< 100 µm) in the turbulence tank using a Coulter counter. The fragmentation potentials of 72 aggregates (with or without oil) were measured at 3 turbulence levels (dissipation rates), reflecting conditions from open ocean surface waters to high turbulent coastal environments. MOS fragmentation was observed only at the highest turbulence level ($\varepsilon = 1.2$ cm^2 s^{-3}) whereas diatom aggregates without oil already fragmented at intermediate turbulence ($\varepsilon = 0.5$ cm^2 s^{-3}). Oil droplets may lead to a tighter packaging of cells within MOS, possibly decreasing aggregate porosity which could explain a greater physical strength of MOS compared to non-oil containing aggregates.

Microscopic Evolution of Biofilm Formation in Dispersed Oil Droplet-Bacteria Agglomerates

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Oil degrading bacteria adhere to and colonize dispersed oil droplets, leading to biofilm formation in the form of free-floating agglomerates with entrapped oil droplets. Using a range of microscopy techniques, we have observed that the size and apparent density of biofilm agglomerates is dependent upon droplet size, which is in turn dependent upon dispersant composition. Biodegradation experiments were conducted in nutrient supplemented artificial seawater with *Alcanivorax borkumensis* utilizing hexadecane (a model oil) dispersed by Corexit 9500, a lecithin/Tween 80 mixture, and lecithin and Tween 80. Low initial bacteria and oil concentrations were used to allow direct imaging of the formation, size, and structure of the biofilm agglomerates as the systems evolved. With

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Corexit 9500, a mixture of non-ionic and anionic surfactants that formed small hexadecane droplets, the agglomerates formed quickly (within 1 day), were large and dense, and persisted for weeks. Comparatively, with lecithin/Tween 80, a mixture of a zwitterionic and a non-ionic surfactant that formed large droplets, the agglomerates took longer to form (2-3 days), were smaller and less-dense, and continued to grow over the course of the study. Lecithin nor Tween 80 alone led to the formation of biofilm agglomerates. Despite the distinct differences in the physical properties observed for the biofilm agglomerates, the extent of hexadecane biodegradation after two weeks was similar and ranged from approximately 30-50% for all dispersants examined. Lecithin/Tween 80 yielded the highest biodegradation possibly due to the surfactants being used as a nutrient or food source. While the size and structure of the biofilm agglomerates did not correlate with the extent of biodegradation, these properties did impact the colloidal properties of the agglomerates and their ability to sediment or cream.

Modification and Characteristics of Two Particles for Oil-Particle Aggregates Formation

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Oil droplets in the water column interact with sediments to form oil-particle-aggregates (OPA). The interactions between oil and fine particles can facilitate the transport of oil from one environmental compartment to another. OPAs play an important role in nearshore waters of oil spill events. Two types of particles (kaolinite and silica) were modified in comparison to change their hydrophobicity. The particles were mixed with 2,4-toluene diisocyanate (TDI) in 110 degree with 1-butanol and toluene as solvent. Different ratios at 0.2 - 1.5 of particle/TDI were researched to get different hydrophobicity ranges. Contact angle of modified particles could be over 38 degree when the ratio is above 0.5. Results of confocal microscopy and X-ray diffraction (XRD) revealed good modification effects of particle structure and hydrophobicity. Using the modified particles, the OPA was formed in the lab using the EPA baffled flask. We considered different factors that could affect the OPA formation process, such as mixing energy and interaction time. The resultant OPAs were analyzed by confocal laser scanning microscopy, which provides the three-dimensional structures of OPA. The detailed structures of the OPA provided the evidence of new mechanisms of the oil-particle coagulation mechanism in turbulent flows.

Investigating the Role of Photoheterotrophic Bacteria in Oil Degradation in Northern Gulf of Mexico Waters

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The fate of oil in the sea depends on various environmental factors such as sunlight, temperature, location of the spill, and the development of oil-degrading microorganisms. Previous studies have demonstrated that sunlight promotes the growth of certain bacteria during oil degradation, such as *Alteromonas*, *Marinobacter*, and *Labrenzia*, indicating enhanced activities of these heterotrophic bacteria under irradiated condition. To investigate whether photoheterotrophic bacteria is present during oil degradation, and to what extent and how these heterotrophic bacteria contribute in the process, a series of microcosm incubations were conducted in summer 2018. Surface water was incubated with amendments of 200 ppm weathered oil for 37 days under different light conditions. At

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designated time points, subsamples were collected to monitor bacterial abundance, bacterial community, bacterial chlorophylls, transcriptome, as well as alkanes and poly aromatic hydrocarbons (PAHs) concentrations. Our preliminary data showed that concentrations of both alkanes and PAHs decreased with time in light incubation, while they stayed relatively constant in dark incubation. In light incubation, the most significant decreases in alkanes (from ca. 15 ppm to ca. 10 ppm) and PAHs (from ca. 0.2 ppm to ca. 0.003 ppm) occurred between day 5 and day 20, coinciding with the increase of bacterial abundance, from ca. 1.2×10^5 mL^{-1} at day 5 to ca. 3.6×10^6 mL^{-1} at day 20. Analyses of bacterial community, bacterial chlorophyll and transcriptome are ongoing and will be presented.

Deep Sea in a Can: Influencing Factors of Crude Oil and Methane Biodegradation in the Sediment

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The Deepwater Horizon (DWH) incident in 2010 released an unprecedented amount of petroleum hydrocarbons into the Gulf of Mexico at a depth of 1500 m. translating to 15 MPa pressure. Indigenous petroleum-degrading bacteria were enriched by the deep-sea oil plume and were responsible for biodegradation of the released hydrocarbons.[1] The isolate *Rhodococcus* PC20, from the DWH site, that is able to grow on crude oil and single hydrocarbon components, demonstrates that selective degradation rates were significantly higher at elevated pressure compared to sea level pressures. Nevertheless, in this case growth rates were not influenced by the applied pressure to a significant extend.[2] Hydrostatic pressure has been shown to also affect bacterial community abundance and diversity as well as hydrocarbon degradation activity.[3-7] Chemical dispersant application aiming to stimulate oil degradation significantly altered microbial community composition.[8] This is studied in sophisticated lab-scale high pressure batch reactors (cans). However, the knowledge on the impact of hydrostatic pressure in the presence of hydrocarbons and dispersant on microbial communities is so far still lacking. It will be demonstrated that pressure has a significant influence on microbial community development. Thus, pressure should be considered as an important parameter in future studies on microbial activities and community dynamics. **Literature**: [1] G. M. King *et al*. (2015) *Ann Rev Mar Sci*. 7; [2] S. Hachbusch *et al*. (2018) submitted; [3] M. Schedler *et al*. (2014) *AMB Express* 4 (1); [4] A. G. Valladares *et al*. (2015) *IEEE J Sel Topics Appl Earth Observ Remote Sens*. 8 (2); [5] A. Marietou *et al*. (2018) *Front Microbiol*. 9 (808); [6] H. Fasca *et al*. (2018) *Microbiologyopen*. 7 (2); [7] U. Nguyen *et al*. (2018) *PLoS One*. 13 (7); [8] S. Kleindienst *et al*. (2015) *PNAS*. 112 (48)

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Geochemical Analysis During Coupled Chemical Oxidation and Aerobic Biodegradation of Buried MC252 Oil Across a Headlands Beach Profile

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Coupled *in-situ* oxidation processes- chemical pre-oxidation with activated persulfate and enhanced bioremediation through the use of an oxygen releasing compound- were used to stimulate

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biodegradation of buried petroleum hydrocarbons at Fourchon Beach, LA. Two treatment processes were employed at the site: Phase 1 (P1, 02/2017) consisted of application of persulfate oxidant within the approximately 100 m^2 zone and Phase 2 (P2, 11/2017) incorporated the subsequent addition of persulfate with a co-application of an oxygen release compound. Distribution of PAHs and *n*-alkane compounds pre- and post-treatment were surveyed by sediment extraction and GC-MS. The impacts of treatment on groundwater chemistry were monitored (ORP, pH, conductivity, temperature and DO). Bacterial communities were characterized in sediments using Illumina Miseq sequencing. Temporary perturbation of groundwater was observed after P1 (ph=6.2, ORP=296 mV), and more prolonged alteration in ph (3.0-6.7) and ORP (>500 mV) were observed in some wells after P1, indicating a dynamic system perhaps due to acid generating reactions or a slow buffering response relative to the initial pH condition because of the second dosing. Sustained oxygen concentrations (wells up to 2.9 mg/L) after P2 indicate that persulfate satisfied a portion of the intrinsic oxygen demand. Chemical oxidation with persulfate directly degraded a differential portion of target contaminants through a variety of non-specific oxidation reactions. Significant removal of PAHs and *n*-alkanes ($p<0.05$) for those samples classified as highly contaminated (>100 mg/kg total PAHs) and low contaminated (<15 mg/kg total PAHs) samples were observed after P1. Chemical oxidation caused significant differences in microbial community structure ($p<0.05$), however samples taken 1 month after P1 were enriched with similar genera as those from pre-P1 samples, indicating a resiliency within the population.

Differences in the Compositional and Transcriptional Responses of Surface Water Marine Microbial Communities to Oil and Chemically Dispersed Oil

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Marine microorganisms play a central role in the degradation, dispersion, and transport of oil after an oil spill. We conducted mesocosm experiments to investigate how the compositional and transcriptional response of microbial communities differ when exposed to crude oil versus chemically dispersed crude oil using 16S rRNA sequencing, metatranscriptomics, quantitative petroleum-hydrocarbon analyses, and epifluorescent microscopy. We performed these experiments using both coastal and offshore waters of the Gulf of Mexico in order to further test how these microbial responses might differ in different marine ecosystems. Four mesocosm treatments were prepared: (1) seawater only control, (2) seawater with oil, (3) seawater with oil dispersed with Corexit®, and (4) seawater with dispersed oil, but diluted ten-fold. We observed that with both coastal and offshore waters, mesocosms amended with either oil or dispersed oil led to an outgrowth of several putative hydrocarbon degrading bacterial taxa (e.g. *Marinobacter*, *Cycloclasticus*, *Alcanivorax*). In coastal water, this manifested as a decrease in community diversity. However, in offshore waters, community diversity instead increased over time. Microbes in coastal waters upregulated genes for alkane degradation when exposed to dispersed oil but this was not observed in the offshore waters. We also uncovered evidence that offshore communities exposed to oil more readily express genes for polycyclic aromatic hydrocarbon degradation than coastal communities. Together, these data reveal how microorganisms differ in their response to spilled oil in coastal and offshore environments and also enable us to further evaluate the effect of chemical dispersants on these communities.

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Formation of Oil Droplets from Underwater Blowouts: Role of Gas to Oil Ratio

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We conducted a large scale experiment of underwater oil and air release in Ohmsett wave tank, which has a dimension of 203 m × 20 m × 2.4 m, making the largest saltwater facility for oil spill research in North America. An oil flow rate of 40 L/min to 140 L/min and combined air flow rate of 6 L/min to 180 L/min were discharged through a 1-in vertical pipe. The objective of this study is to focus on the impact of gas to oil ratio (GOR) on the oil droplet size distribution (DSD) on a realistic scale, especially when churn flow was generated. The whole measurement system consists of shadowgraph cameras and LISSTs for oil droplet size measurements in a range of ~1.0 μm (i.e. LISST 200x) - ~10 mm (i.e. shadowgraph camera), ADVs (acoustic doppler velocimeters) for plume velocity, Fluorometers for dissolved oil contents. Underwater GoPro cameras were also used to capture the plume trajectories. The whole system was towed to allow for the dilution of the oil plume for better visibility, facilitating thus the monitoring of oil droplets by means of the shadowgraph cameras and the LISSTs. Valuable information were obtained from the experiments. Time series DSD were produced from the images capture by the shadowgraph cameras, showing fluctuated droplet size evolution over time at any given location in the oil plume. Preliminary results show that the churn flow indeed reduced the size of oil droplets in comparison with situations where no air or air fraction is small. We also observed that droplet separation occurred across the plume due to individual droplet buoyancy, where the droplet sizes were larger in the upper plume than the ones in the bottom, indicating that the position of the instruments relative to the plume is important to interpret the droplet size distribution in the plume.

Comprehensive Analytical Approaches to Spill Characterization: Case Studies and Examples

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The Deepwater Horizon spill posed major new challenges to the oil spill research community, due to its subsurface nature, heterogeneous distribution of the released oil, concurrent oil releases, and the complexity of post-spill processes, including abiotic weathering and the interactions with marine microbiome.

In contrast to previous major spills (e.g. Ixtoc, Exxon Valdez), oil spill researchers now have new analytical tools, such as two-dimensional gas chromatography, and tandem (MS/MS) and ultrahigh resolution mass spectrometry (e.g. FTICR-MS), at their disposal. These new tools are widening the analytical window for spill characterization, including compounds which typically could not be investigated, due to their low concentration, co-elutions with other compounds, or their high molecular weight and low volatility. In conjunction with more conventional tools such as gas chromatography, stable isotope analyses, thin layer chromatography and optical spectroscopy, to name a few, they afford a much more comprehensive chemical spill assessment.

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In this presentation, some applications of such assessments will be showcased including examples from the Deepwater Horizon and other historic spills, such as the Prestige tanker incident (2002) or the Ixtoc blowout (1979). The presentation will highlight the studies conducted in the past few years, with support of GoMRI and other funding sources, which examined surface weathering of released oil, in particular due to photochemical processes, workflows for oil toxicity assessments, and the molecular evidence of spill sedimentation processes to the deep seabed. Finally, we will discuss how these new analytical approaches can help us to be better prepared for potential future spills.

013: Connecting the Relevant Scientific Research and Findings to Actionable Response Decision Making

Leveraging Science and Academic Engagement During Oil Spills

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NOAA's Office of Response and Restoration (OR&R) provides scientific and technical support for oil and chemical spill preparedness and response, including scientific support to the U.S. Coast Guard. Because OR&R integrates expertise from an array of sources, the substantial increase in post-Deepwater Horizon oil spill research has called for increased scientific engagement with academia. In January 2019, OR&R and the Coastal Response Research Center (CRRC) are hosting a workshop to: (1) develop best practices for advancing OR&R's interaction with the academic community during response, enabled by relationships built during the preparedness phase; (2) build relationships and fostering understanding of the roles and responsibilities of the oil spill response/assessment scientific community and the academic community, including an understanding of each other's strengths and limitations; (3) develop mechanisms that facilitate access for academic research during oil spills; and (4) develop implementation recommendations and metrics for evaluating success. The ~60 participants include spill responders from federal and state agencies and the private sector, and members of the academic/research community. The roles, responsibilities, capabilities, and limitations, as well as existing models for academics to help answer spill questions and have access to spill sites will be presented. Reconciliation of response imperatives with academic modalities will be explored with respect to timeframes, operational and command interfaces, cultural differences, health and safety issues, financial realities and legal/liability issues. The characteristics of best practices for academic participation/interaction with OR&R before, during and after spill response and the mechanisms that could facilitate access for academic researchers during spills will be identified. The findings and recommendations for best practices and their implementation that result from the workshop will be presented.

Understanding the Toxicity and Hazard of Dispersants to Aquatic Organisms within the Context of Operational Field Exposures

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The oil spill response community has proactively developed and improved tools, built in part, from information generated by through scientific research. Two tools developed by NOAA's Emergency Response Decision are available to help inform real-time response decisions, communicate tradeoffs and address concerns by stakeholders: the Chemical Aquatic Fate and Effects (CAFE) database- a database containing fate and effects information for thousands of chemicals, including dispersants; and the General NOAA Operational Modeling Environment (GNOME)- a three-dimensional trajectory model that simulates mass balance, environmental concentrations, and spatial and temporal trajectories of real or hypothetical spills. One challenge in integrating scientific research on dispersant-only toxicity into response decisions is the fact that these data are generated from laboratory exposures that may not be representative of field exposures, but instead provide conservative estimates of toxicity. Thus, correct interpretation of toxicity information would benefit from an improved characterization of field exposures. CAFE and GNOME were used to evaluate risks posed by dispersants to aquatic organisms. Through this exercise: 1) dispersant-only aquatic toxicity data from CAFE were used to develop species sensitivity distributions (SSDs) and hazard concentrations protective of 95% of the species assemblage (HC5); 2) GNOME was used to simulate dispersant-only concentrations in the water column under scenarios bracketing a range of conditions representing operational surface application rates and environmental settings appropriate for dispersants use; and 3) assessments were made based on comparisons of laboratory-derived HC5s versus expected environmental dispersant concentrations. It should be noted that simulated field exposures are only hypothetical as dispersants are applied directly on oil slicks. The goals of this presentation are to: 1) provide an overview of the body of scientific knowledge on dispersant-only toxicity; 2) explore approaches for integrating this knowledge into existing tools; and 3) highlight the importance of generating data that can be translated to relevant response conditions/scenarios.

Evaluation of Potential Impacts of Dispersed and Undispersed Oil Spills on Fish Stocks

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Several response options are available to responders and decision-makers in case of an oil spill. Dispersants use could often be the most effective way to mitigate consequences of an offshore spill, but their use and approvals require special considerations. Many scientific studies focused on testing toxicity of dispersants and dispersed oil to various species in an effort to generate information that could facilitate decision-making. Unfortunately, this information alone cannot improve response decisions. In addition to understanding hazards to individual organisms response decision-makers have to consider exposure conditions as well as recovery rates of individual organisms, populations and habitats. In this presentation we will describe decision-making process for dispersants use and illustrate how LC50 values could be converted into practical information that could be used in Net Environmental Benefit Analysis or Spill Impact Mitigation Assessment. This presentation will summarize the results of two studies evaluating large dispersants use operations and their hypothetical impacts on populations of Arctic Cod in Beaufort Sea and Red Snapper in Gulf of Mexico. In these studies, a spill scenario was defined and an oil spill trajectory model was used to determine distribution and volumes of water having concentrations of oil exceeding LC50 values. Then density of egg and larval fish within these contaminated waters was calculated using several conservative assumptions. Once the level of estimated mortality was evaluated, these losses were placed into context using stock assessment models. A fecundity hindcasting model (FHM) was used to project backwards and converts the total estimates of egg and larval mortalities to "equivalent eggs" - the number of original eggs that would

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have been required to account for the total loss. Then the impacts of dispersants use were expressed as the percentage of eggs lost from the total egg stock, and the number of females needed to replace the lost eggs. This conversion of laboratory toxicity data into an estimation of potential impact on a fish stock provides practical information that could be used for response decision-making.

Spreading and Sheening of Crude Oil in the Open Sea Results in Greater Dispersion than Occurs in Closed-System Dispersant Tests

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There are many closed-system tests used to evaluate the effectiveness of dispersants on oil spilled at sea. These tests are convenient because they are simple and low cost, allow careful control over test conditions, and can be easily repeated. Developers of the more commonly used tests describe how they were never intended to define the amount of dispersion that will occur at sea because of inherent limitations. Rather, they were designed to compare the effectiveness of different dispersants, differences in dispersion behavior between oils, and changes in dispersibility as oils weather/emulsify. Issues with closed system testing are that they only last a limited time (typically 10 - 30 minutes), the mixing energy used may not represent real-world conditions, and the dispersed oil does not dilute as it would at sea. Another less understood issue is that surface slicks do not spread and sheen in closed systems like they will at sea. One reason is that closed system walls and/or oil-slick containment methods impose physical boundaries that restrict oil spreading. In addition to physical constraints, surfactant films that form on the water surface surrounding an oil slick reduce the water surface tension to keep slicks thick. This occurs in the field during a real incident, in flasks in the lab, and in wave basins. Fragile surfactant films, however, can't persist for long periods in the open ocean but can persist throughout 10 - 30 minute dispersant-effectiveness tests. The result is that closed-system dispersant-effectiveness testing maintains oil slicks that are artificially thick. Thick oil slicks will obviously require more energy to disperse than a thin film/sheen of the same oil. Restricting slick spreading and sheening likely results in significantly lower dispersion than would be expected at sea not only for heavier oils but for all oils in tests simulating low-energy conditions.

Driving Science Forward to Support Decision Making in Oil Spill Response: The Multi-Partner Research Initiative

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The Multi-Partner Research Initiative (MPRI) for Marine Oil Spills under Canada's Oceans Protection Plan (OPP) aims to build a research network to bring together the best scientific expertise in oil spill research, both nationally and internationally. The core studies under this program are focused on the provision of scientific knowledge to support the development, validation and regulatory approval of Alternative Response Measures (ARMs) that include: spill treating agents; *in-situ* burning, oil translocation and decanting/oily waste disposal. Additional research will include studies on key topics such as natural attenuation and bioremediation of oil, assessment of toxic impacts associated with oil spills and the application of oil spill countermeasures, oil detection, and mapping by autonomous underwater vehicles. Formation of this network is envisioned to enhance science-based decision making during response operations. A major initiative like the GOMRI program, MPRI is anticipated to

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have a profound influence on the oil spill research community and emergency response agencies within Canada. Over the next 4 years, the projects outlined under the MPRI program are expected to support the development of approximately 90-100 trainees (new technicians, co-op students, MSc, PhD and PDFs) and 10-15 faculty members under a marine oil spill research network that will be further leveraged by funds from the private sector (i.e., spill response organizations and oil industry partners) and other international (e.g., USA, Norway, France, Australia, China) government agencies. This presentation will provide an overview of goals and objectives of projects funded to date and future opportunities to build on the excellent science delivered from the GOMRI program.

A Science-Based Approach to Developing a Sub-Regional Oil Spill Response Cooperation Arrangement for the Guyanas

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The Santos, Campos, and Espirito Santo basins offshore Sao Paulo and Rio de Janeiro, Brazil are prolific and growing oil Exploration & Production (E&P) plays with well-established oil spill preparedness and response (OSPR) regimes. Further north, the Amazon Delta (Brazil), and the Guyana-Suriname basins (French Guiana, Suriname, and Guyana) are emerging frontier E&P opportunities where due to unique location, currents, and other environmental factors, present unique preparedness and response challenges, particularly with regard to the transport of any spilled to up-current significant trans-boundary challenges. As a result, a surface spill or subsurface release in one country would likely move with currents into the waters of adjacent neighboring up-current countries, presenting challenges for transboundary response. This paper discusses the need for a holistic sub-regional oil spill preparedness and response capability based on Tiered Preparedness and Response, and driven by oceanographic currents and stochastically-derived trajectories, environmental components and resources at risk, and Net Environmental Benefit Analysis/Spill Impact Mitigation Assessment, and a political appetite to cooperate across borders.

Quantitative Analysis of Tidal Eddies Affecting Transport of Spilled Oil at a Bay Entrance

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Hydrodynamic models and the GNOME oil spill trajectory model are widely used to predict movement of a marine oil spill. The hydrodynamic models are typically calibrated and validated with point data at a few critical locations, e.g., ADCP-measured velocities in a narrow shipping channel. Unfortunately, there are circulation patterns created at a narrow entrance that are not captured by single-point measurements — in particular tidal eddies generated at the jetty edges of an entrance. The tidal eddies developed on a flood tide can affect the fate of oil transport across the bay entrance as oil can get trapped in and transported by the eddy. Thus, models that do not represent the tidal eddies are unlikely to correctly represent the oil transport across the bay entrance. We have been conducting model studies of the Galveston Bay entrance channel with the SUNTANS hydrodynamic model as part of a model upgrade program of the Texas General Land Office. Our results indicate that a (relatively) coarse grid resolution of 400 m is satisfactory for matching field data representing the bulk velocity through the channel, but could not adequately capture creation and circulation of the tidal eddies. The model representation of the eddies was adequately converged at a 140 m resolution, which implies a

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finer resolution is required than is typically used for many operational models. A key point from this work is that the community should consider more carefully the types of data used for model validation and grid convergence studies.

Assessing Extinction Risk of Gulf of Mexico Deep-Sea Fishes

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Restoration efforts related to biodiversity impacted by the Deepwater Horizon oil spill lacked access to a publicly available data source on the specific status of most Gulf of Mexico marine species. Recognizing this knowledge gap, an initiative was completed in 2016 that resulted in the publication of extinction risk assessments for over 950 Gulf bony shorefishes on the IUCN Red List of Threatened Species (www.iucnredlist.org). To expand the breadth of these assessments, an ongoing GoMRI-funded initiative aims to assess all Gulf deep-sea bony fishes, a further ~560 species. IUCN Red List methodology applies expert-vetted, scientific data on each species' distribution, population, habitat, life history, conservation efforts and impact of threats to estimate the level of extinction risk. As a result, Red List assessments can identify priorities for conservation planning, increase awareness of biodiversity loss, identify key gaps in scientific research and provide a vetted data source to the public of species-specific information. Red List data can also be used for constructing species vulnerability indices to threats, including petrochemical exposure. Here we provide example analyses to estimate probability of exposure and toxicological impacts based on life history, distribution and other surrogates for several species, including the commercially-valued Golden Tilefish (*Lopholatilus chamaeleonticeps*). These sample analyses demonstrate the framework methodology that will be applied in constructing a comprehensive petrochemical vulnerability ranking for thousands of species in the Gulf, the majority of which lack controlled toxicological studies.

Physical and Biochemical Response to a Cold Front Using Floats

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Technology for measuring the deep ocean currents is available using the recently developed APEX floats with electromagnetic sensors (APEX-EM) developed by Teledyne-Webb. The float acquires temperature and salinity profiles using a Seabird sensor. In addition, the APEX-EM profiling floats were equipped with chemical and bio-optical sensors: Aanderaa Optode sensor measuring dissolved oxygen, and the WET Labs ECO puck sensor which combines measurement of chlorophyll fluorescence, measurement of backscatter and CDOM fluorescence. The ECO puck has been specifically designed to minimize space and power requirements for applications in autonomous measuring platforms, and is rated for sampling to 2000 m depth. These technological advancements have relevance to the

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response to subsurface oil spills such as the blow out of the Macondo well. To illustrate this capability, the impacts of wind-driven current and shear on the biochemical response are investigated during the passage of a cold front in early May 2017 using profiles from multiple floats and shipboard instruments. During frontal passage, the surface winds approached 20 m s^{-1} that forced strong near-inertial currents in the upper ocean. Current shear across the base of the ocean mixed layer, forced layer deepening of more than 20 m over the two days of strong forcing. The associated biochemical response indicated a dissolved oxygen and chlorophyll fluorescence maxima at depths of 90-100 m during the event. This deep chlorophyll maximum tends to correspond to the oxycline lying between the 24-25 isopycnal in temperature and salinity space. During this period the floats resolved these responses as continuous measurements were acquired over time scales of a few hours. This float technology enables investigators to look more closely at the oceanic response to strong forcing events that impacts biochemistry and hydrocarbon dispersion for subsurface spills. Sampling rates can changed by updating mission profiles from continuous to profiling modes between specific depths to once every five to ten days. Data are transmitted over Iridium system including the GPS position when the float reaches the free surface allowing for adaptive 3-dimensional sample strategies to resolve ocean processes that impact the movement of hydrocarbons.

Advancements in Satellite Detection of Marine Oil by Using Available Ground Validation

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In 2011 the NOAA Satellite and Information Service (NESDIS) put into practice a 24x7 operational desk to identify potential man-made oil slicks in visible satellite imagery and Synthetic Aperture Radar. Oil identification is based on a visual inspection, subjective interpretation. Report issuances are at the discretion of the trained analyst. The end product is a Marine Pollution Surveillance Report (MPSR) that's becoming more widely used in response. Key information includes the oil location and areal extent. Though operational, the program inherently relies on research fieldwork and user feedback to calibrate satellite observations. It is necessary to improve detection capabilities and reduce the occurrences of reporting on false positives. NOAA's Marine Pollution Program (MPP) participates in field campaigns in order to be able to exploit the data from newer sensors. The presentation will cover MPSRs that have ground confirmation, based on a sequence of response actions. A succinct overview of MPSR text and graphical information will be given, with an emphasis on the "Confidence Criteria", the parameter which conveys how strongly the analyst believes that the anomaly is oil. The Confidence level can be used to prioritize decision-making. A High Confidence anomaly should be investigated if possible, whereas a Medium Confidence should be addressed at a lower priority. The audience will note that sometimes satellite analysis is the first indication of an oil release, sometimes it's used to corroborate an existing report, while other times highlights the need to establish better correspondence with responders to confirm or disprove the presence of oil. The presentation will also include advances in oil thickness assessments in high resolution multispectral imagery. For oil clean up, it's helpful to have an indication of whether the oil is thick enough to be skimmed. For Natural Resource Damage Assessment, it's helpful to know the extent of the oil that is relatively thin vs. thick. Color characteristics of oil in 2 visible satellite images will be assigned thickness ranges according to the Bonn Agreement, to yield a first guess volume estimate. Brief comments on limitations will be stated. A summary of the presentation will highlight the tangible uses of satellite derived information in decision-making.

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Multi-Dimensional Oil and Gas Leak Risk Mitigation and Community Resilience

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Gas leaks are present in all phases of operational petrochemical processes, which gives rise to severe damages to human health and environments, and occasionally leads to large accidents causing economic damage and casualties. Moreover, the number of leaks and accidents in the Gulf region has increased due to intensifying coastal hazards. The resulting environmental and socioeconomic impacts have risen in line with population growth, infrastructure aging, and higher interdependencies across nearby communities. Numerous efforts to enact rules and regulations for oil and gas (OG) safety and environmental impact have been implemented after historic OG spill disasters induced by operational accidents or natural hazards. However, most of these environmentally protective solutions have been challenged and only limitedly adopted by petrochemical industries. As a result, OG release incidents have occurred ceaselessly, and the communities in this region have not yet overcome the adversity to take economic benefits from natural resources. Multidisciplinary experts collaborate to develop a framework to demonstrate that industry and communities can work together to mitigate risks of OG leaks in this study. The proposed framework includes a scalable novel OG leak risk model integrating a multi-purpose sensor network which can be locally adapted for a selected facility. The framework demonstrates how multi-dimensional loss-benefit measures can leverage a strategic initiative to implement the proposed risk mitigation model into other facilities in the community, engaging multi-agency practitioners from a community including practitioners from the petrochemical industry, federal agencies, and local government offices or citizen groups in affected low-income communities. Finally, this study provides real-time responsive and preventive actionable items in the short and long term to improve the neighborhood community resilience in terms of economy and health against future leak events.

Advanced Oil Spill Transport across the Bay/Coastal Boundary

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Accurate simulations needed for responding to coastal oil spills require a fundamental understanding of tidal eddy driven transport. Tidal eddies are commonly formed along barrier islands and shipping channels connecting bays/estuaries to the coast. The transport in and out of the bays/estuaries caused by these eddies is critical for many barrier island coastlines across the United States such as the Texas coastline, Mobile bay entrance, and a large portion of western Florida. Understanding this major form of transport in areas like Galveston Bay can greatly assist response efforts to disasters such as the Texas City Y spill. In this spill, a bulk carrier collided with an oil tanker spilling 168,000 gallons of oil, which later became stranded on the coastlines of Galveston and Matagorda island. Models used for responding to these oil spills are generally too coarse to resolve tidal eddy behavior. Fine scale models capable of resolving these eddies are computationally expensive and require amounts of time that are impractical for responders attempting to mitigate damages from an oil spill. Responders need simulations that can forecast out several days and can be ran in a matter of hours. The new tool that is needed is a coarse grid simulation that can be run in a short amount of time and can also accurately model tidal eddy behavior. To achieve this, we are developing a sub grid scale probabilistic model that can predict tidal eddy behavior at bay inlets through funding from the Texas General Land Office

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(TGLO). The model is developed and validated using new experiments conducted at Texas A&M University on eddies caused by tidal flow between barrier islands with realistic bathymetry. These new data will act as a benchmark for developing accurate numerical models. Using the data from the experiments, the coarse grid models will be empirically tuned to capture the behavior of the eddies while also having the capability of relatively short run times. These models will then be made available to responders to immediately improve oil spill forecasts. This presentation will discuss the main problems caused by tidal eddies during potential oil spills and the way research is developing tools that will be used by responders when future spills occur.

Closing Remarks

D. S. Tulis
U.S. Coast Guard, Washington, DC

014: Identifying Gaps at the Intersection of Spiritual Displacement, Environmental Justice, and Community Power

Time after Time: Multiple Traumas and the Path to Community Power

R. S. Hanks (Invited)
University of South Alabama, Mobile, AL

Even a superficial survey of recent literature reveals studies of the intersection of cultural narratives and environmental injustices but may not produce a clear picture of the role of culture in relation to social justice in shaping activism (Banerjee and Steinberg, 2015). For example, Kim (2013) argues to integrate citizenship into the race, class, gender frameworks that traditionally examine community activism around environmental justice. Further, individual and community histories - as well as current policies and community context - shape what a community does with the experience of environmental injustice. This presentation explores questions around the intersection of spiritual displacement, environmental justice, and community power in Cambodian and Laotian communities in lower Alabama. Elders in these communities have endured the trauma of displacement due to war. Immigrants have faced hostility in the workplace. Massive losses to Hurricane Katrina and the Deepwater Horizon oil spill have further tested these communities. A research team is currently employing community-based participatory research methods in these communities to discover barriers to disaster preparedness, response, and recovery and to better understand the intersections of culture, spirituality, and social justice along the path to community empowerment and resiliency.

Who is a Community? Questioning Community Framing in the Gulf Coast

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With funding from The Gulf of Mexico Research Initiative through The Consortium for Resilient Gulf Communities, a Tulane University research team explored the predictors of disaster preparedness and resilience towards future hydrocarbon disasters, among individuals residing in Gulf of Mexico

communities in southeastern Louisiana. The study investigated the role of social networks, risk perceptions, preparedness measures, individual resilience and demographics as predictors of preparedness and resilience towards future oil spill events among households in the Gulf of Mexico. The data consisted of 326 individuals residing in areas surrounding Port Sulphur and Galliano, Louisiana and Bayou La Batre, Alabama in the Gulf of Mexico. Preliminary analysis of the Social Network data of survey respondents show that their sources of support (both to prepare for and respond to disasters) vary across sex, race, age, and geographical location. This is significant because, though there is no cohesive narrative across studies, disciplines, or research methods for disaster resilience, there is still a common theme of "community", "local level", and "relationships" that run across the literature. Yet, there appears to be an implicit assumption of identity-based or geographic social networks among populations. This data begins to put into question the notion of identity/geographic-based concepts of community. Further research is needed to understand what influences sense of community among populations along the gulf coast to inform strength-based approaches to risk-reduction that purposefully address the contextual differences of sub-populations. Defining 'community in the context of disaster resilience,' paying attention to the cultural context of sub-populations, to capitalize on group identity and lived experiences around disaster exposures can support a platform for resilience building.

Child, Family and Community Resilience Seven Years after the Deepwater Horizon Oil Spill: Qualitative Insights from Louisiana Parents

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The BP Deepwater Horizon Oil Spill (DHOS) stands out as an industrial disaster of unprecedented scale and ongoing impact. Rebuilding and rebounding after this type of event is a process that unfolds at the individual, family and community level over many years. In November of 2017, 46 parents and caregivers across seven spill-affected Louisiana parishes participated in a series of focus groups as part of the Resilient Children, Youth, and Communities (RCYC) project. In this presentation, we draw on the analysis of narratives from these focus groups to understand the strategies individuals, families, and communities use to cope with the disaster process in the years following the DHOS. This "deep-dive" into family and community resilience themes-- in the words of local people-- will provide important context and nuance, especially when triangulated with other forms of RCYC data e.g., longitudinal survey and social media analysis.

Religious Context, Social Embeddedness, and Alcohol Misuse in the U.S. Gulf Coast Region

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There is mounting evidence that disasters are linked to a number of adverse health outcomes, including alcohol misuse. In recent year the U.S. Gulf Coast region has been impacted by a series of disasters, including the 2010 Deepwater Horizon oil spill, putting people at greater risk of problematic drinking. Further, while social capital is consistently considered a cornerstone of community and individual resilience after disasters, research on the relationship between social capital and alcohol misuse is mixed. This paper considers whether the inconsistencies of these findings may be related to

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the religious context of place. Specifically, the predominant cultural norms of places surrounding alcohol use differ based upon their "morality theodicies" (i.e., religious ideologies about health and illness). In the case of the U.S. Gulf Coast, the religious ecology of places tends to be dominated either by Catholicism or conservative Protestantism, religious orientations with more and less permissive views toward alcohol, respectively. This paper explores how the relationship between social embeddedness (a form of social capital) and alcohol misuse at the individual-level differs by religious context. Individual-level data on alcohol misuse, social embeddedness, and oil spill impacts will be derived from the 2016 Survey of Trauma, Resilience, and Opportunity among Neighborhoods in the Gulf (STRONG). County/parish-level demographic information will be drawn from the 2012-2016 5-year American Community Survey (ACS) estimates, and county/parish-level religious adherence data will come from the 2010 Religious Congregations and Membership Study (RCMS). Results will speak to the relevance of religious context, social embeddedness, and the intersections thereof, to alcohol misuse in a disaster-prone region of the country.

Perceptions of Sea-Level Rise, Well-Being, and Community in Cambodian and Laotian Americans Living in the Gulf Coast Region of the United States

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We researched psychological sense of community, well-being, and perceptions of sea level rise to identify gaps in understanding spiritual displacement and environmental justice within Cambodian & Laotian communities in the US Gulf of Mexico. Data were collected in Alabama, Mississippi, Florida, and Louisiana (N=454). Using a multiple regression model, the independent variables predicted 58% of the variance in the dependent variable of well-being. The belief in sea level rise was not a significant contributor to the model. The model summary indicates that the overall model is significant, R^2= .58, R^2_{adj} = .58, F (4,373) = 130.06, p < .001. However, only 3 of the 4 variables, sense of community β = .54, t (373) = 21.348, p <.001, age β = -.074, t (373) = -2.346, p = .019 and number of children in the household β = .86, t (373) = 2.101, p = .036 significantly contributed to the model. There is a negative relationship between age and well-being; the older a person, the lower their well-being score. Belief in sea level rise was not a significant predictor of the model β =.437, t (373) = -0.460, p = .646. We also compared belief in sea level rise with the type of occupation using chi-square analyses, which yielded significant results. Those who work in marine-related occupations were less likely to indicate belief of sea-level rise. Although that seems surprising, the finding is similar to past research that suggests a vested interest in protecting seafood industry interests from marine protection legislation. Implications include incorporating beliefs about land, natural resources, and other measures when establishing community interventions for coastal communities. The relationship between sea-level rise and occupation supports mutually reinforcing systems of vulnerability. Long-term marine degradation will become more detrimental to the entire region. Policies should focus on providing a sense of meeting short-term needs of communities and long-term environmental protection.

Building Bridges to Better Understand Fishing Communities

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The Mississippi Coalition for Vietnamese-American Fisher Folks & Families (MSCVAFF) & The University of Southern Mississippi-Gulf Coast Research Laboratory (GCRL) are collaborating on *Building Bridges to Fishing Communities*, a capacity-building project supported by the National Academy of Sciences. Fisher folks and research scientists are conducting research on the health of oyster reefs in the Mississippi Sound, which has declined after the Deepwater Horizon/BP oil spill and freshwater inflow from the Bonnet Carre Spillway opening. The goal of the project is to foster a cross-sector relationship and cultivate trust between fishing and research communities, and cultivate greater engagement of fishers to share their Traditional Ecological Knowledge (TEK). The cooperative research includes quarterly sampling of oyster reefs located in the Western Mississippi Sound, with basic water quality measurements, processing activities in the citizen science lab at the USM-Marine Education Center, followed by laboratory analysis of oysters, sediment, and oyster shells for polyaromatic hydrocarbons (PAHs). Quarterly trainings are conducted with both classroom and on-the-water trainings. Additionally, trained fishers collect relevant, monthly water quality data during routine fishing trips. Further, social science research is assessing relationship-building among fisher folks and researchers. Preliminary statistics will describe fisher folks' priorities and interests. This project is unique in establishing a multi-sector partnership that addresses a longstanding community need to evaluate the health of oyster reefs, a natural resource deemed vitally important to the sustainability of fishing communities, their livelihoods, and cultural heritage.

Resilience in Louisiana: A Longitudinal Study of Recovery from the Deepwater Horizon Spill

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In the past 40 years, the United States has experienced more frequent and more severe natural disasters. The cost of these disasters has continued to increase as the density in urban areas surges, infrastructure continues to age, and over-development continues. Louisiana is one of many states that has experienced an increasing number of natural and technological disasters affecting an increasing number of vulnerable communities.

As a part of understanding the impacts of disasters, children are among the most important indicators of a community's recovery. To better recognize the dynamics of resilience and recovery, a three-wave longitudinal study is being conducted by the National Center for Disaster Preparedness at Columbia University together with Louisiana State University. The study is looking at the long-term recovery of children affected by the Deepwater Horizon oil spill and the resulting economic and social impacts of the spill. A random sample of respondents in areas highly-impacted by the Deepwater Horizon Oil Spill have participated in this study, with household interviews conducted in 2014 (n=655), 2016 (n=484), followed by a phase taking place in 2018. The survey includes questions about spill exposure, child behavior and health, social cohesion, compensation, self-perceived recovery, socioeconomic status, and other demographics.

To better understand the impact of increasing frequency and intensity of disasters, this presentation will use analyses of data from the first two waves of this study to help improve understanding of the relationship between exposure to a disaster, the perceived health effects, and what characteristics predict resilience. A series of analyses using socioeconomic factors, social cohesion, exposure to the oil

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spill, economic effects of disasters, access to health services, and compensation will provide insight on resilience factors and what policies should be in place to allow for a better recovery after future disasters.

Complex Coordination of Disaster Management: Potential Uses of GIS Analysis of EMS and Community Centers in Bayou La Batre, AL

S. M. Wraight*, R. Hanks, S. Lio, H. Min, B. Moss
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Disaster management requires the complex coordination between resources, equipment, skills and human resources from a variety of agencies and organizations (Thomas *et al* 2007). Emergency management have increasingly been using geographic information systems (GIS) as a crucial tool for risk assessment and hazard mapping as well as the locations of officially-designated evacuation centers and emergency services. We will be using GIS to map out the Cambodian and Laotian communities in relations to both the EMS services as well to the cultural assets that they actually use in response to natural disasters. Thus, the GIS analysis will provide the better understanding of EMS availability and proximity to the Cambodian and Laotian communities, cultural centers such as temples, in a graphical way. The GIS map presents 1) the locations of EMS centers and community centers such as temples and a church, and its distances, 2) the EMS size and available resources of EMS centers (with a separate table for this as a list), and 3) past supporting experience to Cambodian and/or Laotian communities. The GIS analysis and the results from the social network analysis will offer useful implications on the development of a more culturally-responsive disaster management and recovery structure.

Getting to the Table: Preliminary Results of Individual Interviews with EMS Managers in Bayou La Batre, AL

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This study presents the preliminary results of individual interviews with EMS managers. We conducted phone and email interviews with EMS managers from June 2018 to December 2018. Phone interviews lasted about an hour and email interviews were short screening surveys for the phone interview. Although the results are preliminary because we are still transcribing the interviews, we would like to share the some of the major findings from the interviews and obtain valuable comments from the audience for the further step of the analysis. The main results are 1) the basic characteristics of the managers, e.g., the average years of work experience, the years of providing service to this area, 2) their experience working with a Cambodian and Laotian population and the reasons of services, including time (year), 3) the service and resource they have provided, 4) the major obstacles to providing service, including communication (language barrier), and 5) the way of emergency alert (radio, TV, phone, etc.). Finally, we would explain how we would develop a table-top exercise, for more effective culturally-responsive disaster preparedness with emergency managers and community leaders from Cambodian and Laotian population and the resolution of the major barriers identified from the interviews.

*Student Presenter

Creating and Curating Effective Social Media Content to Build Community Resilience During Each Phase of the Disaster Cycle

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LSUHSC, New Orleans, LA

Beginning in 2015, Researchers and Faculty at the Louisiana State University Health Sciences Center Department of Psychiatry (LSUHSC-NO) began a Facebook based Social Media campaign to increase the reach of behavioral health information relating to each phase of the disaster cycle. Being part of the Gulf Coast translates to a vulnerability of multiple disasters including the Deepwater Horizon Oil Spill and multiple natural disasters. With more than 2 billion users active on Facebook in 2018, it is logical to utilize social media platforms as a means to distribute behavioral health and other information relevant to the life cycle of disasters. Through CYPRESS (Community Psychiatry Resilience, Education, and Social Strengths) LSUHSC-NO has been able to supplement our in-person community outreach, reach a wider audience with relevant preparedness and recovery information, invite professionals to pertinent trainings, and has overall shaped the way we develop and disseminate information.

Over the past three years, we have been able to examine trend data related to what type of content has the highest reach and engagement, what types of media (video, graphic images, and text) attract the most users, and other factors that contribute to successful utilization of social media. With CYPRESS LSUHSC-NO has curated over 900 posts, averaging 26 per month. Curated content from other sources averaged 81 reach and 7 engagement compared to 400 reach and 50 engagement for original content. Posts created by LSHHSC-NO consistently performed better than shared curated content, and allows more individualized, region specific knowledge to be transmitted.

By sharing lessons learned and examining these findings in more detail we believe we can help other community organizations and other institutions, working to build resilience in communities impacted by natural and technological disasters, build successful social media content and reach their target audience.

Measuring Disaster Preparedness at Different Social and Spatial Scales on the Mississippi Gulf Coast

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University of Southern Mississippi, Hattiesburg, MS

Disaster preparedness is a complex phenomenon related to numerous factors that operate at multiple social and spatial scales. This study examines disaster preparedness using variables measured at micro (individual), meso (family and friend networks), and macro (community) scales of analysis. It draws from a survey conducted in 2017 by an interdisciplinary research team from the University of Southern Mississippi. The team developed and administered the survey instrument to a spatially stratified, random sample of Mississippi households (N = 328) located south of Interstate 10 along the coast of the Gulf of Mexico. The survey included a number of published instruments, notably the Communities Advancing Resilience Toolkit (CART), as well a series of questions devised by the team to measure sociodemographic characteristics, social capital, risk perception, and disaster preparedness. Multivariate regression analysis identified the role of different key variables in defining preparedness at micro, meso, and macro scales. The results of this study provide insight into how to identify target populations and how to predict disaster preparedness in communities at risk from tropical cyclones, oil

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spills, and other coastal hazards. These results build upon previous findings of the team that highlight the intricate connections linking perception, experience, preparedness, and resilience among residents of the Mississippi Gulf Coast.

Engaging Communities through Regional Surge Consortiums to Reduce Risk and Enhance Resiliency

M. Hopkins, J. Lopez
Lake Pontchartrain Basin Foundation, New Orleans, LA

Vulnerabilities to natural hazards like storm surge in southeast Louisiana are due to a combination of factors that have both natural and anthropogenic origins. In Louisiana, the land loss crisis and intricate flood protection system creates a condition whereby the effects of natural events can be exacerbated by the very system that seeks to protect the region. Interconnected and overlapping state, local and federal entities also create challenges to disaster mitigation and resiliency, which stems from confusing or circuitous policies and management. Community engagement is an essential component to reduce risk and enhance resiliency to storm surge from tropical cyclones. This is accomplished by creating a platform for interconnected entities to see and hear what others are doing and to engage with community leaders and technical experts. For the past several years, the Lake Pontchartrain Basin Foundation has spearheaded a cooperative endeavor to leverage local expertise and additional technical resources into a regional collaboration. Rather than focus on specific locations, this 'consortium' focuses on regions with shared risks and interests, and works to the betterment of the group as a whole. The first consortium focused on the region near New Orleans and the communities surrounding Lakes Pontchartrain and Maurepas. The workshop series, the Pontchartrain-Maurepas Surge Consortium, concluded in 2017, but a new series is focused on the Lake Borgne-Breton Sound region. A region by region framework enables us to tailor risk reduction strategies and community resilience based on the needs and wants of the involved communities' direct feedback. Simply, the goals of this consortium strategy are to 1) gain a broader understanding of surge dynamics in the relevant basin(s), 2) create informed risk reduction strategies for all communities, and 3) create a sustainable environment, resilient community and safe residents through enhanced storm surge risk management.

015: Modeling for Synthesis - Progress in Linking the Natural Sciences and Connecting to Politics, Economics, Health, Psychology and Further

Introductory Remarks

C. Mauritzen[1], K. Wowk[2]
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*Student Presenter

Earth System Prediction: A Regional Example for the Gulf of Mexico

A. J. Busalacchi (Invited)
UCAR, Boulder, CO

The Gulf of Mexico is an example of a region under the influence of multiple stressors across the physical, natural, and human coupled systems. The region is subject to the effects of the Loop Current in the Gulf, eddy dynamics, severe storms, oil spills, harmful algal blooms, coastal wetland loss, nutrient loading from the Mississippi, hypoxic dead zones, and the boom and bust cycles of heavy industry, to name a few. The role of coastal habitats in protecting people, their properties, and the built infrastructure can hardly be overemphasized. Yet, strategies for reducing human impacts on the water quality and habitats suffer from a lack of comprehensive and skillful predictive tools that can generate usable and useful information, and what-if scenarios for management and policy decisions. The Gulf of Mexico will experience increasing climate and environmental change over the next 50 years, exceeding the scope of natural variability. A paramount question facing decision makers in the region is how to prepare and adapt to this certainty of change in the next half century. A regional Earth System Prediction approach has the potential to provide integrated Earth System analyses and prediction capabilities for the Gulf of Mexico basin with products designed to address user needs at time scales from days to decades.

Advance understanding of the Gulf of Mexico region as a dynamic system with complex, interconnecting human and environmental systems, functions, and processes to inform the protection and restoration of ecosystem services is a strategic goal of the Gulf Research Program (GRP) of the National Academies of Sciences, Engineering, and Medicine. The GRP plans to develop and invest in a Gulf Region Co-operative (Gulf Co-op) - a research and decision-making cooperative. The envisioned new data streams provided through the GRP Gulf Co-op, along with their integration with other related external data, will enable the creation of a new caliber of regional modeling tools for the Gulf region that are able to assist decision-making in this uniquely complex and multi-stressed environment. This presentation will address the challenges and opportunities of developing a regional Earth System Prediction capability over the 30-year lifetime of the Gulf Research Program.

Development of Earth System Model Components to Quantify the Connectivity of Remote Ecosystems in the Gulf of Mexico

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The health and sustainability of coastal ecosystems largely depends on remote influences, especially in marginal seas as the Gulf of Mexico. The marine ecosystem conditions are a strong component of sustainable management, while they have socioeconomic implications and linkages to human health. Earth System Modeling provides a holistic approach that can accommodate the appropriate components to accurately quantify the related pathways under variable forcing mechanisms and to help management planning by providing predictive capabilities and scenario-based simulations. Specific components of such a system will be described for the Gulf of Mexico, focusing on two examples of remote interactions. The first example involves the accurate modeling of the evolution of low-salinity, high in chlorophyll content waters of Mississippi origin. Two major pathways were studied

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in 2015 by combining biophysical modeling with remote sensing and *in-situ* data from GoMRI and NOAA cruises. For the first time, the three-dimensional structure of such branches was revealed from observations, while the model simulations confirmed data findings and provided additional information on the connectivity of northern (Mississippi Delta) and southern (Florida coral reefs) coastal ecosystems. The second example involves the extreme 2016 coral die-off in the Flower Gardens Bank National Marine Sanctuary (offshore, deep reefs), which was found to be highly related to low dissolved oxygen conditions that were connected to cross-shelf transport of coastal waters. Unusually high local precipitation had created the accumulation of turbid waters in an area of normally low river run-off. The modeling system, in tandem with satellite and *in-situ* observations, reveals the synergy of a number of physical and biogeochemical conditions that were found important to explain this extreme event and provide recommendations for future management strategies.

Predicting the Impacts of Oil-Spill Related Fishery Closures on Fishery Revenues - A Spatially Explicit Approach

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Major oil spills are catastrophic events that immensely impact environment and society. Coastal fishery-dependent communities are especially at risk as their fishing grounds are susceptible for closure due to the seafood contamination risk. During the Deepwater Horizon (DWH), ~4.9 million barrels of oil were discharged into the Gulf of Mexico (GoM), resulting in fisheries closures covering approximately a third of the U.S exclusive economic zone in the GoM. As a result, fishery revenues decreased with coastal states losing up to a half of their yearly fishery revenues. An important component in the interaction between science and management is the capacity to harness scientific knowledge to improve management. In the current study we focus on the potential impacts of oil spill on fishery-dependent communities at the county and state levels. We make use of a 3-D oil-transport model, along with "longline" and "bandit-reel" Vessel Monitoring System (VMS) data to predict the effects of oil spills on fisheries revenues, simulating two spills in the western and eastern areas of the GoM. Finally, we map the lost revenue back to the county level assuming a “maximum loss” scenario to estimate an upper bound of the economic impact. We find that the simulated oil spills at our two locations would have markedly different county-level impacts, depending on which fleet is analyzed. The impacts of the eastern spill are strongest in the Florida panhandle for the bandit reel fishery, whereas the bottom longline fleet is most impacted in mid-Florida. Outside Florida, the impacts are negligible. Similarly, the impacts of the western spill are evident mostly in southern Texas for the bandit reel fleet and in eastern Texas for the longline fleet, with minimal impacts in other locations. We conclude that this multi-modal spatially explicit quantitative framework can be used as a management tool for predicting the consequences of oil spills at locations throughout the Gulf, adding an important dimension to the assessment of oil-spill associated risks at various management levels.

Development of a Coupled Modeling System for Simulating Oil-Microbial-Sediment Interactions in the Ocean

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*Student Presenter

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Since the Deepwater Horizon oil spill, there have been considerable resources spent on developing modeling tools, collecting and analyzing measurements, and performing scientific studies to understand different aspects governing the eventual fate of the oil. Armed with these tools and understanding, the Consortium for Simulation of Oil-Microbial Interactions in the Ocean (CSOMIO) is synthesizing these capabilities and knowledge into a coupled modeling system to perform simulations to advance understanding of the linkages between physical transport, microbial biodegradation, weathering and sedimentation processes on determining the fate of oil released in the ocean. The CSOMIO Coupled Model is an adaptation and extension of the Coupled Ocean-Atmosphere-Wave-Sediment Transport modeling system. A biogeochemical modeling component incorporating the GENOME microbial model is implemented in the system and adapted for the presence of hydrocarbons. The sediment transport component (Community Sediment Transport Modeling System, CSTMS) is modified to include computationally efficient flocculation parameterizations developed from laboratory experiments. The ocean modeling component (Regional Ocean Modeling System, ROMS) is modified to simulate three-dimensional oil transport and compositional changes (weathering). These modeling components are linked together allowing for tracking of hydrocarbons from a source blowout to deposition in sediment, microbial degradation, and evaporation while being transported through the ocean.

Gulf of Mexico Modeling Community of Practice: Connecting Modeling Capacities to Restoration & Management Needs

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A Gulf of Mexico Modeling Community of Practice (ModCOP) is self-organizing to provide a forum for communicating key modeling activities and sharing modeling knowledge with the Gulf restoration, management and scientific community. Models are integral to effective decision making under adaptive management. Community awareness of existing modeling applications is essential to advancing the state of knowledge and to well-informed decision making. The ModCOP is developing a platform to share modeling capacities, expertise, lessons learned, data and delivery systems to enhance the availability, use and collaboration by partners. It will also provide opportunities for leveraging resources and advancing the state of knowledge of numerical modeling development and applications in the Gulf Region. This presentation will provide an overview of the Gulf of Mexico Modeling Community of Practice, describing purpose, need, structure and function, and will illustrate a draft template for inventorying existing modeling efforts and discuss potential platforms for communicating modeling efforts and/or outcomes. Additionally, we will highlight successful partnerships between model developers and model end-users to develop integrated modeling applications that informed management decision-making.

*Student Presenter

Progress Towards an Agent-Based Model that Explores the Effects of the Deepwater Horizon Oil Spill on Fish and Fishers in the Gulf of Mexico

S. Saul
Arizona State University, Mesa, AZ

The Deepwater Horizon oil spill disrupted the livelihoods of many in the fishing industry who had to modify their operations (i.e. alter their fishing locations, target species, gear used, or trip duration) in the months after the spill due to spatial closures restricting access to potentially polluted waters. This re-tasking had a direct effect on fishing catch and effort in 2010, and perhaps beyond, as well as the resilience of fishing communities. Fisher decision making can influence the effectiveness of management measures and determines the spatial and temporal locations of fishery-dependent observations. In many stock assessments observations from fishers are used to infer the abundance of fish populations. To improve our understanding of how fisher and ecosystem dynamics interacted during this time, we are developing a spatially explicit, agent-based bioeconomic model, which represents some the most important commercial fishery species and the fleets that harvest them on the West Florida Shelf in the Gulf of Mexico. The model evaluates the direct effects of oil pollution on the survival of adult fish, recruitment, and fishing behavior, and examines the feedbacks between them and how these feedbacks were affected by the spill. Alternative fisheries related responses to the spill will also be considered to test their performance, and how they could affect fisher livelihoods, and resource assessment. The presentation will provide an update on project progress and present preliminary results.

Integrating Oil Spill Trajectory Simulations to Guide Estimates of Human Exposure

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Current approaches for assessing risk from oil spill chemicals (OSCs) are traditionally based upon measurements of contaminants in nearshore environments and comparisons to threshold values, after the oil spill has impacted the shoreline. Models are needed that combine oceanographic information proactively with knowledge about human activities to estimate risks a-priori. Such a model will require the: 1) realistic statistical distributions of concentration of OSCs in nearshore environments from readily available oil spill trajectory models, and 2) Quantification of human activities for scenarios relevant to nearshore environments (e.g., first-responders, recreational beach users, and shellfish consumers). In order to convert OSC concentrations to exposure for these scenarios estimates will be needed for ingestion rates, inhalation rates, and dermal contact. Monte Carlo techniques can then be used to sample the statistical distributions for OSC concentrations and the parameters needed to estimate ingestion, inhalation and dermal exposures. The result is a range in probabilities of disease associated with oil spills. Examples will be provided in terms of how oceanographic models can be potentially combined with risk assessment approaches to assess health risks to children during beach play activities at oil impacted beaches.

*Student Presenter

The Holistic Individual Preparedness Model (HIPM): Accounting for Social, Health, and Technological Capacities across Disaster Response and Recovery

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Disaster preparedness programs, investments, and research have focused on planning and information. The underlying assumption is if people are knowledgeable and have sufficient resources, they will be ready for disasters. The intent is good, but it does not recognize the mounting evidence that social, health, and technological factors are associated with response and recovery experiences in addition to subsistence, knowledge, and loss minimization. This gives the impression that the concept of preparedness is oriented only to response, as opposed to capabilities for recovery. Further, it misses opportunities to connect social systems to ecological systems, fails to account for the effects of multiple disaster events, and neglects the inherent resilience that individuals and communities often demonstrate. To fill this gap, this study offers the Holistic Individual Preparedness Model (HIPM). The HIPM defines individual preparedness as a state of readiness for effective response and holistic recovery to hazard events determined by: 1) knowledge - understanding of hazard risk, suitable behavior in response, and recovery processes/resources; 2) subsistence - resources to survive autonomously or with little support in response and recovery from a hazard event; 3) loss minimization - reduction of loss relative to the primary risks faced; 4) social integration - number, types, closeness, and geographical distribution of social networks that support response and recovery; 5) technological integration - connectedness to technologies that communicate risk and response/recovery resources; and 6) mental and physical adaptive capacity - ability to move away from danger and absence of pre-existing mental/health conditions that impede recovery. A quota-based survey of 1,000 residents in the 41 Texas counties affected by Hurricane Harvey in 2017 is used to measure the HIPM and test its utility as a model of disaster preparedness. Statistical analyses explore the associations between HIPM components and recovery outcomes in terms of property/environmental damages as well as public health. While the study is focused on a natural disaster, the model may be applied to technological and environmental hazards; further, it may be integrated with other models to more fully understand how to better prepare for disasters.

016: Bridging Recent Advances in Marsh Ecology with the Future of Gulf of Mexico Ecosystems

Testing the Effectiveness of Large-Scale Living Shoreline Projects at Restoring Fringing Marshes

E. Sparks (Invited)
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In the wake of the Deepwater Horizon oil spill, large-scale breakwater projects have been constructed to restore and conserve marshes across the northern Gulf of Mexico. These breakwater projects are often termed living shorelines, due to the perceived increase in secondary productivity around the breakwaters and within the fringing marsh shoreward of these structures. However, evaluations of the

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effectiveness of breakwaters at preserving natural shorelines are limited. To evaluate the effectiveness of large-scale breakwaters at protecting or restoring marshes in high wave energy environments, we conducted experimental plantings and a shoreline monitoring program landward of six-year-old breakwaters (OBW), recently constructed breakwaters (RBW), and reference no breakwater sites (NBW) along Bon Secour Bay, AL. The OBW, RBW, and NBW complexes cover 0.6km, 3km, and 1.2km of consecutive shoreline, respectively. Within the OBW and NBW sites, eight replicates of planted (4m2 of nursery grown *S. alterniflora* sods planted in checkerboard pattern), natural stand, and no vegetation treatments were randomly distributed throughout each site. Within the RBW sites, an additional planted design was also established (clumped plantings), yielding four shoreline vegetation treatments. Each plot was visited quarterly with a suite of vegetative measurements taken, including: percent coverage, species diversity, biomass, porewater DIN, and soil organic matter. Additionally, the perimeter of all of the natural *S. alterniflora* patches within each site was field mapped using an RTK GPS to compare *S. alterniflora* area across breakwater treatments. Preliminary results indicate marginal or no effect of breakwaters for any of the measured metrics. If these resulting trends continue throughout the duration of the monitoring, they will show that large-scale breakwaters could have a small impact on preserving and enhancing fringing marsh vegetation in high wave energy environments.

Spatial Patterns of Long-Term Marsh Edge Loss in Barataria Bay

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Marshes are retreating rapidly in coastal Louisiana, largely driven by wind waves. The amount of wave power hitting the marsh is the dominant predictor for marsh retreat rates; however, marsh erodibility (erosion rate per unit of wave power) has a large spatial variability. Identifying the causes of this variability is essential to obtain more reliable predictions and to optimize marsh protection strategies. Here we investigate marsh edge erosion in Barataria Bay, LA. Long-term (140 yr) erosion data and short term (2 yr) field measurements show that, for the same wave power, north-facing marsh edges erode twice as fast as south-facing marsh edges. A possible explanation might reside in the peculiar hydrodynamics of coastal Louisiana, where northerly winds are associated with low water levels and southerly winds are associated with high water levels. This causes south-facing shores to experience high water levels when being impacted by waves and north-facing shore to experience low water levels when being impacted by waves, which affects marsh edge erosion in three different ways: (1) south-facing shores experience a higher frequency of wave overshooting, limiting the ability of waves to cause erosion, (2) north-facing shores experience a higher frequency of waves impacting the highly erodible soil below the root mat, undercutting the marsh, and (3) south-facing marsh edges have a higher elevation and soil shear strength in the root layer, which is likely linked to the fact that these shores receive more sediment during wave events. These processes were combined into a single empirical correction to represent effective erodibility and was used in a 2D model of marsh edge retreat. The model accurately predicts marsh edge erosion and can be used to identify the amount of land loss prevented from specific restoration projects. Our results show that, while marsh oiling accelerates erosion on a short time scale, the effect is not significant on a centennial time scale.

*Student Presenter

Distribution and Recovery Trajectory of Macondo (Mississippi Canyon 252) Oil in Louisiana Coastal Wetlands

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We measured the concentration of total alkanes and aromatic hydrocarbons in 700+ wetland sediment samples taken from 3 estuaries immediately before the April 2010 Deepwater Horizon disaster led to their broad-scale oiling, and returned to them to sample 4 more times over 8 years. We also sampled seven times at 30 different sites in Bay Batiste, and for 16 trips to 13 other marshes located in western and eastern Barataria Bay, and in Terrebonne Bay. The average concentrations of alkanes and PAHs peaked at three times the pre-spill baseline values. The concentrations of targ*et al*kanes and PAHs has since fallen, but remains 5-10 times higher than in May 2010. There was a significant decline in 22 of the 28 alkane analytes (0.42% day^{-1}), no change in 6, over the first few years, whereas the concentration of five aromatic petroleum hydrocarbons (PAH) increased (range 0.25 to 0.70% day^{-1}), and the total PAH pool did not change much. The PAH concentration profile went from predominately petrogenic through 2014, and was predominately pyrogenic from 2015 through 2017, being dominated by fluoranthrene and pyrene and their C1 alkyl homologs. However, these sediments also contained low levels of the petrogenic 2 to 3 ringed PAHs and their alkyl homologs. Of these, naphthalene and C-1 to C4 alkyl naphthalenes are of higher toxicity than the other three because of their relatively higher volatility or solubility. The relative proportions of alkane analytes transitioned in 2014 to those alkanes with odd carbon number preference, indicating biogenic sources, but levels were elevated above pre-spill levels. The trajectories of nine indicators for degradation/weathering were either inconclusive or misleading (alkanes).

Seasonal and Annual Variation in Allometry and Primary Production in *Spartina alterniflora*

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Salt marsh primary production and carbon storage vary along environmental gradients. Much of our knowledge of environmental drivers is derived from short-term manipulative experiments or observational sampling along spatial gradients. We examined the role of natural temporal variation in environmental drivers by monitoring *Spartina alterniflora* stem allometry and production at three brackish Louisiana marshes, sampled monthly over six years. We examined natural variations in nutrient availability, sea level, and climate variables to infer their relative importance as drivers of variation in stem allometry and production. Using minimally destructive sampling methods, monthly standing crop was estimated and above and belowground production were calculated using the Smalley (aboveground) and max-min (belowground) methods both of which have been shown to be good approaches at these sites. Additionally, vegetation reflectance indices were calculated at all sites beginning in 2017. Simultaneous measurements of local water quality (nutrients and salinity), hydroperiod, and climate variables were used as predictors of mass-height allometry and primary production. Stem allometry varied seasonally at all sites with shorter stems weighing more in the summer and fall. Aboveground peak biomass ranged from July to October and productivity was approximately 2,122 g m^{-2} $year^{-1}$. Belowground productivity was approximately 3,370 g $m^{-2}year^{-1}$ and live belowground biomass was consistent with no seasonal or annual pattern. Above and belowground

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production were positively correlated with dissolved nutrients and negatively correlated with salinity. Our study demonstrates the strong influence of water quality on seasonal and annual productivity in Louisiana salt marshes.

Does Stranded Oil Slow the Recovery of Saltmarsh Macroinfauna?

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Weathered oil stranded in salt marshes may persist for long periods of time even in surface sediments. The long-term impact of such oil on marsh recovery is rarely studied, but has been shown to affect marsh vegetation and some benthic invertebrates for decades. Here, we examine the long-term recovery of macroinfauna - benthic invertebrates large enough to be retained on a 0.5 mm sieve - from the Deepwater Horizon oil spill. We quantified the densities of macroinfauna at replicate oiled sites in northern Barataria Bay Louisiana from 18 mo to 8 y after the spill along with total petroleum hydrocarbon concentrations. Effects ratios were used to compare faunal responses in heavily and moderately oiled sites to those at reference sites. Although densities of annelids, amphipods and tanaids were uniformly lower at oiled compared to reference sites for about 2 years after the spill, variability was high from about 2-4 years after the spill; densities were highest at oiled sites where chlorophyll a biomass was also high. However, from 4-8 years post spill, amphipods were consistently highest in density at heavily oiled sites while tanaids remained consistently highest in density at reference sites. Given that total petroleum hydrocarbons remained high in surface sediments over time (~100 mg/g marsh soil after 6 years) and that macroinfauna are in close contact with oiled sediments, a comparison with the recovery trajectory of macroinfauna from restored marshes (in which *Spartina alterniflora* was planted but not oiled) should prove useful to address the question, 'Does the legacy of stranded oil slow recovery?' Results of a meta-analysis indicate that the presence of oil does not slow recovery of marsh macroinfauna compared to restored marshes, suggesting that factors other than stranded oil are important to marsh resiliency.

Soil Microbial Community in Barataria Bay Salt Marshes, Louisiana Eight Years after the Deepwater Horizon Oil Spill

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The soil microbial community is an important component of wetland ecosystems, responsible for breaking down organic matter and cycling nutrients. In order to determine the effects of oiling on the indigenous salt marsh soil microbial community following the Deepwater Horizon oil spill, we collected surface samples from reference, moderately oiled, and heavily oiled sites in Barataria Bay, Louisiana for eight years following the spill concurrently with vegetation, meiofauna, and soil characteristics data. We utilized 16s DNA sequencing and cultivation-based analysis to determine possible direct and indirect impacts of the oil spill on soil microbial communities. In this talk, we will examine the microbial

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community across reference, moderately oiled, and heavily oiled sediments in Barataria Bay salt marsh eight years after the spill. We will compare this long-term impact and recovery to the short-term impacts of the oil spill. Relationships between the microbial community and environmental data collected concurrently with microbial samples from the sites will be described. Our results show that although oil degrading taxa responded quickly to the spill and microbial diversity recovered from the initial oiling, the long-term reduction in vegetation at heavily oiled sites may have resulted in changes to the soil microbial community after eight years. Our study is unique in showing the possible effects of long-term vegetation loss due to oiling on the soil microbial community.

Teasing Apart the Influences of Plant Type, Soil Properties, Inundation History, and Weathered Oil on Marsh Microbial Communities through Time

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Salt marsh ecosystems are economically and societally valuable, largely due to the ecosystem services they provide for fisheries and as storm surge buffers. Indicators of marsh health and stress response, such as to the 2010 Deepwater Horizon oil spill, can be tracked from microbial community compositions and functional diversity. We biannually sampled 13 marshes in three regions of coastal Louisiana over the course of seven years to determine key microbial response to oiling and potential recovery in the context of plants, water and soil physicochemistry, and extrapolated rates of subsidence, inundation, and accretion history. Half of the sites were selected as “controls” because they did not receive weathered oil originally. But, after storm events redistributed weathered oil, all marshes were oiled and evidence of trace amounts of weathered oil persisted for up to five years. Marsh microbial communities exposed to large quantities of labile organic carbon (as weathered oil) were distinct from pre-spill communities and converged on a similar community structure dominated by hydrocarbon-degraders. Persistence of weathered oil in the marshes impacted standing vegetation types, soil strength, and erosion rates. As the quantity and quality of weathered oil diminished, microbial community compositions (as taxonomic representation) diverged but functional diversity decreased. Microbial community compositions continued to shift through time, despite the lessening impact of oil, due to confounding variables such as differences in regional rates of subsidence and sea-level rise, inundation history, as well as salinity of flooding waters, wave energy and remobilization of sediment, soil properties, and priming effects related to changes in organic carbon lability. Yet, with all of the changes to these and likely other undiagnosed coastal conditions through time, it is highly unlikely that these marsh microbial community compositions and their functional diversity can return to “pre-oil” conditions.

Meta-Analysis of Salt Marsh Vegetation Impacts and Recovery: Synthesis following the Deepwater Horizon Oil Spill

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In order to examine impacts of the Deepwater Horizon oil spill on important foundation species in the salt marsh ecosystem, namely salt marsh vegetation dominated by *Spartina alterniflora* (smooth cordgrass) and in some cases *Juncus roemerianus* (black needlerush), collaborative meta-analyses

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across multiple studies were conducted to examine a larger geographic span of study sites (including Louisiana, Mississippi, and Alabama), greater variability in marsh and oiling conditions across the study area, and a more complete time sequence post-spill (2010-2017), allowing for greater understanding and synthesis of impacts and recovery of the salt marsh vegetation. This work builds on our prior meta-analyses on salt marsh fiddler crabs and periwinkles. Salt marsh vegetation data from multiple Gulf of Mexico Research Initiative (GoMRI) and Natural Resource Damage Assessment (NRDA) studies, as well as several other sources, were jointly analyzed. The combined data set includes ~200 sites and 7-8 years of data post-spill. The meta-analyses approach allowed us to answer key questions that could not be addressed (or could not be addressed as thoroughly) by individual studies. Multi-year impacts were identified, although the degree, duration, and types of impacts and recovery trajectories varied by vegetation metrics examined (e.g., plant cover, stem density, height, biomass). In this talk we plan to compare and contrast findings from the meta-analyses and recent studies of salt marsh vegetation, placing our findings in ecological and applied context, including post-spill recovery and implications for other estuarine and salt marsh species and the coastal ecosystem, future spill response, and natural resource damage assessment.

Predicting Disturbance-Driven Impact on Ecosystem Services in Coastal Wetlands in the Northern Gulf of Mexico

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Natural and human-induced disturbances pose significant threats to the health and long-term productivity of Alabama coastal wetlands. As wetlands are increasingly impacted by recurrent pulse and chronic disturbances in this century, decisions on management, restoration, and remediation require actionable data if socio-economic demands are to be balanced with efforts to sustain these habitats. In 2010, the BP oil spill was a severe disturbance that threatened coastal Gulf ecosystem services. The largest marine oil spill to date served to highlight fundamental gaps in our knowledge of oil-induced disturbances and resiliency and restoration of coastal Alabama wetland functions. To address these gaps, a year-long mesocosm study was conducted to investigate oil-induced effects on (i) plant-microbial interactions, (ii) microbial and plant biodiversity, and, (iii) the contributions of microbial genetic biodiversity to ecosystems services. In this study, *Avicennia germinans* (black mangrove), a C3 plant that grows from the tropics to warm temperate latitudes, were grown with or without mono- and polyculture mixtures of *Spartina alterniflora*, a C4 plant. At an interval of 3-months, 1.9 L m-2 of Louisiana sweet crude oil was introduced as a pulse disturbance. Molecular based analyses of microbial community biodiversity, genetic diversity, and functional metabolic genes were compared to controls (i.e., No oil). To assess oil-induced effects on the nitrogen (N) cycle, measurements of denitrification and N fixation processes were conducted. Our results showed that community diversity and phylogenetic diversity significantly changed and that the oil disturbance contributed to the creation of niches for distinct microbial types. The abundance of N-fixing microbial types increased as the abundance of denitrifying microbial types decreased as a result of the oil disturbance. As denitrification is an ecosystem service that directly contributes to removing nitrate (NO_3) loading to coastal zones, impairment of this process is detrimental to the long-term health and productivity of the Gulf of Mexico. Our results are designed to investigate controlling factors and yield insights to aid decision-makers in their ongoing management efforts to restore wetlands along the Alabama coast and related habitats.

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Metabarcoding of Seaside Sparrow (*Ammospiza maritima*) Diet: Deepwater Horizon Oil Spill and Hurricane Isaac Altered Food Webs and Bird Resource Use

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Seaside Sparrows (*Ammospiza maritima*) act as upper-level predators in northern Gulf of Mexico saltmarshes; as such, their diet is a unique indicator of how the terrestrial food web responds to large-scale disturbances. By studying the species of prey consumed over a 7-year period, we can identify plasticity in sparrow feeding ecology and infer potential food web disturbances after both the Deepwater Horizon (DWH) oil spill (2010) and Hurricane Isaac (2012). We used DNA barcoding and metabarcoding techniques to determine the species of prey consumed by Seaside Sparrows from over 280 diet samples taken from oiled, unoiled, and control sites. Diet was variable among individuals, but the majority of prey DNA sequences belonged to crabs, spiders, moths, and true bugs, suggesting these are the dominant prey taxa. Despite documented changes to invertebrate communities following the DWH spill, preliminary analyses suggest diet composition remained largely unaffected by oiling—corroborating findings from previous stable isotope and fatty acid analyses. While oiling alone does not appear to be a significant predictor of diet, taxonomic composition varied among years, with 2011, 2012, and 2013 each different from all other years. Diet composition appeared to stabilize in 2014, with no significant differences among 2014-2017, suggesting resources stabilized approximately two years after Hurricane Isaac. In addition to documenting these differences, our findings also identified unexpected prey items in the diet, such as blue crab.

Why Were Saltmarsh Fish and Invertebrates So Resilient to the Deepwater Horizon Oil Spill?

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There has been a disconnect in the documented impacts of the Deepwater Horizon oil spill in estuarine environments between individuals and populations. The spill left a clear signal of oil exposure in individuals across taxa; experiments have shown oil to be a stressor that leads to lethal and sublethal impacts; and there were changes observed in lower trophic level communities. Combined, this indicates a strong potential for population declines of commercially and recreationally valuable fishes and aquatic invertebrates. However, there has been little evidence of such declines, and in some cases, brief increases were observed. Two hypotheses to explain this apparent paradox include a fishing moratorium following the spill and changes in predation pressure following high predator mortality events. Using food web models, we quantified both the direct (predator and fishing mortality) and indirect impacts (impacts that are propagated through multiple food web interactions) of changing fishing intensity and predator mortality. We found the direct impacts of the fishery closure are likely the most significant factor we tested to explain population resilience. Our ability to account for

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uncertainty in functional responses indicated that different predator responses to changing prey abundance can lead to either slightly negative or slightly positive responses for certain species. We emphasize that oil spills are one influence within a large social-ecological system, and understanding oil spill impacts requires consideration of the impact of the oil spill on all aspects of this system, as well as accounting for the myriad other stressors acting simultaneously.

Effects of Oil on Marsh Ecosystems: An Evaluation of Approaches and Future Recommendations

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GoMRI aimed to determine the effects of the Deepwater Horizon (DWH) oil spill on ecosystems in the Gulf of Mexico (GoM). Such efforts are constrained by the availability of baseline data from which to quantify effects and distinguish them from other drivers of temporal and spatial variation. Here, I evaluate the approaches used by GoMRI projects to document impacts on marsh ecosystems. I reviewed all 93 publications archived at GoMRI website that were returned using the keywords "marsh," "shoreline," "*Spartina,*" "*Littoraria,*" "sparrow," or "ants." Papers that focused on effects of oil were inspected further to assess the approach taken (e.g., time series/intervention analysis, space-for-time substitution, descriptive without regard to formal inferential methods). Most studies inferred effects of oil without being able to differentiate effects from other sources of spatio-temporal variation - they lacked suitable baseline data. Such limitations are common in assessments of environmental disasters. While GoMRI has increased our understanding of the GoM ecosystem and the DHW oil spill, anticipating future environmental impacts requires proactive, not reactive, approaches. Successful efforts undertaken in other contexts provide useful models for the future. For example, the Multi-Agency Rocky Intertidal Network (MARINe), funded by multiple groups (including BOEM) over several decades, characterizes rocky intertidal communities along the west coast of North America (from Alaska to Baja). The intent of the program was, in part, to ensure baselines from which to assess effects of environmental impacts (e.g., due to an oil spill), to assess longer-term change (e.g., due to climate shifts or invasion by exotic species), and to support other research efforts. The establishment of a coordinated research network, modelled on MARINe or the NSF LTER program, will facilitate ongoing knowledge of GoM ecosystems and their response to human activities.

017: Out of the Blue: What Have We Learned about the Pelagic Gulf of Mexico, What Remains Unknown, and How Can We Use the Information?

Faunal Composition and Spatiotemporal Dynamics of Tuna (Family: Scombridae; Tribe: Thunnini) Early Life Stages in the Oceanic Gulf of Mexico

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Fishes within the family Scombridae (tunas, mackerels and bonitos) are of high ecological and economic value, as they are heavily targeted by commercial and recreational fisheries. In coastal and

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offshore ecosystems, adults are high-level predators, while larvae and juveniles serve as prey for numerous species. Much is known about the distribution and abundance of adult tunas, but high taxonomic uncertainty and limited knowledge regarding the distributional patterns of tuna early life stages have led to an "operational taxonomic unit" gap in our understanding of tuna ecology. Scombrids were collected across the Gulf of Mexico (GoM) during seven research cruises from 2010-2011, as part of the NOAA-supported Offshore Nekton Sampling and Analysis Program, and during five research cruises from 2015-2017, as part of the GOMRI-supported DEEPEND Consortium. Species composition, distribution, and abundance of tunas collected from the surface to 1500 m depth were characterized in relation to depth, time of year, and physical oceanographic features. Evidence of sampling gear selectivity was observed, with a MOCNESS collecting larvae predominantly, and a large, high-speed rope trawl catching only larger juveniles. Species-specific environmental preferences and seasonality were the main drivers of tuna spatial distribution patterns across the epipelagic GoM. Generalized additive models and distributional plots indicated that early life stages of coastal species (e.g., *Euthynnus alletteratus*) preferred productive continental shelf and slope environments (low salinity, high chlorophyll-a concentrations, nearer to shelf break), while oceanic species (e.g., *Thunnus atlanticus*) preferred oligotrophic habitats (high salinity, low chlorophyll-*a* concentrations, further from shelf break). Integrating aspects of scombrid ecology in neritic and oceanic environments improves management and conservation efforts for this highly important taxon.

Spatial Variability in Larval Growth between Two Spawning Grounds: Calibration and Analysis

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Atlantic bluefin tuna, *Thunnus thynnus* (Linnaeus, 1758), is a migrating large predator that spawns in oligotrophic open waters with two well established spawning areas, the Gulf of Mexico and the Balearic Sea in the Mediterranean Sea. As in many other species, survival at early life stages is crucial for future recruitment success and viability of the populations, in which larval growth has a determinant role. Precise larval age estimations are required to obtain reliable growth parameters. The most reliable method to estimate larval age is the direct examination of the microstructure of otoliths by counting individual daily increments. However, ageing studies require laborious extraction and mounting process and one of the main sources of error is the differences of reading criteria among readers. An inter-calibration exercise targeting the two main spawning grounds was carried out for each population between two experienced readers to establish common reading criteria, identify and reduce source of error. Larvae were aged from the 2014 bluefin tuna spawning seasons in May in the Gulf of Mexico (n=106) for the western stock and in June in the Balearic Sea (n=103) for the eastern stock. In addition, inter-otolith differences were examined for sagittal otoliths in 32 larvae in the Gulf of Mexico and for 40 larvae from the Mediterranean. Age estimations and larval growth patterns (SL vs AGE and DW vs AGE) did not show differences between readers or between sagittal otoliths. Comparisons between populations indicated higher growth rates for larvae captured in the Gulf of Mexico in comparison to Mediterranean collections. The reading criteria along with larval growth parameters will be incorporated in concurrent genetic, environmental and trophodynamic ecosystem comparisons for Atlantic bluefin tuna.

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Why Tag a Captive Fish? Evaluating Spawning Behavior of Mahi-Mahi Using Pop-Up Satellite Archival Tags

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Mahi-mahi (*Coryphaena hippurus*, "mahi" in the following) is a highly migratory ecologically and commercially important pelagic fish species that inhabit tropical and sub-tropical waters around the world. The 2010 Deepwater Horizon blowout released around five million barrels of crude oil into the northern Gulf of Mexico (GOM) and coincided spatially and temporally with the spawning window for mahi. As a high-performance fish, the ecology of mahi is tied to their vertical dives, migrations, and spawning; all of which is poorly studied and may be affected as a result of crude oil exposure. To better understand behavior in wild mahi, we collaborated with Wildlife Computers™ to build pop-up satellite archival tags (PSATs) to measure acceleration, depth, temperature, and light levels for geo-location modeling. To model acceleration patterns around spawning we tagged wild-caught captive mahi with PSATs and observed them in a 30,000 L tank for three weeks and 24 cumulative spawning events. We followed this captive-based experiment with the deployment of 16 PSATs on wild mahi in the Florida straits (n=14) and the GOM (n=2). A boosted regression tree model was built to predict observed spawning events based on the accelerometer summary output and time of day. The model was then applied to PSAT data from wild mahi and the depths associated with the potential spawning and non-spawning events were extracted. We found a median spawning depth of 13.7 meters (11.8 m for females and 16.3 m for males; $p>0.05$) while the median depth for non-spawning periods was 1.04 meters (0.96 m for females and 1.08 m for males). These data are the first to predict spawning of a wild marine teleost from accelerometry data and a critical component of understanding the ecology of mahi under both control and oil exposure conditions. This research was made possible by a grant from The Gulf of Mexico Research Initiative. Grant No: SA-1520; Name: RECOVER.

An Innate UV-Protection System in Mahi-Mahi Embryos, Part 1: Laboratory Measurements of Embryonic Specific Gravity and Buoyancy

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The pelagic fish species, mahi-mahi (*Coryphaena hippurus*) are known to produce positively buoyant, transparent embryos which develop rapidly and hatch into floating larvae. The maintenance of buoyancy is critical to early-life staged (ELS) marine teleost survival and aids in dispersal by facilitating transport through ocean currents and positioning newly hatched larvae in the upper water columns where planktonic food is most abundant. However, stressors occurring in surface waters in the Gulf of Mexico (GoM), such as increased temperature, cardiotoxic oil slicks and ultraviolet radiation (UVR), also pose a serious threat to the fitness and survival of the vulnerable ELS of pelagic fish. Therefore, a mechanism in which embryos can alter buoyancy and thus control their vertical position in the water column may be indispensable to the sustainability of these fisheries. Specific gravity of control versus UVR exposed embryos were measured using density gradient columns and subsequently employed to estimate terminal velocity. Mahi-mahi embryos exposed to UVR throughout development exhibited loss of buoyancy at earlier time points compared to control embryos, producing distinctive vertical distributions in the natural environment. Further, once the UVR exposure was terminated, embryos displayed fast recovery of positive buoyancy indicating this response is highly dynamic and not

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pathological. Embryos exposed to UVR on both days of development displayed increased recovery potential compared to those exposed only on the first day. These results may point to a priming mechanism, producing embryos that are better equipped to alter buoyancy and thus control their position in the water column when exposed to UVR earlier in development. This research was made possible by a grant from The Gulf of Mexico Research Initiative. Grant No: SA-1520; Name: Relationship of Effects of Cardiac Outcomes in fish for Validation of Ecological Risk (RECOVER).

An Innate UV-protection System in Mahi-Mahi Embryos, Part 2: Modeling the Embryos' Vertical Distribution in the Gulf of Mexico

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Mahi-mahi (*Coryphaena hippurus*; hereafter "mahi"), is a highly migratory species distributed from subtropical regions to the warm waters of the Gulf of Mexico. Because mahi population renewal is rapid, the species is not subjected to management quotas but remains exploited for its high commercial value and for sportfishing. Very little is known, however, on the ecology of the early life stages of mahi. Following the Deepwater Horizon (DWH) oil spill, mahi was selected as a model species to study the oil impact on a fully pelagic, open sea species, which enabled crucial questions such as the vertical distribution of fish embryos to be addressed. Pelagic fish embryos are assumed to be floating at the surface where damaging UV radiation is intense; however, the impact of UV radiation on fish embryos has rarely been assessed. Here, we used a Lagrangian, individual-based biophysical model to simulate the vertical distribution of mahi embryos throughout the Gulf of Mexico. The model was parameterized based on *in-situ* tagging data on spawning behavior and laboratory experiments on embryos' terminal velocity. Virtual embryos were released throughout the year, above the thermocline (i.e. between the surface and 30 m depth), and the hourly measurements of terminal velocity were used to determine the embryos' buoyancy through time. Each virtual embryo was tracked for 48 h, the maximum time before hatching, considering the minimum surface water temperature in the Gulf of Mexico (around 20°C). The model outputs show that: (i) UV-exposed embryos sink faster and deeper than non-UV exposed embryos, (ii) vertical distribution patterns change among regions due to changes in temperature and salinity, and (iii) mahi embryos are not residing at the surface. When assessed in realistic environmental conditions, embryos face less UV and thermal stress than previously assumed. This research was made possible by the RECOVER grant from The Gulf of Mexico Research Initiative (No: SA-1520).

Food Web Dynamics and Trophic Interactions Associated with Pelagic *Sargassum* Features in the Gulf of Mexico

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In the Gulf of Mexico, two pelagic brown algae species - *Sargassum fluitans* and *S. natans* - form floating mats, lines, and dispersed congregations that provide habitat for numerous fish and invertebrate species. This study aims to characterize residency and food web dynamics of juvenile fishes common to these features through stable isotope analysis (^{13}C, ^{15}N) of fish tissues (muscle, liver, blood, plasma), invertebrates (crabs, shrimp), marine primary producers, and particulate organic matter (POM). Samples collected at *Sargassum*-associated locations during 2017 and 2018 found

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community structure varied spatially and temporally. In general, stable isotope values of some fish species cluster tightly in isotope space (Greater Amberjack, Blue Runner, Sargassumfish, Spotted Triggerfish, and Orange Triggerfish) suggesting these species have more specialized diets while other species such as the Grey Triggerfish and Tripletail exhibit a wider range of isotopic values, implying a more varied diet across multiple trophic levels. Small shrimp and crabs make up the majority of invertebrate biomass in *Sargassum* collections and have a relatively broad range of stable carbon and nitrogen isotope values suggesting they occupy a large isotope niche space. Stable isotope mixing models are being developed to better assess community structure. Compound specific stable nitrogen analysis of selected consumer muscle tissue is underway to better elucidate basal resource use in *Sargassum* food webs.

Oceanic Fishes of the Gulf of Mexico: the DEEPEND Synthesis

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As of 2009 the total number of fish species known in the Gulf of Mexico was 1541. To date, DEEPEND researchers have identified 897, of which 186 are new records for the Gulf, and 21 putatively new to science. This number is a function of: 1) intensive, multi-mode pelagic sampling, from the surface to 1500 m depth; 2) rigorous taxonomic analysis, integrating morphological and molecular taxonomy; and 3) the unique ecotonal, mesotrophic, and oxygenated nature of the deep Gulf itself. Each of these functions will be described in detail. Functionally, 4% of these fish species are primarily epipelagic, 7% mesopelagic, 44% meso/bathypelagic (spanners), 20% bathypelagic, 17% coastal juveniles, and 32% benthic/demersal juveniles. Of the latter, the species richness of larval benthic eels was exceptional, with 109 species (vs. 7 species of truly pelagic eels). These results depict the overall Gulf ichthyofauna as being highly speciose, oceanic, and vertically and horizontally connected, befitting its status as the "American Mediterranean." In an era of rapidly expanding resource extraction in the deep Gulf, there is an immediate need for informed stewardship of this exceptional ecosystem.

Diel Vertical Migration Facilitates Connectivity between Mesopelagic Prey and Epipelagic Predatory Fishes

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The interactions between vertically migrating mesopelagic fishes and epipelagic predators creates potential pathways connecting open ocean fish communities. This is particularly important in the case of ultra-deep (>1,500 m) oil spills because contamination of fauna through submerged hydrocarbon plumes may therefore not be sequestered in deep ocean biota. In this study we evaluate feeding strategies and dependence of important epipelagic predators (e.g., yellowfin tuna, swordfish, escolar, lancetfish) on both mesopelagic and epi-pelagic prey (fishes, squids and other invertebrates). During summer 2018 we undertook spatially coherent sampling of mesopelagic prey using vertically-stratified MOCNESS trawling in the northern Gulf of Mexico. We sampled their predators at the same locations in

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the upper 200 m using pelagic longline sets. We describe and quantify predator-prey interactions, stomach fullness, diel patterns of vertical fish and invertebrate migrations and vertical structure of the water column (temperature, salinity, CDOM florescence) in relation to predator density, migration and temperature/depth preferences. Recent information on the oil contaminants found in mesopelagic fishes is summarized to evaluate potential contaminant interactions between predators and prey resources in the instance of an ultra-deep oil spill.

DEEPEND: Illuminating the Deep, Dark Sea: Generation and Assessment of a DNA Barcode Library for the Deep-Pelagic Fishes of the Northern Gulf of Mexico

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One of the primary goals of a habitat assessment is to understand the faunal diversity of the ecosystem being surveyed. Species identifications and species counts are the primary means of doing so. However, in poorly-characterized environments, where sampling is difficult and expensive, obtaining robust species counts can be problematic. The deep-pelagic is a difficult environment to sample, requiring extensive ship time and specialized collection gear. The deep-pelagic waters of the Gulf of Mexico are characterized by a diverse assemblage of fish species. However, most of the species are known only from formalin-fixed samples, identified and preserved at sea. Species identity can be confused when solely relying on morphology for species diagnosis. For this reason, one of the primary goals of the DEEPEND project was to create a DNA “barcode” library for all fishes collected over the course of six cruises, spanning 2015-2017. We have collected DNA sequence data from over 2,000 individual specimens, representing 29 orders and over 300 species. Of these data, many represented novel sequences for species with no previously obtained genetic data. In addition, evidence of morphologically similar, yet genetically distinct samples indicated a substantial amount of “cryptic” species diversity. The library also revealed pervasive taxonomic confusion in certain groups, such as the anglerfishes and eels. This DNA barcode library of the fishes of the deep-pelagic ecosystem in the northern Gulf of Mexico is a legacy product of the DEEPEND grant, and serves as a foundation for biodiversity assessment, as well as biodiversity discovery.

Atlantic Bluefin Tuna (*Thunnus thynnus*) Maternal Isotopic Niche Estimated from Preflexion Larval Isotopic Signatures in the Gulf of Mexico

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The Gulf of Mexico (GOM) is the primary spawning ground for western Atlantic bluefin tuna (ABFT, *Thunnus thynnus* Linnaeus, 1758). ABFT larval studies have focused on distribution and habitat associations, trophic ecology and growing strategies in their spawning grounds contributing not only to a better understanding of their ecology but also to management decisions. The current study shows that the evolution of the stable isotope analysis (SIA) in fish early life stages can be used to infer

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isotopic information from the breeders, in addition to the standard usefulness of SIA in evaluating the diet and trophic relationships in marine ecosystems. An isotopic maternal transmission model, previously developed for ABFT, allows us to estimate maternal isotopic signatures from nitrogen and carbon isotopes values analyzed in pre-flexion larval stages. We selected preflexion larvae, 43 and 42, from eastern GOM in 2014 and 2017 respectively, two hydrologically different years. We estimated maternal isotopic trophic widths using a SIBER package (Stable isotope Bayesian ellipses in R) of SIAR (Stable Isotope Analysis in R). Results showed significant higher maternal isotopic trophic widths in 2014, with higher maternal $\delta^{15}N$ together with lower $\delta^{13}C$. Here we discuss interannual variability of the maternal isotopic signatures and niches under a comparative ecosystem approach, suggesting differences in the trophic strategies of the ABFT breeders, according to their opportunistic and generalist trophic behavior. This pioneering methodology to estimate the nutritional status of the spawners through the $\delta^{15}N$ and $\delta^{13}C$ signature of their offspring opens new research horizons to assess the maternal trophic characteristics that influence larval survival, growth and condition with a direct effect on recruitment. This study has been financed by ECOLATUN CTM2015-68473-R (MINECO/FEDER) to IEO and funded by NOAA RESTORE to NOAA-SFSC.

Constraining the Sources of Nitrogen Fueling Phytoplankton and Food Webs in the Gulf of Mexico Using Nitrogen Isotope Budgets

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The availability of nitrogen in surface waters has the capacity to limit rates of photosynthesis and affects ecosystem structure. In spite of low dissolved inorganic nitrogen concentrations in the euphotic zone, Atlantic Bluefin Tuna (ABT) spawn in oligotrophic Gulf of Mexico surface waters in the late spring and early summer. The presence of larval ABT, which require a robust food web for successful recruitment, has raised questions of the potential role of di-nitrogen (N_2) fixation as a source of nitrogen fueling phytoplankton at the base of the ABT food web. In this study, geochemical tools were used to identify and quantify the relative and absolute importance of both subsurface nitrate and N_2 fixation as sources of new nitrogen fueling export production in the Gulf of Mexico. In particular, samples were collected on cruises in May 2017 and May 2018 from oligotrophic waters in the central Gulf of Mexico. We present measurements of water column nitrate+nitrite $d^{15}N$ that are compared with the $d^{15}N$ of sinking particulate N collected by sediment traps deployed below the base of the euphotic zone. Preliminary $d^{15}N$ budget results suggest N_2 fixation supports <10% of export production in the central Gulf of Mexico, with rates <40 µmol N m^{-2} d^{-1}, and the majority of export production supported by subsurface nitrate, consistent with results from many other oligotrophic regions. We compare our results with incubation-based assays of nitrate uptake and N_2 fixation rate measurements, phytoplankton and diazotroph abundance, as well as other metrics of new and export production made on the same cruises.

Impacts of Match-Mismatch between Local and Remote Forcings on the Occurrence of Florida Red Tide

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*Student Presenter

The red tide that contains toxic dinoflagellate *Karenia brevis* occurs regularly along the West Florida Shelf (WFS), and the harmful algal blooms produce hazardous brevetoxins which adversely affect marine life and human. Decades of efforts have been made to understand the mechanism of bloom formation. Existing observational and numerical evidences suggest that, for slow-growing dinoflagellates like *K*. *brevis* (e.g. 0.3 d^{-1}) to outcompete other fast-growing species in an oligotrophic water, growth strategy alone is not sufficient and it must interact with and take advantages of shelf physics. Given that *K. brevis* are diel vertical migrators which are adapted for low-light, low-nutrient conditions, a number of working hypotheses converged to suggest that the mature blooms observed nearshore are developed from the seed population offshore, and recent studies have shown that an offshore niche/origin is plausible based on its biological advantage to seed population and its physical connectivity to coastal water. However, the WFS features dynamical circulation influenced by seasonal winds and the Loop Current. Whether physical conditions allow for the formation (e.g., including timing and location) of such a niche remains unaddressed. This study offers an integrated investigation of the winds and tide gauge observations, the satellite altimetry and derived currents and long-term red tide monitoring dataset over the last two decades (1998-present). The data-based analysis resolves a key period of each year on the WFS where a bottom convergence zone can form in waters between 50 and 100 m isobaths near 28^{o}N. This zone results from the coexistence of bottom Ekman upwelling in the outer shelf and the wind-driven downwelling in the inner shelf, and usually appears 1-2 months before the red tide is observed near the coast. Interannually, a dynamically consistent pattern emerges: the presence (absence) of this zone is in line with years of strong (weak/no) fall red tide along the WFS. The result confirms the existence of an offshore niche for seed populations of *K. brevis*, and the dynamical explanation has important implications for red tide prediction.

018: Cross-Disaster Lessons in Community Resilience: Deepwater Horizon and Other Disaster Events along the Gulf of Mexico

Cumulative Disaster Exposure, Gender, and the PADM

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Purpose: Though there is an increasingly robust body of literature exploring the factors that impact the ability of individuals and communities to cope after a disaster, far less research focuses on how gender, and exposure to multiple disaster events, impacts recovery and preparedness in post-disaster settings. The present research investigates the relationship between gender, disaster exposure, and the Protective Action Decision Model (PADM). **Methods**: An in-person mixed-methods survey was administered to a total of 326 Gulf Coast residents following the Deep-Water Horizon oil spill. Structural Equation Modeling was used to analyze gender differences in the relationship between disaster exposure and the PADM for participants. **Findings**: Disaster exposure demonstrated a significant negative effect on PADM, such that greater exposure was associated with lower scores on the PADM ($\gamma = -3.09$, $p < 0.001$). Similarly, gender was a significant covariate in the model, such that being female was associated with an increase in scores on the PADM ($\gamma = 0.33$, $p < 0.05$). All models were estimated in STATA version 13.1 **Conclusion and Implications**: This manuscript offers a unique perspective in highlighting the relationships between gender, cumulative disaster exposure, and the

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PADM. Originality/Value: This is the first study to explore the impact of cumulative disaster exposure on the PADM and the first to explicitly look at gender differences in the PADM following the Deepwater Horizon Oil Spill. **Keywords**: Gender, PADM, resilience, SEM, technological disaster, disaster recovery, disaster preparation.

What's Demographics Got to Do with It? Race, Sex, and Resilience in the Gulf Coast

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With funding from The Gulf of Mexico Research Initiative through The Consortium for Resilient Gulf Communities, a Tulane University research team explored the predictors of disaster preparedness and resilience towards future hydrocarbon disasters, among individuals residing in Gulf of Mexico communities in southeastern Louisiana. The study investigated the role of social networks, risk perceptions, preparedness measures, individual resilience and demographics as predictors of preparedness and resilience towards future oil spill events among households in the Gulf of Mexico. The data consisted of 326 individuals residing in areas surrounding Port Sulphur and Galliano, Louisiana and Bayou La Batre, Alabama in the Gulf of Mexico. The analysis in this paper used OLS regression (testing for both moderation and mediation effects of disaster exposure) to explore the relationship between Race and Sex with Connor-Davidson Resilience Scale scores. Results indicate that Race has a significant association with CD-RISC Score explaining about 16% of the variance. Interestingly, Sex does not appear to have an association with CD-RISC Score. Both results held even when accounting for exposure to disaster or the number of disasters exposed to. Contrary to popular discourse in disaster resilience which explores the gendered differences of preparedness and response, this sample group demonstrates that socio-cultural characteristics play a more significant role in resilience building. Further research is needed to identify the characteristics of resilience for different racial/ethnic groups in order to adequately inform strength-based approaches to risk-reduction, and address the contextual differences of sub-populations, in order to truly build resilience.

Disaster Exposure, Disaster Preparedness, and Individual Resilience in Three Gulf Coast Communities

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To gain a better understanding of the predictors of disaster preparedness and resilience for future hydrocarbon events in the Gulf of Mexico region, this study investigated the social networks, oil spill associations, past disaster exposure, protective action decision making, perceived oil spill consequences, interdependence questions, resilience attributes, and participant demographics in three Gulf Coast communities as part of the larger Consortium for Resilient Gulf Communities project. Using a cross-sectional, mixed-methods design, the research team administered a 60-minute in-person survey to 326 individuals in the Galliano area (Lafourche Parish) and Port Sulphur area (Plaquemines Parish) in southeastern Louisiana, and in Bayou La Batre (Mobile County) in Alabama between June 2017-November 2017. Basic descriptive statistics (i.e., frequencies, means, medians) were generated for all quantitative data and bivariate and multivariate analysis was used to answer a suite of research questions. The results of this study shed light on the way residents prepare for and respond to

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disasters and gives insight into resident resilience. Our results indicate the importance of characteristics such as gender, age, education, geography, and racial/ethnic identification in disaster resilience in these communities. The work also gives crucial insight into the factors residents consider when preparing for disasters, and who they rely on in their social networks. This research highlights the importance for policy development of studying these topics in disaster-affected and disaster-prone communities, in order to mitigate the impact of future hydrocarbon event on individuals, households, and communities in the Gulf of Mexico.

Work-Related Health and Safety Concerns and Oil-Spill Exposures among Florida and Mississippi Fisherman

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The fishing industry is characterized as a high-risk work environment with frequent workplace injuries and fatalities. Despite an increase in natural disasters (e.g., hurricanes), environmental disasters (e.g., oil spills, toxic algal blooms), and anthropogenic changes (e.g., pollution) little is known about how workplace chemical exposures impact the safety and health of fisherman. In the Fishing Industry Safety and Health (FISH) pilot study we describe workplace safety and health perceptions, attitudes, and exposures of individuals employed in the Mississippi and Florida fishing industry. Between August 2018 and September 2018, we conducted 11 in-depth semi-structured interviews with fishermen to document their health and safety concerns (6 additional interviews pending). Participants completed a 1-page survey prior to the start of the interview and were asked to wear a silicone-based wristband during a regular work shift to capture environmental exposures to polycyclic aromatic hydrocarbons (analysis underway). Among the 11 fishermen, the mean sample age was 47.5 years ± 12.5 (standard deviation [SD]), 81.8% were male, and 72.2% were commercial fisherman (shrimpers) with mean sample work tenure of 18.0 years ± 13.9 (SD). Over 63% reported having a second job, and several health conditions including: joint pain (72.7%), sinusitis (63.6%), and runny nose (45.5%) at work in the past 12-months. Across environmental exposures 63.6% had exposure to engine exhaust fumes and 9.1% to harmful algal blooms in the prior 12-months. Major themes that emerged from the interviews included: 1) fishermen have a greater sense of belonging out at sea regardless of environmental hazards, 2) preservation of oceanic resources is of highest importance; and 3) natural disasters such as hurricanes and oil spills continue to impact the health and safety of fishermen. Careful attention to the health and safety of gulf coast fisherman from chemical and environmental exposures is needed, as well as innovative intervention designs targeting this workforce.

Illness Anxiety and the Deepwater Horizon Oil Spill- Relationship to Actual and Perceived Risk from Exposure, and Health Service Utilization Post Disaster

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In 2016 the Consortium for Resilient Gulf Communities conducted the Study of Trauma, Resilience, and Opportunity among Neighborhoods in the Gulf (STRONG), a representative survey of 2520 Gulf Coast

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residents, designed to assess an individual's actual and perceived exposure to the Deepwater Horizon oil spill (DHOS), as well as long-term health, economic, and social impacts. Among the measures included was a six-item, modified Whiteley Index designed to detect illness anxiety during the previous two weeks. We used this data to test three hypotheses: 1) that actual exposure would correlate with illness anxiety; 2) that perception of health impacts of exposure (independent of actual exposure) would be correlated with illness anxiety symptoms; and 3) that illness anxiety symptoms would correlate with increased general health service utilization. Our results largely confirmed our a priori hypotheses, with some nuances. The relationship between actual exposure and illness anxiety became significant only after controlling for demographic factors. Perceived likelihood of physical health consequences due to exposure was significantly related to the outcome of the Whiteley Index. This fits with current understanding of illness anxiety as being driven more by anxiety and perceived risk than actual exposure, though it also suggests that exposure may have a triggering effect. Our analysis found higher rates of physical (but not mental) health care utilization among those with illness anxiety symptoms. This aligns with the theoretical underpinnings of illness anxiety, as an individual's preoccupation with and/or fear of physical illness, and a lack of awareness of the potential underlying mental health cause. To date, most studies of illness anxiety following disasters have largely focused on somatic symptoms, but this data allows for deeper examination of mental health symptoms, which could be important for the care for communities affected by public health disasters.

Enhancing Disaster Resilience by Focusing on Stress-Associated Health Impacts in Preparation, Response, and Recovery Plans

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A goal of many disaster preparedness, response, and recovery plans is to reduce the impacts of disasters through increased individual and community resilience. Unfortunately, most plans do not address directly major drivers of long-term disaster impacts on humans - i.e., chronic and cumulative stress. Stress can lead to or exacerbate ailments ranging from mental illness, domestic violence, substance abuse, post-traumatic stress disorders, and suicide to cardiovascular disease and respiratory problems. Individuals, groups, communities, organizations, and social ties are all vulnerable to stress. Based on a comparative review of recent disasters, resilience, and disaster-associated stress effects, we recommend eight actions to improve resiliency through a focus on stress alleviation. These are: (1) Improve existing disaster-related health responses to better address, leverage, and coordinate resources for stress reduction, relief, and treatment. (2) Emphasize pre- and post-disaster collection of relevant biomarker and other health-related data to provide a baseline against which impacts could be assessed, and continued monitoring of these indicators to evaluate recovery. (3) Enhance capacity of science and public health early-responders. (4) Use natural infrastructure to minimize disaster damage. (5) Expand the geography of disaster response and relief to better incorporate displacement of affected people and far-reaching effects. (6) Where possible, utilize nature-based treatment to alleviate pre- and post-disaster stress effects on health. (7) Review existing laws and related policies, regulations, and implementation plans to identify opportunities to strengthen public health preparedness and provision of health services and better engage affected communities. (8) With community participation, develop and institute equitable processes pre-disaster for dealing with damage assessments, litigation, potential payments, and housing.

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Child Mental Health Outcomes following the Deepwater Horizon Oil Spill: A Multilevel Longitudinal Analysis of Spill Exposure and Health Care Context

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The BP Deepwater Horizon Oil Spill (DHOS) stands out as an industrial disaster of unprecedented scale and ongoing impact. This study seeks to understand individual child mental health resilience following the DHOS with consideration of healthcare context at the community level. Nested within the family system, children may experience disaster differently from adults as they rely on caregivers for support and stability. Multilevel logistic regression analysis is employed to answer the following questions: 1) How are child mental health symptoms following the DHOS related to disaster exposure and other characteristics at the individual and household level 2) Is contextual level healthcare need related to child mental health outcomes above and beyond micro-level considerations? The analysis utilized data collected as part of the Resilient Children Youth and Communities study—a face-to-face, longitudinal panel survey with corresponding focus groups that follows over 480 parents with children living in spill-affected Louisiana parishes. This information is analyzed in combination with current secondary data on healthcare need and access. Findings indicate that six years after the DHOS, secondary spill-exposure through negative household economic effects, co-occurring physical symptoms, and history of reported depressive symptoms among children positively predict current depressive symptoms.

Disastrous Consequences: Comparing Communities after a Human-Caused and a Natural Disaster

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Disasters all have profound economic, social, and medical impacts. Each disaster is different from others in terms of the number of people affected and how they were affected. One growing field of research is comparing the effects of natural and human-caused disasters. Both of these types of disasters affect the most vulnerable populations in profound ways and the paths to recovery are very different. In order to elucidate the differences in recovery in the type of disasters, especially those in the Gulf Coast in the United States, data will be compared from two different studies. One study is an ongoing three-wave longitudinal study of families with children in areas highly impacted by the Deepwater Horizon Oil Spill with interviews conducted in 2014 (n=655), 2016 (n=484), and 2018. The other study will be from a study of around 800 respondents that were affected by Hurricane Katrina. Both study respondents were surveyed about their level of exposure, parents' health, child behavior and health, social cohesion, and demographics. This presentation will use analyses of comparable information collected on health, economic, and social impacts of the disaster to allow for a comparison in recovery trends after a disaster. These comparable factors will look at the relationship between exposure to the disaster, socioeconomics, and social cohesion on predicting self-perceived health and health issues. One specific proxy for recovery from both disasters will be children's health, since children can act as a bellwether of recovery. These analyses will clarify which factors most predict vulnerability and worse outcomes after a disaster. The better understanding of perceptions of recovery in this presentation from both a natural and human-caused disaster will allow policymakers and researchers to better understand how to improve community resilience in coastal communities and take action to improve resilience for the next disaster in the Gulf Coast.

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Factors Influencing Relocation Consideration by Gulf Coast Residents for Hazard Risk Reduction

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The United States experienced a series of record-breaking climate and weather-related disasters in 2017. The cumulative cost of these events is estimated at $306.2 billion with Hurricanes Harvey, Irma and Maria responsible for $265 billion. While this was a record-breaking year, studies show that disasters will become more frequent and costlier. Experience with frequent or catastrophic disasters shape how individuals perceive and respond to their environment thus influencing economic choices, health, and community resilience. A recent study suggests that many of low-lying coastal communities need to relocate by 2100 to avoid chronic flooding exacerbated by sea level rise. Many of these communities are also those that experienced the Deepwater Horizon Oil Spill and recent hurricanes. Since individual relocation weakens community ties and sense of place, it is important for us to understand how disaster experiences influence relocation to better understand community resilience. This research investigates: How does the relocation consideration vary spatially across the Gulf Coast? What social characteristics increase likelihood of individuals to consider relocating to an area of less risk? Does experience with disasters influence this consideration? This study uses online survey data collected from 73 Gulf Coast counties following the 2017 hurricane season to test for the influence of disaster experiences on relocation consideration. Associations between storm tracks and protective infrastructure (e.g. levees) and spatial distribution of relocation consideration are explored using GIS analysis. Regression analysis indicates that individual characteristics including as age, risk perception, home ownership, political ideology, and trust in government have significant impacts on individuals' relocation consideration. These results have implications for how coastal risk managers can predict, and in some cases, encourage migration out of hazard prone areas.

Evacuating for Disasters: Insights from a Longitudinal Survey

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The Study of Trauma, Resilience, and Opportunity among Neighborhoods in the Gulf (STRONG) is a representative telephone survey of 2520 Gulf Coast residents from Texas through Florida, designed to assess long-term health, economic, and social impacts of the Deepwater Horizon oil spill (DHOS). In Spring of 2018, only months after Hurricane Harvey, the Consortium for Resilient Gulf Communities fielded a follow-on survey of Texas residents designed to assess the impacts of the hurricane on the same individuals as the first STRONG survey, with follow-up interviews for the other regions occurring in the Fall of 2018. We use this data to understand respondents' hurricane-associated losses and their decision to evacuate. Among the original 623 Texas respondents, 295 responded to the follow-up interview, yielding a 47.4% response rate. There was no apparent difference between those who did and did not respond based on their prior exposure to the DHOS. Of these, 71.5% were present for the hurricane and regional flooding, 35.6% experienced some home damage, and 44% incurred monetary losses. Seventy-six percent of respondents did not evacuate, mostly because they were not instructed to do so (57.1%), they did not think the storm would be as bad as it was (29.9%), and 27.2% reported that they "just did not want to leave." Since evacuating is such an important part of mitigating the

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human toll of disasters, understanding why people do and do not leave when disasters approach can help regional evacuation planning. There is a dearth of longitudinal research to help inform this planning, thus highlighting the unique contribution our study makes.

Third Time's A Charm: A Case Study in Longitudinal, Face-to-Face Disaster Survey Research Protocol in South Louisiana

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South Louisiana is home to diverse communities and a vibrant blend of culture, livelihoods, and identity. Over the past two decades, this region has experienced numerous natural and technological disasters such as hurricanes, catastrophic flooding, and the Deepwater Horizon oil spill (DHOS). Coping with and rebounding from such events is a dynamic process that unfolds over time at many levels of social functioning. Studying social processes in the years following such events often involves a longitudinal approach by evaluating a cohort over time. Respondent engagement can become increasingly difficult as distance increases—in time, place, and psychology—from the disaster onset and as a result, special considerations should be made during outreach and re-interview.

This presentation offers a methodological case study of the third wave of data collection from the Resilient Children, Youth, and Communities (RCYC) project to explore efficacy in field technique, technology, and protocol. RCYC is a longitudinal study of households with children living in highly impacted areas of Louisiana at the time of the DHOS. Beginning in May of 2018, interviewers conducted face-to-face follow-up surveys with cohort respondents. Building on insights from previous waves of the RCYC field effort, we will explore project management and outreach techniques for maximizing respondent retention, managing effective field teams, and efficient use of project resources. This includes the way that field outreach strategies are shaped over time alongside RCYC cohort and community characteristics.

How Risk Related Worry Changes over Time: A Longitudinal Survey across Multiple Disaster Events

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The amount of worry that individuals experience after a disaster is related to factors such as the nature and extent of exposure to disaster impacts, prior trauma, and sociodemographic characteristics. Most research on worry has used cross-sectional designs, resulting in limited understanding of whether and how worry may strengthen or dissipate when additional disasters are experienced. This paper examines whether and how worry about the impacts of the 2010 Deepwater Horizon Oil Spill (DWHOS) have changed over time. In particular, we examine how worry about health, social, and economic impacts of DWHOS changed among residents in coastal areas of Texas following Hurricane Harvey in 2017. We compare responses to Waves I and II of the Study of Trauma, Resilience, and Opportunity among Neighborhoods in the Gulf (STRONG), a probabilistic telephone survey conducted by the Consortium for Resilient Gulf Communities in the Summer of 2016 and the Spring of 2018. Using several analytic strategies, we test hypotheses about how experiences with Hurricane Harvey affected worries related to the DWHOS, including whether hurricane exposure and impacts compound or have

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no effect on worry levels. Among the original 623 Texas respondents, 295 responded to the follow-up survey (47.4% response rate). The research underscores the need to examine multiple pathways by which worry may evolve and impact individuals' social and psychological functioning over time. Practical implications of this more nuanced understanding of pathways by which worry may increase or decrease will be highlighted for disaster preparedness and management practitioners.

019: Clogged Pipelines: Examining Gaps in the Use of New Science for Fisheries Management and Restoration in the Gulf of Mexico

Direct and Indirect Deepwater Horizon Oil Spill Impacts on Northern Gulf of Mexico Reef Fishes

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There is a growing body of evidence that northern Gulf of Mexico (nGOM) reef fishes suffered both direct and indirect effects of the DWH. Direct effects are easier to examine as one must simply demonstrate evidence of exposure to petroleum compounds, have an understanding of the toxicological or physiological consequences of that exposure, and then measure the response at the cellular, tissue, organ, or organismal level. Examining indirect effects is often less tractable because baseline data on pre-spill conditions and covariates are essential, and one must also have a means to measure and tract indirect effects over time that is independent of the biogeochemical markers utilized to estimate direct exposure to petroleum compounds. Expansive pre-spill time series of reef fish community and trophic structure on the nGOM shelf, as well as newly developed stable and radio isotope biomarkers, has enable long-term indirect effects of the spill to be estimated. Furthermore, simulations conducted with a nGOM Ecopath with Ecosim (EwE) ecosystem model enable DWH effects to be separated from other sources of ecosystem variability, such as climate cycles, fishing pressure, or invasive lionfish. In this talk, we will trace measures of direct exposure by reef fishes to DWH petroleum compounds in the weeks to months following the spill, as well as the temporal and spatial distribution of longer-term isotopic biomarkers. We will also report direct and indirect effects from individuals to populations. A focal species will be red snapper, but evidence from other species across the broader reef fish community will also be presented.

Fishery Management in the USA: An Overview of the Process and a Summary of Challenges and Opportunities

J. Froeschke
Gulf of Mexico Fishery Management Council, Tampa, FL

United States federal fishery management policy is derived from the Magnuson-Steven Fishery Conservation and Management Act (MSA) that was most recently reauthorized in 2006. The MSA was enacted in 1976 to prevent overfishing, promote the recovery of overfished stocks, and manage fishery resources for the maximum benefit of the nation. As part of the MSA, eight regional fishery management councils were created to enable fishery management strategies that can be responsive to

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the challenges and needs of distinct regions. The Gulf of Mexico Fishery Management Council (Council) is responsible for the conservation and management of federally managed fish stocks in the Gulf of Mexico. The Council is composed of 17 voting members including industry representatives, directors of the five Gulf of Mexico state marine resource management agencies, and the regional administrator of National Marine Fisheries Service. The Council manages dozens of fish stocks through six fishery management plans. To carry out this responsibility, the Council relies on the expertise of state and federal agencies, academics, and the public. National Standard 2 of the MSA requires that fishery management measures be based on the "best scientific information available," and the Council appoints a Scientific and Statistical Committee (SSC) to advise on technical and scientific aspects of the various fisheries. As part of its guidance, the SSC provides recommendations about fish stocks, provides feedback on Fishery Management Plans, and provides an acceptable biological catch for each stock that the Council cannot exceed. The Council process to develop, implement, and amend fishery management plans is an open and deliberative process. The aim is to balance stakeholder objectives while meeting the conservation objectives of the MSA. The Council process requires evaluation and comparison of alternative management strategies and presents unique opportunities for scientists and user groups to collaborate and provide solutions to complex problems.

The Relationship of Fishermen to Science Used in Restoration and Fisheries Management: The Perspective of One For-Hire Captain from Texas

Capt. S. Cantrell
Galveston Professional Boatmen's Association, Galveston, TX

The dynamic engagement and educational opportunities between fishermen and scientists often go unrealized or overlooked in the context of fisheries science and management. Fishery science and data collection allow a unique opportunity to work hand in hand with professional fishermen, cultivating a two-way exchange of professional experience to address complex scientific issues. When professional fishermen with their on-the-water fishing knowledge partner with trained scientists to conduct research projects the result is often a more effective approach to creative problem solving. Through efficient utilization of existing pathways of information exchange and collaboration, the scientific and fishing communities will achieve a better mutual understanding of fishery science issues and management challenges that might not otherwise be attainable if formal or informal opportunities for cooperation did not exist.

Relationships between Spawning Behaviour and Life History Traits in Gulf of Mexico Fishes: Implications for Vulnerability Assessments

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The vulnerability of fish populations to fishing is dependent upon their productivity (intrinsic indicator) and their susceptibility or exposure to fishing effort (extrinsic indicator). A suite of life history traits (e.g. late maturity, slow growth, and long lifespan) reliably serve as intrinsic indicators of high

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vulnerability and thus are incorporated within stock assessments to prioritize management. Certain spawning behaviour traits (e.g. short spawning periods, aggregating behavior, large density increases) are also consistently associated with high vulnerability but are rarely incorporated into assessments. We synthesized existing biological and fisheries information for populations of 28 fish species in the Gulf of Mexico to: (1) determine the relationship between life history traits and aspects of reproductive behaviour; and (2) assess their vulnerability to fishing during spawning. We found that spawning behaviors are not correlated with life history traits, indicating that vulnerability assessments relying on life history traits alone will not identify populations that are highly vulnerable to fishing during spawning. A principal component analysis showed that spawning behavior traits were a better predictor of stock status than life history traits. Our vulnerability assessment showed a high extrinsic vulnerability to fishing during spawning for all exploited species. Related to this, spawning behaviour traits (aggregating behavior, density changes, spawning season duration) were tightly linked to overall vulnerability. Collectively, our results illustrate that traits associated with spawning behavior represent a distinct aspect of fish ecology that is important to consider for predictions of vulnerability and resilience in exploited stocks within the Gulf of Mexico. This distinction is important, because while there is evidence that most exploited stocks are highly susceptible to overfishing during spawning, aspects of spawning behaviour are underrepresented within regional stock assessments or management, and few regulations exist to protect spawning fish in state or federal waters of the Gulf of Mexico.

The Fisheries Science-for-Management Pipeline: Key Directions

J. Powers
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In the recent past the emphasis of fisheries scientific advice has been on the determination of individual species productivity measured by biological reference points and status determination criteria such as maximum sustainable yield. Great strides have been made in this area, leading to sustainable fishing policies for many species. However, a management need to address ecological regime changes, disruptive environmental events and climatic shifts is forcing new research directions in support of ecosystem-based fisheries management policies. But there are many uncertainties as research moves in this direction. To integrate ecological variability into management policies, we must recognize that the time-scale of impacts is longer than normal fishery impacts, that effects are cumulative and that spatial aspects (movement, local habitats) are important. We must define indicators of ecological impact that can detect important changes quickly and determine the remedial actions that should be taken. The likely responses of both fish and fishers to these changes, including migration and spatial variability will be important. And, perhaps, most importantly we must define criteria for what are well-managed fisheries ecosystems. Sustainability of individual species will remain an important component, but a biologically and socially acceptable ecosystem structure that is measurable should also be determined, i.e. “ecosystem” reference points that will suggest policies that are robust to future uncertainties, both known and unknown. Examples of possible indicators are provided and their limitations discussed.

Current Tools for Understanding and Supporting Fishing Community Resilience in the Gulf of Mexico

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Thriving and sustainable fisheries are critical to the economic and cultural well-being of residents throughout the Gulf of Mexico; however, environmental (hurricanes), economic (increasing fuel costs), and cultural (graying of the fleet) stressors create obstacles that can prevent the proliferation of successful fisheries and fishing industries. One challenge to overcoming these obstacles is a lack of sustained engagement between resource managers, scientists and fishermen. Here we present three tools designed to help overcome these challenges: The Marine Resource Education Program (MREP), the Gulf of Mexico Fishery Management Council's (GMFMC) web portal (Something's Fishy), and the Mississippi-Alabama Sea Grant Fisheries Resilience Index (FRI). The MREP is a series of workshops designed to educate commercial and recreational fishermen so they can more confidently engage in the fishery management process. During these workshops, fishermen interact with NOAA Fisheries scientists and policy makers from the regional offices and science centers while sharing feedback from the fishing community. Something's Fishy is a new web portal that allows anglers and divers to share anecdotal trends about a particular fishery with the GMFMC. This strategy is being used for the first time during the current red grouper assessment, and is intended to expand the types of information included in traditional stock assessments. The Fisheries Resilience Index is a self-assessment tool developed for fishing industry leaders and businesses, and provides a simple and inexpensive means of assessing resilience to a variety of stressors. While not a panacea in and of themselves, these tools offer platforms to increase communication between resource managers and stakeholders, thereby bolstering Gulf of Mexico fishing community resilience.

Depleted, Dubious, or Just Different? Using Data and Models to Better Understand How Ecosystem Change Will Impact Gulf of Mexico Fisheries

M. Drexler
Ocean Conservancy, St. Petersburg, FL

There is now ample evidence that both fishing pressures and climate dynamics drive major reorganizations in the Gulf of Mexico ecosystem. Luckily there is a wealth of ecosystem data collected in this region to help understand these processes. However, there have been limited efforts to synthesize this wealth of data for the purpose of understanding how ecosystem change might impact our fisheries. A range of tools will be required to extract critical information from the existing data and create products that are usable to fisheries managers. These tools include informational-only products such as ecosystem status reports, multivariate time series models such as ELMIST, and fully mechanistic ecosystem models such as Atlantis. These models and products will be relevant to different scales of fisheries management and could be used to develop early warning indicators of regime shifts, establish ecosystem level reference points, and identify environmental drivers for stock assessments. Incorporating ecosystem information into fisheries management will result in fewer unanticipated outcomes and decrease uncertainty in our estimates of stock health and fisheries yield.

Commercial Fishermen - Partners, Problem Solvers, and Pioneers

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Today's fishermen work hard to secure a future for the fish they depend on, their fishing businesses, and their fishing communities. At the core of these efforts are strong science and sound data. Commercial fishermen use sound data to enhance fishery *management*. For instance, commercial red grouper fishermen in Florida began waving a warning flag to managers in 2015 as they began to see their landings decline and catch-per-unit-effort increase. Yet the red grouper stock assessment, which was not able to incorporate near real-time fishery data, projected positive growth in the population. These conflicting data streams continued to diverge until in 2018, when managers finally recommended a reduction in red grouper quota.

Commercial fishermen also use sound data to augment fishery *science*. Commercial fishermen in the Gulf of Mexico have been proactively testing the efficacy of video cameras and electronic fishing logbooks as tools for faster, more accurate, and more precise data collection. These same fishermen also offer their vessels as research platforms to conduct vital ecological sampling that is used to inform fishery models.

Commercial fishermen use sound data to enrich the broader fishery *community* with private sector solutions. Commercial red snapper fishermen built a red snapper "quota bank" in 2014 to help reduce red snapper discards in the Eastern Gulf's grouper fishery (an unintended consequence of a successful fishery rebuilding plan). Snapper fishermen now help grouper fishermen secure access to some of the quota they need to retain, track and report the red snapper they catch, as opposed to wastefully discarding them at sea. In short, commercial fishermen are data-driven problem solvers. Their contributions both at sea and on land are helping to improve fishery science, enhance fishery management, and built lasting solutions for the Gulf of Mexico.

The Gulf of Mexico Headboat Collaborative - A Fishermens' Solution to Improving Science and Management

Capt. S. Tomeny
Steve Tomeny Charters, Fourchon, LA

The federally-permitted charter/for-hire (CFH) fishing industry in the Gulf of Mexico is a primary means for the country's non-boat owning public to access the Gulf's fishery resources. Facing ever-shortening fishing seasons, declining public access and incapacitating management uncertainty, a subset of these fishermen formed a cooperative in 2013 called the Headboat Collaborative (HBC). The HBC requested, and was granted, an exempted fishing permit from the National Marine Fisheries Service to test an alternative management system for red snapper and gag grouper that included a new electronic data collection method designed to produce accurate, next to real-time catch and effort data. To ensure 100% catch accountability and to enable a transparent monitoring system, HBC fishermen adhered to strict protocols to track each fish caught during a trip including use of vessel monitoring systems, fishing (hail-out) and landing (hail-in) declarations, use of approved landing locations, fish tags, electronic fishing logbooks, a quota management system, automated law enforcement notifications, and catch validation procedures. The program was in place for two years (2014-2015) and 19 participating vessels completed over 6,600 trips during the study period. Results demonstrated 1) improved angler access to red snapper and gag grouper over the course of the fishing year, 2) reduced discards, 3) increased business profitability, and 4) success in developing a recreational catch data validation program. The success of this fishermen-run pilot program set the stage for the Gulf's federally-permitted CFH fleet to secure management opportunities tailored to their business practices.

*Student Presenter

These include implementation of their own sub-annual catch limit, development of an electronic logbook program, and reduced management uncertainty buffers. The HBC is a prime example of how the fishing industry can come together and forge creative, scientific solutions that improve data, protect fish, increase profitability, and enhance sustainable fishery access for anglers.

Identifying Information Gaps for Key Marine Fish Species in the Gulf - Frameworks and Processes to Create a "Menu" of Science Needs for Funders

L. Fetherston-Resch
Florida RESTORE Act Centers of Excellence Program, St. Petersburg, FL

A number of marine research and monitoring activities are anticipated in the Gulf of Mexico over the coming 10-15 years. These will be carried out in association with the programs established by different Deepwater Horizon settlements and through the course of regular agency and academic research. These science activities will undoubtedly fill priority needs and knowledge gaps for key marine populations, and an effort to deliberately compile these priorities and track progress toward closing gaps seems worthwhile. This effort is underway for eleven resource categories, largely based on the NRDA inured resources list, with the goal of having research needs compiled, prioritized by regional experts, and out for the wider community to review before the end of 2019. Ultimately, this is targeted to be a resource for funders looking to direct money at key information gaps, and be a menu, of sorts, that different programs can use to select topics for RFPs. For those programs with an emphasis on applied science or research-in-practice, however, the limited on-ramp for research to inform assessments of federally-managed marine fish populations remains a problem. Even if the marine research community makes headway in addressing critical information gaps, there remains the question of how to operationalize this information within the existing science-for-management pipeline. This may ultimately represent the largest challenge in addressing fisheries science and research needs with settlement funding, and one worth exploring in greater detail. The Florida RESTORE Act Centers of Excellence Program has funded a number of fish and fisheries related projects and has a keen interest in conversations around closing the gap between research and management for federal-managed species that are of great interest to Florida.

020: Understanding the Shelf Ecosystem – A Critical Intermediary between Open Water and the Coast – By Combining *In-Situ* Measurements, Modeling, and Remote Sensing

Satellite Data Reveals Estuarine-Shelf and Shelf-Slope Exchange Processes and Biogeochemical Impacts Involving the Mississippi River Outflow

N. Walker (Invited)
Louisiana State University

This talk employs satellite and in-situ measurements to discuss wind- and eddy-driven circulation around the Mississippi River bird-foot delta, and adjacent continental shelf areas. Circulation in this region is notably complex due to the coastline morphology, the submarine bathymetry, and the large

and variable river inputs (freshwater, nutrients, sediments) from the Mississippi/Atchafalaya as well as many smaller rivers. The bird-foot delta protrudes seaward about 60 km, providing an impediment to major east-west shelf flow, although measured volume transport is relatively high during easterly winds between these two shelves. Hypoxia has been most thoroughly studied on the Louisiana/Texas shelf and is known to be most severe and widespread during summer as a result of high phytoplankton production and buoyancy that enhances water column stratification. Past research has shown a 4 to 5 week lag between nutrient inputs to the Louisiana shelf and large-scale phytoplankton blooms. Diverting river water through the Bonnet Carre Spillway into Lake Pontchartrain during major floods may impact hypoxia on both shelf areas; however little research has been performed in the Mississippi Bight in this regard. The nGoM shelves are frequently subjected to high-energy wind events from tropical storms/hurricanes and winter storms, conditions that reduce hypoxia by rapidly mixing the water column. In their wakes, large-scale estuarine flushing has been observed as well as rapid transport of shelf water onto the continental slope, where counter-rotating eddies provide the most efficient mechanism for the advection of shelf water farther offshore. Satellite surveillance during episodic events over the last few decades are discussed to reveal the spatial and temporal scales of exchange processes from the coast to the deep Gulf.

Characterization of Offshore Pathways of Mississippi Waters under Eddy Influence: Observations and Modeling

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The offshore southward pathways of low-salinity riverine waters, originating from the northern Gulf of Mexico (GoM) shelves, may influence the physical features in remote areas such as the central GoM and the Straits of Florida. High-resolution numerical simulations in tandem with several satellite and *in-situ* observations in the summer of 2015 were used to characterize such offshore pathways and examine, for the first time, their vertical structure. Two pathways of brackish waters were detected: along the eastern boundary (eastern pathway) and along the western boundary of the Loop Current (LC) (western pathway). Specific meteorological and oceanic conditions, both on the shelf and offshore, were involved in their formation and evolution. The proximity of the LC Eddy (LCE) and the westerly winds over the Louisiana-Texas (LATEX) shelf reduced the westward downstream Mississippi River (MR) currents and contributed to the initial formation of the western pathway. The eastern branch was formed when the anticyclonic LC main body was close to the MR Delta and counter-rotating eddies (cyclonic LC Frontal Eddies, LCFEs) were also present. The interaction of anticyclonic (LC for the eastern pathway and LCE for the western pathway) and cyclonic (LCFE) circulation patterns along the branches may influence their dynamical and structural characteristics. The depth and several vertical characteristics of the offshore brackish plumes were investigated from their origin in the northern GoM shelves through their extension in the Straits of Florida. Their depth extended to 40 m depth in specific areas but the strongest pycnoclines were observed at very shallow depths (~5 m). The two types of pathways revealed different origin of the low-salinity waters. Although the MR-originated waters prevailed in both types, precipitation inputs contributed to the eastern pathway while waters from additional northern GoM rivers contributed to the western pathway.

*Student Presenter

Shelf Convergence and Transport near an Ebb Tidal Delta in the Mississippi Bight, Northern Gulf of Mexico

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Oil spill transport prediction and the associated management response is difficult near tidal inlets due to highly variable currents as a result of multiple forcing agents (e.g. winds, tides, river discharge) and complex bathymetry. To better understand the circulation in these regions, the CONCORDE program deployed moorings, released drifters, and simultaneously conducted two hydrographic cruises during the spring of 2016 near the mouth of Mobile Bay. Results from the mooring array indicated the flow was prominently wind-driven with the subtidal momentum balance being semi- geostrophic. The wind forcing also generated strong mode 1 near-inertial oscillations that became smaller approaching the coast. Modification of these wind-driven currents by local bathymetry and the tidally pulsed Mobile Bay river plume were observed to generate complex, spatially variable flow features. The protruding ebb tidal delta constricted and amplified the along-shelf currents, an effect that extends ~10km offshore beyond the bathymetric feature. The offshore effect was similar to the length scale of the ebb tidal delta. Wind transitions generated a strong convergence and offshore subsurface flows at the tip of the ebb tidal delta due to the combined effect of spatial variability in the wind response (i.e., shallow water changes direction faster than deeper waters) and flow separation as the circulation rounds the delta. The timing of the tidal pulsing of the river plume and offshore near-inertial oscillations enhanced this convergent behavior creating more shear and mixing. The convergences were repeatedly observed 25 km from the delta, generating subsurface seaward currents reaching as much as 30 cm/s. These results suggest that ebb tidal deltas are critical constraints for accurately predicting coastal circulation that can significantly modify oil transport in near-shore regions.

A Case Study of Inertial Oscillations and Diurnal Dynamics Offshore of Mobile Bay

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The northern Gulf shelf has a natural resonance at diurnal frequencies because the period where the circular acceleration of currents can perfectly balance Coriolis acceleration at 30°N is close to 24 hours. Complicating this normal ocean resonance in this region are land-sea breezes forced by solar radiation and diurnal tides that also act in 24 hour cycles. These dynamics are investigated using six sets of moorings that were deployed as part of the CONsortium for oil exposure pathways in COastal River-Dominated Ecosystems (CONCORDE) spring experiment to observe the spatial structure of the riverine driven outflow of Mobile Bay. Three acoustic Doppler current meter moorings were deployed to form a fan across the Mobile Bay outflow path and three additional mooring sets were deployed in a line array

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extending offshore from the fan array. Together these six short-term mooring sets complemented the long-term observations made by one Dauphin Island Sea Lab mooring located nearby. A major inertial oscillation event was observed from April 3-14 by all seven moorings. The inertial currents were strongest further offshore and had a subsurface peak of opposite phase of the surface currents as is typical for such events. More surprising was that inertial-like currents with sub-surface patterns were observed as far inshore as the fan mooring array at the 10 m isobath. Also, the semi-minor to semi-major aspect ratios of the currents were typically much less than one everywhere and were close to 0.75 for the strongest inertial currents. This indicates that frictional forces, wind stress, and/or coastal convergences/divergences are playing important roles in breaking the Coriolis and circular acceleration balance for these events. The implications are that significant vertical energy and mass fluxes are occurring during these events and these could have important biological and oil dispersal consequences that have not yet been adequately studied.

Vertical Structure of Ocean Surface Currents Under High Winds from Massive Arrays of Drifters

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Very near surface ocean currents have large impacts on the transport of buoyant materials in the ocean, but have proved difficult to measure with modern instrumentation. Here, observations of ocean currents at two depths within the first meter of the surface are made utilizing trajectory data from both drogued and undrogued CARTHE drifters, which have draft depths of 60cm and 5cm, respectively. Trajectory data of dense, co-located drogued and undrogued drifters, were collected during the LAgrangian Submesoscale ExpeRiment (LASER) that took place from January to March of 2016 in the Northern Gulf of Mexico. Examination of the drifter velocities reveal that the surface currents become strongly wind- and wave-driven during periods of high wind, with the pre-existing regional circulation contributing only a small fraction (~5-30%) to the total surface velocities. During these high wind events, we deconstruct the full surface current velocities captured by each drifter type into their wind- and wave-driven components after subtracting an estimate for the pre-existing circulation. The submesoscale to mesoscale circulation preceding each high wind event is estimated using a Lagrangian variational method to create hourly velocity fields using both drifter types, separately. Synoptic wind and wave output data from the Unified Wave INterface-Coupled Model (UWIN-CM), a fully coupled atmosphere, wave and ocean circulation model, are used for analysis. Results show that the purely wind-driven component of the surface flow exhibits a rotation to the right with depth between the two surface layers measured, with both surface layers reaching higher deflection angles at higher wind speeds. Results provide new insight to the vertical structure of near surface wind-driven flows, in addition to the relative strengths of wind-wave-driven currents and characteristic submesoscale to mesoscale circulations.

Satellite Remote Sensing of Phytoplankton Diagnostic Pigments in the Northern Gulf of Mexico

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Phytoplankton are the foundation of marine food webs, yet there are many questions about their future in a changing climate and under expanding human uses of the seas. Because of their spatial and temporal coverage, satellite images are an important data source for phytoplankton monitoring and research at broad spatial scales. Over the last decade, researchers have thus proposed algorithms for mapping different aspects of phytoplankton community composition from space. However, these algorithms have not been fully validated, and it is unknown how well they perform in the Gulf of Mexico. Building on recent advances in statistical learning methods for spatial data, we thus developed a new algorithm that predicts the global spatial distribution of phytoplankton diagnostic pigments that serve as proxies for major taxonomic classes. We validated this algorithm with global in-situ data as well as specifically for the northern Gulf of Mexico continental shelf. It achieved adequate prediction accuracy in this region. We also compared the regional spatial distributions of different phytoplankton classes according to our algorithm to results obtained with a previously published algorithm, identifying major differences between the algorithms' predictions. For example, our algorithm suggested much higher concentrations of zeaxanthin, a diagnostic pigment found in cyanobacteria, in the northern Gulf's coastal waters. We conclude by discussing the potential and challenges of developing a regional version of our algorithm, optimized for phytoplankton monitoring in the Gulf of Mexico.

Approaches and Challenges to Modeling Transport and Exchanges in the Northern Gulf of Mexico

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Understanding and projecting the transport and exchange of materials on continental shelf systems requires integrated modeling frameworks that encompass the riverine-coastal ocean-continental shelf continuum, resolve seasonal and annual variability, and include complex biogeochemical interactions. Such a modeling framework has been implemented for the Mississippi Bight region of the northern Gulf of Mexico continental shelf. This modeling system consists of a circulation model, based on the Coupled-Ocean-Atmosphere-Wave-Sediment Transport Modeling System, and biogeochemical and sediment transport modules. This biogeochemical module includes multiple size classes of phytoplankton, zooplankton, detritus, and fish larvae, and tracks dissolved oxygen and benthic cycling interactions. Passive tracer simulations provide insights into transport pathways from the northern Gulf of Mexico to the outer shelf. The simulations improve understanding of the across-shelf coupling that advances the ability to predict the effects of impacts, such as oil spills or managed freshwater discharges, on the northern Gulf coastal regions. The integrated modeling framework also provides a basis for comparing with other continental shelf systems and for identifying the challenges of including in these models the effects of climate change and interactions with socio-economic systems.

Could Oil-Degrading Bacteria Have Assisted in the Formation of a Harmful Dinoflagellate Bloom After the Texas City "Y" Oil Spill in 2014?

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The association between phytoplankton blooms and oil spills is still controversial despite numerous studies. Surprisingly, to date, there have been no studies on the effect of bacterial communities

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exposed to crude oil on phytoplankton growth, even though crude oil leads to variation in bacterial communities, and this variation can affect phytoplankton growth and species composition. *Prorocentrum* blooms were reported in Galveston Bay 3 days after the Texas City "Y" oil spill. To elucidate the role of oil-degrading bacteria in bloom formation, we isolated oil-degrading bacteria from sediment samples collected from oil-contaminated sites after this oil spill, and investigated variation in dinoflagellate growth after addition of isolated bacteria. A total of seven oil-degrading bacterial cultures were established, and two bacterial cultures (C1-T3 and E1-Gal-T2) clearly enhanced the growth rate and yield (17-103%) of dinoflagellate cultures; axenic *Amphidinium carterae* and *Peridinium sociale*, and xenic *Karenia brevis*, *Pr. gracile*, *Pr. minimum*, and *Pr. texanum*. To determine whether or not these bacteria can enhance dinoflagellate growth by releasing nutrients, nutrient limited medium was prepared by removing the each one of components (nitrogen, phosphorous, trace metals or vitamins), and C1-T3 and E1-Gal-T2 were inoculated into each nutrient limited media, containing *A. carterae* and *P. sociale*. These two bacterial cultures greatly enhanced the growth rate and yield of the two dinoflagellates, regardless of any limited media. These results suggest that growth enhancing activity of these bacteria may not be derived from releasing nutrients. Free-living bacteria isolated from a *Pr. texanum* culture have exposed to crude oil (100 ppm) for a month, and then we investigated the growth change in *Pr. texanum* after addition of these oil-treated bacteria. Interestingly, the growth rate and yield of *Pr. texanum* in bacterial treatment was clearly enhanced, compared to control.

Novel Observations of Positively Correlated Dissolved Organic Nitrogen and Dissolved Iron Concentrations in Gulf of Mexico Surface Waters

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A near- to off-shore transect collected in June 2015 in the Gulf of Mexico showed novel observations of significantly positively correlated surface ocean dissolved organic nitrogen (DON) and dissolved iron (dFe) concentrations across the West Florida Shelf (WFS). The salinity in all samples was >35, indicating minimal freshwater influence. We consider potential explanations for the correlation between dFe and DON, including that dFe availability supports new production, a fraction of which is released as DON, including by the cyanobacterial diazotroph *Trichodesmium* spp. that was observed along the transect. However, abundances of *Trichodesmium* spp. on the cruises paired with previously reported ranges of regional di-nitrogen (N_2) fixation rates by *Trichodesmium* spp. suggest that N_2 fixation alone is unlikely to account for all of the elevated DON observed on the 2015 transect. Alternatively, samples collected along the WFS in March 2018 showed significant positive correlations between DON, barium, and silicate concentrations, suggesting a potential groundwater source of elevated DON to WFS surface waters. Additional measurements, including Fourier Transform - Ion Cyclotron Resonance Mass Spectrometry analysis of DOM, DON d15N, and C and N fixation rates are used to infer sources of DON and dFe on the WFS on both the 2015 and 2018 cruises.

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Hypoxia in the Mississippi Bight: Understanding Interactions of Circulation and Biogeochemistry in a Complex River-Dominated Coastal Ecosystem

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Coastal areas are key regions between the continent and the open ocean where land-derived chemical elements transported by rivers and groundwater mix with seawater. They play a key role in various economic activities and regulate the ecosystem; yet, they are also especially vulnerable to human activities. The Mississippi Sound and Bight, to the east of the Mississippi River Delta, contain productive fisheries, are subject to environmental issues such as oil spills, and experience seasonal hypoxia due to excess nutrient inputs from agricultural use. The CONCORDE Consortium and other projects have recently been investigating this complex, river-dominated ecosystem. In particular, a large hypoxic area was observed in bottom waters of the Mississippi Bight in summer 2016. Water isotope measurements in the Mississippi Bight showed very little influence of nutrient-rich Mississippi River water, which suggests that other mechanisms may play a role in hypoxia. Here, we explore the role played by submarine groundwater discharge (SGD) in the enhancement of bottom water hypoxia. SGD fluid bypasses the estuarine filter and is recognized as a pathway for chemical elements such as nutrients and metals. In addition, recent work has shown that the delivery of anoxic groundwater could be responsible for the development of coastal hypoxia. Significant inverse correlations were observed between bottom water oxygen and both radium isotopes and barium, two known indicators of SGD. This implies a common mechanism relating hypoxia and SGD. Moreover, changes in bottom water macronutrient compositions were also observed during hypoxia. In particular, we saw a sharp rise in the NH_4^+/DIN ratio, consistent with the delivery of anoxic SGD fluid directly into bottom waters creating an oxygen demand. Further evidence for this mechanism comes from the increase of radium in Mississippi Sound surf zone water shortly after a fish kill in July 2017 that was attributed to low oxygen content.

Using a Budget Analysis to Understand Variability in Modeled Bottom Hypoxia of the Texas Louisiana Shelf

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Seasonal hypoxia occurs in the northern Gulf of Mexico as a consequence of increased river discharge, augmenting stratification and nutrient load. The Texas-Louisiana shelf (TXLA) is known to display complex surface gradients due to river plume induced instabilities on this time, and models show the formation of bottom features of similar complexity enclosing low oxygen concentrations. We a use realistic eddy-resolving hydrodynamic model, with a simple oxygen parametrization, to investigate variability in the seasonal bottom hypoxia over the TXLA. The model simulates the formation of oxygen-depleted eddy-like features, which are initiated in early summer by an increase in the sediment oxygen demand (SOD) and a decrease in the downward oxygen fluxes due to stratification. These features then oscillate and grow, undergo events of destruction and regrowth, until hypoxia is finally eliminated in fall. A budget analysis of oxygen concentration reveals that advective fluxes are dominant on time-scales shorter than a day, but are almost completely suppressed for periods longer than near-inertial. Vertical advective fluxes are enhanced at weather-band timescales, following strong wind bursts and downwelling favorable wind periods. The net diffusive flux is negative most of the time due

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to SOD, except for these occasional atmospheric events when mixing due to strong winds increases the surface-bottom oxygen gradient enough to surpass bottom respiration. At monthly timescales the budget is dominated by the SOD during periods when the hypoxic region is large and growing, switching to a positive vertical advective flux when the hypoxic region is shrinking. Understanding the physical mechanisms driving the formation of bottom features ranging from low oxygen pockets, to a full extent hypoxic region, can give us insight in the variability of the bottom layer, increasing our understanding of the different scales of vulnerability of the shelf's benthic ecosystem.

Modeling the Effects of Mississippi River Diversions on Hydrodynamics, Nutrient Transport Pathways and Hypoxia in the Northern Gulf of Mexico

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River systems worldwide are increasingly influenced by flood control measures and river diversion operations. Yet, surprisingly little is known about the effects of river management on coastal hydrodynamics, nutrient transport pathways, and hypoxia. Freshwater diversions on the Lower Mississippi River play a central role in the proposed 50-billion, 50-year strategy for restoring the Louisiana's coast. Under the proposed 2017 Coastal Master Plan, four large-scale river diversion projects are being considered that would divert a third of the Lower Mississippi River into deltaic Louisiana estuaries. The effects of existing and proposed river diversions on nutrient transport pathways and hypoxia were investigated using a high-resolution, three-dimensional, coupled hydrodynamic-biogeochemical model (FVCOM-WASP-LATEX). The numerical model domain covers most of the Alabama-Mississippi-Louisiana-Texas continental shelf and includes high resolution (on the order of 20 meters) nested grids in Barataria and Breton Sound estuaries. The model was driven by tidal and subtidal forcing at the open Gulf of Mexico boundary, freshwater and nutrient loads from rivers and river diversions, and surface wind stress. A number of different diversion scenarios were assessed, including a concurrent operation of six river diversions with a combined flow of 6,500 cubic meters per second. Numerical modeling results indicate that, depending on the scenario considered, the proposed large-scale river diversions would have the potential to strongly influence hydrodynamics and estuarine-shelf exchanges, which in turn could profoundly affect nutrient transport pathways and hypoxia in the northern Gulf of Mexico.

021: MOSSFA Events: Microbial Responses, Ecosystem Impacts, Predictions and High-Pressure in Navigating Future Deep Oil Spills in the Gulf of Mexico

Sunlight Induced Aggregation of Dissolved Organic Matter in Seawater: Role of Proteins in Biologically Mediated Processes

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The two major geochemical cycles in the ocean are carbon (C) and nitrogen (N), with organic matter export from the euphotic zone identified to drive the two cycles. Although the major interactions

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between these two cycles are important, studies on the evidence of geochemical processes to directly connect them are limited. Here we show that sunlight can induce aggregation of dissolved organic matter (DOM) into high N containing photo-aggregates; these micro-gels increased in size 18-25% relative to those found in natural coastal seawaters. Within relatively short time (1h), the C and N sequestered into the photo-aggregates accounted for about 4% and 10% of the bulk particulate C and N. The N/C ratio of the photo-aggregates was two times higher after sunlight irradiation. We further show reactive oxygen species (ROS) influence the aggregation. To accommodate the different organic compositions in marine environment, we monitored the aggregate size increase of various extracellular polymeric substances (EPS), as well as model biopolymers, by flow cytometry, dynamic laser scattering, and scanning electron microscopy. We found proteins play important roles in light-induced aggregation. In contrast to previous concept that sunlight can break down DOM and interrupt aggregation, our study suggests the N pool may play an opposite effect on DOM photoreaction and potentially link the C and N cycles. Our study provides new insights into organic matter transformation and transportation in the marine environment.

Intracellular Mechanisms Contributing to Oil Resistance by the Green Alga, *Dunaliella tertiolecta*

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Exposure to oil has been shown to be lethal to most phytoplankton species, however some are able to survive and grow at a normal or reduced growth rate. This ability to tolerate oil exposure appears to be independent of the class and phylum of the phytoplankton and their ability to consume components of oil heterotrophically. We therefore conducted an experiment on oil resistant chlorophyte, *Dunaliella tertiolecta*, in controls and a water accommodated fraction of oil with and without metabolic inhibitors targeting biochemical pathways (photosynthetic electron transport, cyclic electron transport of PSI, Kreb's cycle, mitochondrial electron transport, pentose-phosphate pathway and photo-respiration). We found inhibiting pathways such as photosynthetic electron transport and pentose-phosphate pathway were lethal, however inhibition of pathways such as mitochondrial electron transport chain and cyclic electron transport around PSI caused growth arrest in cells but not death. Pathways such as photorespiration and Kreb's cycle played a critical role in oil tolerating ability of *Dunaliella tertiolecta*. Analysis of photo-physiology revealed alteration in the photosynthetic apparatus under inhibition of photo-respiration and not Kreb's cycle. Further studies on photo-respiration and Kreb's cycle metabolites are underway to explain how these pathways helped *Dunaliella tertiolecta* resist oil exposure.

Impacts of Crude Oil and Corexit on Extracellular Polymeric Substances: Their Production and Chemical Composition

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After the Deepwater Horizon (DwH) oil spill accident, a large amount of Corexit dispersants was applied to accelerate oil dispersion into small droplets. Spilled oil and Corexit can cause a wide range of long-

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term adverse consequences on marine ecosystems. Therefore, the factors that control fate and interaction of oil and Corexit in the marine environment have attracted intense interests from the research community. Among these factors are extracellular polymeric substances (EPS), as the types and chemical characteristics of EPS in the marine system are believed to play an important role in the oil degrading process and in oil-containing particle transport (e.g., marine oil snow (MOS) formation). However, the impacts and detailed mechanisms from Corexit and oils on EPS are still unclear and remain to be fully understood. Here we grew individually 12 microbial species, including phytoplankton (diatom) and bacteria, with water accommodated fraction (WAF), chemically-enhanced WAF (CEWAF), and Corexit, to observe changes in DNA content, production behavior and/or chemical composition of EPS. We found that the highest EPS production of phytoplankton and bacteria was found when grown in CEWAF; the DNA and protein content of the EPS decreased with increasing concentrations of EPS. The hydrophobicity (e.g., protein/polysaccharide ratio) of EPS was affected by crude oil and chemical dispersants, and showed remarkable variations in various species in different situations. This study highlights the link between EPS production and their chemical characteristics during an oil spill and after Corexit applications, indicating that spilled oil and Corexit treatment may alter the composition of dissolved organic matter, thereby potentially altering the organic carbon pool.

How Oil is Transported via Exopolymeric Substances Mediated Marine Snow Formation

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Large amounts of mucous-rich oil containing marine snow formed in surface waters adjacent to the Deepwater Horizon spill; this marine oil snow (MOS) was implicated in oil delivery to seafloor. Whether the use of chemical dispersants (i.e., Corexit) increased or decreased MOS sedimentation remains controversial. Exopolymeric substances (EPS) are an important component of MOS that are released by microbes and likely involved in the oil-Corexit-MOS interaction. We conducted mesocosm (M) experiments including four treatments: 1) a water accommodated fraction of oil (WAF), 2) a chemically-enhanced WAF with Corexit (CEWAF), 3) diluted CEWAF (DCEWAF); and 4) a control. Four mesocosms mimicked different environmental conditions: a near shore seawater seeded with natural microbial concentrate (M2); an open ocean seawater amended with f/20 nutrients (M3); a coastal seawater amended with f/20 nutrients (M4); and a near shore seawater seeded with microbial concentrate for an elongated duration of 16-days (M5) compared to 4 days for M2-M4. The purpose of these experiments was to investigate 1) if the application of Corexit enhances or reduces the transport of WAF to the depth via incorporation into MOS under the specific conditions; 2) if there is a difference in the oil incorporation into sinking MOS in a coastal (M4) versus open ocean region (M3); 3) if there is any difference in the incorporation into sinking MOS in a more terrestrially-affected near-shore region (M2) versus a less impacted coastal region (M4); 4) the development (i.e., formation of sinking MOS and incorporation of petrocarbon into the sinking MOS) in a short-term (M2) versus a long-term mesocosm (M5); 5) what are the EPS production and composition in different systems in the presence of oil and/or Corexit and how this information is related to petroleum distribution in the water column versus in the sinking MOS.

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Using Radiolabels as an Indicator to Understand the Interplay of Phytoplankton and their Associated Bacteria in the Presence and Absence of Oil

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Extracellular polymeric substances (EPS), as secretions of marine microbes under stress, are the precursors of aggregates as gels, transparent exopolymeric particles (TEP), marine snow, and/or marine oil snow. EPS are largely comprised of protein and polysaccharides which provide a nutrient rich substrate for microbes. While it is accepted that there are important synergistic dynamics between phytoplankton and bacteria, little is known about the contribution of each to the formation of EPS, or the use of EPS as a nutrient source for bacteria. To illucidate these interactions, natural seawaters from the Gulf of Mexico with their ambient communities were sampled. The treatments were 1) a control with no additions, 2) incubation of $NaHC^{14}O_3$ and H^3-Leucine, 3) incubation of $NaHC^{14}O_3$ and H^3-Leucine with a water accommodated fraction of oil (WAF), 4) incubation of H^3-Leucine and C^{14}-dodecane with WAF. The treatments were analyzed for radioisotope activity in different size fractions, to operationally isolate phytoplankton (≥3 µm), phytoplankton+bacteria (<3 µm, ≥0.2 µm), EPS (< 0.2 µm, ≥3kDa). Exoenzyme activity was measured to account for the process of bacterial uptake of phytoplankton-derived EPS. At the beginning and end of the experiments, the phytoplankton and bacteria assemblages were determined using 18s and 16s DNA sequencing. This experiment provided data on the contribution of bacteria and phytoplankton to the EPS pool, the interaction of bacteria and phytoplankton through tracking the exchange of EPS contents between them, and insight on how both these processes were affected by the presence of oil in seawater.

Drastic Differences in Aggregation on a Rising Oil Droplet Caused by Different EPS

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The realization of seafloor sedimentation as an initially unconsidered fate of oil in the Deepwater Horizon oil spill has sparked considerable research efforts to understand the responsible mechanisms. Marine oil snow sedimentation and flocculent accumulation (MOSSFA), wherein sticky marine snow flocs facilitated by microbial secretions (extracellular polymeric substances or EPS) laced with oil (marine oil snow or MOS) precipitated to the seafloor, is a significant responsible mechanism corroborated by field observations, sediment data, and numerous laboratory experiments. The EPS acts like the glue of the MOS and is a complex mixture of proteins, carbohydrates, nucleic acids, lipids, and other compounds. EPS composition varies significantly depending on the microbial community and their environment, and the composition also plays a crucial role in aggregation. In this collaborative study between GoMRI-funded DROPPS and ADDOMEx research consortia, we study the ability of EPS to facilitate aggregation on a single submillimeter oil droplet by utilizing a microfluidic microcosm that emulates a droplet rising through an EPS-particle suspension. EPS extracted from various microbial isolates and consortia exhibit drastic differences in aggregate growth rate, size, and shape with some aggregates growing in under an hour and others taking weeks. Previous results suggested a positive correlation between EPS protein/carbohydrate ratio and aggregation rate, but recent experiments have challenged this correlation. Experiments are ongoing with additional EPS samples and environmental conditions to better understand what makes EPS sticky.

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Comparison of Marine Snow Formations of Stationary and Exponentially Growing *Thalassiosira pseudonana* in Current and Future Ocean Conditions

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Diatoms play a key role in the marine carbon cycle due to their high primary productivity rates, their worldwide distribution, and their contribution to marine snow formation through the production of extracellular polymeric substances (EPS). These polysaccharide-rich compounds help to aggregate organic material and transfer nutrients and carbon through the water column to either be consumed or stored long term in the sea floor sediments. Ocean acidification could impact organisms that utilize inorganic carbon for photosynthesis, including the diatoms. In turn, diatom EPS production could be altered by stressor such as oil pollution. Using *Thalassiosira pseudonana*, a small centric diatom, in stationary and exponentially growing cultures, roller tank experiments were conducted to replicate aggregation and sinking through the water column. Six treatments with three replicates were used to examine ocean acidification and oil spills effects on *T. pseudonana* marine snow production: control, enhanced pCO_2 level, water accommodated fraction of oil (WAF), enhanced pCO_2 and WAF, diluted WAF chemically enhanced with Corexit (DCEWAF), and enhanced pCO_2 and DCEWAF. Measurements included physiological responses of *T. pseudonana*, EPS production, aggregate analysis, changes in oil concentrations, and ambient water conditions. The two growth phases of the culture exhibit distinct responses to treatments in terms of aggregate formation and composition, but photosynthetic activity was unaltered. The results of this study will provide insights into how CO_2 availability affects marine snow production and aggregation, and how phytoplankton may respond to harmful events such as oil spills in the future.

Response of Natural Phytoplankton Communities Exposed to Crude Oil and Chemical Dispersants during a Mesocosm Experiment

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During the 2010 Deepwater Horizon oil spill, the chemical dispersant Corexit was applied over vast areas of the Gulf of Mexico. Marine phytoplankton play a key role in aggregate formation through the production of extracellular polymeric substances (EPS). This study examined the impacts of oil and dispersants on the composition and physiology of natural marine phytoplankton communities from the Gulf of Mexico during a 72-hour mesocosm experiment. The communities were treated using the water accommodated fraction (WAF) of oil, which was produced by adding Macondo surrogate oil to natural seawater. A chemically enhanced WAF (CEWAF) was made in a similar manner, but using a mixture of oil and the dispersant Corexit in a 20:1 ratio as well as a diluted CEWAF (DCEWAF). Phytoplankton communities exposed to WAF showed no significant changes in PSII quantum yield (F_v/F_m) or electron transfer rates (ETR_{max}) compared to Control communities. In contrast, both F_v/F_m and ETR_{max} declined rapidly in communities treated with either CEWAF or DCEWAF. Analysis of other photophysiological parameters showed that photosystem II (PSII) antenna size and PSII connectivity factor were not

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altered by exposure to DCEWAF, suggesting that processes downstream of PSII were affected. The eukaryote community composition in each experimental tank was characterized at the end of the 72h exposure time using 18S rRNA sequencing. Diatoms dominated the communities in both the control and WAF treatments (52 and 56% relative abundance respectively), while in CEWAF and DCEWAF treatments were dominated by heterotrophic Euglenozoa (51 and 84% respectively). Diatoms made up the largest relative contribution to the autotrophic eukaryote community in all treatments. EPS concentration was four times higher in CEWAF tanks compared to other treatments. Changes in particle size distributions (a proxy for aggregates) over time indicated that a higher degree of particle aggregation occurred in both the CEWAF and DCEWAF treatments than the WAF or Controls. Our results demonstrate that chemically dispersed oil has more negative impacts on photophysiology, phytoplankton community structure and aggregation dynamics than oil alone, with potential implications for export processes that affect the distribution and turnover of carbon and oil in the water column.

Chemotactic Response of Marine Bacteria to Hydrocarbons: Experimental and Theoretical Analysis

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Marine oil snow provides a food and energy source for microorganisms that are able to degrade hydrocarbons in the trapped oil. Interestingly, some motile marine bacteria (e.g. *Halomonas sp*.) exhibit chemotaxis toward these hydrocarbons, i.e. they swim preferentially toward chemicals, which they perceive to be beneficial for their survival. After the Macondo Well oil spill, it was reported that the bacterial density in a plume of dispersed oil was two orders of magnitude greater than the background level surrounding the plume. Processes that concentrate bacteria in the vicinity of dispersed oil affect the formation of marine oil snow and the biodegradation of the hydrocarbons. Both outcomes are critical to oil spill clean up and environmental restoration. To analyze chemotaxis we exposed a *Halomonas* strain to hexadecane in a microfluidic device designed such that migration of bacteria is solely in response to a linear gradient of hexadecane. This device allows us to readily quantify chemotaxis from the resulting bacterial distribution. Experimental data was used to determine parameters for a theoretical model of bacterial motility and chemotaxis derived from first principles. Specifically, the random motility coefficient was obtained from experiments in a hydrocarbon-free condition and chemotaxis parameters were determined from experiments over a range of hexadecane concentrations. The parameters we obtained were compared with previously published responses of *Pseudomonas putida* to the hydrocarbon toluene. As expected the faster swimming speed of the *Halomonas* strain allowed its density to reach a steady state in the device in less time than *P. putida*. This research enables us to understand the extent to which bacterial chemotactic processes can influence remediation of dissolved oil compounds, which can then aid decisions on whether to use other techniques (such as dispersants) to treat oil spills in the future.

Modeling the Conditions Required for a MOSSFA Event

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Marine Oil Snow Sedimentation and Flocculant Accumulation events are known to be important for removing oil from surface waters and transporting it to the deep ocean and sea floor. After the Deepwater Horizon oil spill, estimates of up to 14% of the oil spilled into the environment ended up on the sea floor. Similarly, estimates of between 3-25% of the spilled oil was transported to the seafloor after the Ixtoc-I oil spill in 1979. It is thought that aggregates of oil and marine snow (marine-oil-snow, MOS) are the main vehicles of transport for oil from the surface ocean to the sea floor, and high concentrations of marine-oil-snow were observed in the water column shortly after the Deepwater Horizon oil spill. MOS formation depends on the size distributions of oil and non-oils particles (e.g. phytoplankton, mineral particles, fecal pellets etc.) in the water column. We have used a stochastic Lagrangian particle aggregation model to delineate the conditions under which significant MOS form and under which MOSSFA events occur. To do this, we have varied biological parameters (e.g. phytoplankton concentrations and sizes), inorganic particle properties (mineral particle concentrations and composition), and physical parameters (e.g. turbulence) that affect particle aggregation and settling rates. We compare our results with previous models of oil clearance from the surface waters and with estimates of conditions during the Deepwater Horizon and Ixtoc-I oil spills.

Insights into the Adaptation of Hydrocarbon-Degrading Microbes to Life at High Pressure: The Role of Motility and Chemotaxis

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The unexpectedly large microbial response to the deep-sea oil plume that developed at approximately 1,200 meters below sea level (mbsl) following the Deepwater Horizon (DPWH) oil spill raised issues regarding the impact of hydrostatic pressure on microbial access to, and degradation of, hydrocarbons. While studies have demonstrated that high hydrostatic pressure inhibits the motility of mesophilic bacteria (Meganathan & Marquis, 1973; Eloe *et al*., 2008) and microbial hydrocarbon degradation (Nguyen *et al*., 2018), the impact of pressure on hydrocarbon chemotaxis has yet to be investigated. Here we address this question using hydrocarbon-degrading bacteria - belonging to the genera *Halomonas, Shewanella*, and *Alcanivorax* - isolated from the Gulf of Mexico following DPWH as model organisms. The long-term goal of this research is to understand these impacts in terms of hydrocarbon biodegradation in the deep sea. We originally hypothesized that our model strains - since they are not piezophiles - will show inhibited motility and chemotaxis at depths relevant to the DPWH oil spill. Impacts on motility (swimming speed and fraction of motile cells as a function of pressure) were assessed using a high pressure microscopy system in collaboration with Dr. Masayoshi Nishiyama from Kyoto University, Japan, while a capillary assay is being used to determine pressure effects on chemotaxis towards various hydrocarbons - including heptane, hexadecane, and MC-252 crude oil. The study strains were found to be relatively resilient to pressure in terms of short-term motility, showing nearly no change in fraction of motile cells and swimming speed between 0.1 and 60 MPa (equivalent to ~6,000 mbsl). On the other hand, hydrocarbon chemotaxis is much more sensitive to increased hydrostatic pressure, cutting out completely at pressure as low as 10-25 MPa. Ongoing studies include isolation and characterization of motility and chemotaxis mutants using transposon mutagenesis, to determine genes that are important for hydrocarbon chemotaxis both at atmospheric and high pressure. Cumulatively, these analyses will enable a better understanding of the impacts of pressure on microbial motility and hydrocarbon chemotaxis in the deep sea.

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Influence of Hydrodynamic Interactions and Chemotaxis on Accumulation of Bacteria Near Oil Drops

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Marine bacteria played a pivotal role in the degradation of the crude oil spilled in the Deepwater Horizon oil-spill. As oil is insoluble in water, degradation takes place at the oil-water interface. It is well known that the fluid flow set up by a swimming bacterium is affected by nearby interfaces, resulting in changes in bacterial motility. We postulate that these 'hydrodynamic interactions' have important consequences in bioremediation. We first discuss the swimming dynamics of a model bacterium near a stationary oil drop. We demonstrate how hydrodynamic interactions cause bacteria accumulation at the surface of oil drops that are larger than a critical size. We find that addition of surfactant increases the likelihood of this surface accumulation. But hydrodynamics fails in guiding the colonization of stationary nutrient sources that lie far away from a bacterium. In these scenarios, we postulate an initial chemotactic approach followed by hydrodynamic attraction, to be a possible mechanism that allows bacteria to find nutrition. We unveil non-trivial ways in which chemotaxis and hydrodynamics combine and yield quite different distributions of bacteria around oil drops. Finally, we describe the hydrodynamics mediated capture of bacteria around nutrient sources like sinking marine snow, or rising oil drops. We discuss parametric regimes-like size and density of the source, and motility and morphology of the bacterium-under which hydrodynamics enables the passive capture of an approaching bacterium onto the source. We find that hydrodynamic trapping significantly amplifies the nutrient exposure of both chemotactic and non-chemotactic bacteria. Our studies provide a consistent description of how motility, fluid flow and nutrient distribution affect foraging by marine microbes. We develop insights regarding the mechanisms governing microbial behavior near nutrient sources, isolate their effects, and offer greater predictability of this phenomenon.

022: Where the Oil Goes: Applications of Modeling for Oil Fate, Transport, Biological Effects and Safety

A Framework for Modeling Near-surface Processes for Oil Spills

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NOAA

Oil spill modeling algorithms are often based on the assumption that oil on the surface is a film with a defined surface area and thickness. This assumption then guides algorithms for estimating evaporation and other surface processes. However, the situation in a real sea state in other than calm conditions is quite a bit more complex. Real sea states are characterized by many waves of varying height, period and phase, often with breaking or white capping in stronger winds. Under these conditions, the oil at the surface is not really a continuous film.

This complication is considered in traditional modeling of the dispersion or entrainment process: The turbulence of the waves, primarily white capping, is considered to break the oil film into droplets, the smallest of which do not rise to the surface and are thus "dispersed". Oil that is in droplets under the

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surface is not exposed to either the water or the atmosphere in the same way as a surface film. In particular, these models have difficulty capturing the partitioning of oil between evaporation, dissolution, and dispersion of very small droplets.

This work presents a framework for considering the film processes vs. droplet processes, so that the model can more realistically capture the nature of evaporation from the surface and dissolution and degradation while under the surface. In a real sea state, the level of turbulence is highly variable; as a gross simplification, the near surface is fairly calm in-between white caps, and experiences a large but brief burst of turbulence as a white cap passes by. This burst of turbulence breaks the oil into droplets, and pushes them under the water. After the white cap passes, the turbulent energy level rapidly drops, and the droplets rise to the surface.

This formulation allows us to separately model underwater processes such as dissolution, biodegradation, and oil-sediment aggregation, and surface processes such as evaporation and photo-oxidation.

Constrained Scales in Forecasting the Gulf of Mexico Currents

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Present near real time data stream from satellite and *in-situ* sources have limited capability for observing spatial and temporal scales. When these data are used to regularly correct forecast ocean models, there is also a constraint on the scales that are predicted in the forecast. Larger scales that are well resolved have lower prediction errors than small scales not resolved. The scales at which there is skill in the forecast are “constrained” while smaller scales are not constrained. The regular corrections made to the initial condition through the data assimilation have a prescribed decorrelation length scale, which does vary spatially, and this scale must be consistent with the constrained scales.

The LASER drifter observations provide a data source for testing this problem. The LASER experiment consists of 1000 surface drifters deployed January through February 2016, and the drifters transmitted position into March 2016. We use velocity inferred from successive positions to evaluate constrained scales in model experiments.

A series of ocean forecast experiments are set up with a range of decorrelation scales from 9 km to 140 km. The scales constrained in the model experiments are not the same as the decorrelation scale of the assimilation process. The LASER data are used to determine the constrained scales. As small scale unconstrained features are filtered from the model, the correlation to the LASER data increases. If the filtered scale is too large, correlation decreases as constrained features are smoothed out. The spatial scale at which the correlation to the LASER data is largest provides an estimate of the constrained scales. We can then evaluate the constrained scales as a function of the assimilation decorrelation scale from the experiments.

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Biased Wind Measurements in Estuarine Waters

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Near surface wind - conventionally measured 10 m above the ground, U_{10} - is a fundamental variable for many processes acting in bays and estuaries. For practical reasons, wind in bays and estuaries is often measured at the land-water interface, e.g. on docks, piers, and jetties. By analyzing time-series of U_{10} from 15 stations in the Mississippi Delta, Louisiana, we show that wind measurements at the land-water interface are biased and not representative of the wind over estuarine waters. Specifically, measurements at the land-water interface underestimate the speed of winds blowing from land, because even short (<1 km) stretches of land with large bed roughness can significantly reduce U_{10}. Wind measured next to large channels is biased not only in speed but also in direction, which tends to align with the channel axis. We suggest that very local (<1 km) variability in the boundary layer properties contributes to the large spatial variability of the measured estuarine wind field. Simple anisotropic corrections based on bed roughness should be applied to measurements made at the land-water interface to estimate wind over adjacent estuarine waters. Alternatively, wind measured at offshore stations - even if located hundreds of km away - provide reliable estimates of estuarine wind. A more systematic use of wind measurements would likely increase the accuracy of estuarine numerical models and allow for more direct comparison between different estuarine systems.

Wind LiDAR Measurements of Wind Turbulence and Aerosol Distribution in the Marine Atmospheric Boundary Layer

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Spatio-temporal organization and energy distribution of wind turbulence in the marine atmospheric boundary layer (ABL) play a fundamental role on production of aerosolized oil droplets at the sea-air interface, their transport and deposition over a coastal region. In order to investigate these complex physical processes, a scanning Doppler wind LiDAR was deployed over the coast of the Galveston Island State Park, Texas, to measure wind speed, while distribution of the marine aerosol was probed through the LiDAR backscatter coefficient. Atmospheric stability and turbulent surface fluxes were monitored through a 3D sonic anemometer installed on a 3-m tripod deployed in proximity of the LiDAR location. The LiDAR was at a distance of about 100 m from the shore and its measurement range was about 2 km. Various LiDAR scans were executed, such as conical scans with different elevation angles (PPI), scans over vertical planes (RHI) and fixed scans over several lines of sight in order to maximize the temporal resolution of the LiDAR measurements (about 2 Hz). The spatial resolution in the direction of the LiDAR laser beam varied between 9 m and 18 m, while it was smaller than 1 m in the transverse and vertical directions for PPI and RHI scans. Statistics and energy spectra of wind speed and aerosol distribution are investigated for different regimes of the atmospheric stability, surface wind speed, wind shear and wave characteristics. This research aims unveiling the mutual interaction between aerosol distribution and organization of coherent turbulent structures in the marine ABL. Furthermore, quantifying variability of aerosol fluxes at the sea-air interface for different wind and wave conditions is also a scope of the project. These field observations will be instrumental for development of eddy-diffusivity models used for regional meteorology algorithms in order to provide more accurate

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predictions of aerosol transport, fate and deposition over coastal regions. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

Simulation of Surface Conditions and Plume Extent from Shallow Oil and Gas Spills

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Shallow releases of gas-dominated plumes from oil and gas blowouts can transport a large amount of gas and oil to the surface within a dynamic plume creating hazardous conditions to floating structures and response personnel. Horizontal surface waves and reduction of buoyancy near the surface due to presence of gas in the surface layers affect the stability of floating structures. The extent of this surfacing plume limits the access of response personnel to reach the source of the release for capping or mitigation purposes. The amount of gasses and volatile compounds released into the atmosphere may be a fire hazard and create hazardous breathing conditions. We improved an existing near-field plume model of oil and gas to predict the extent of the surface plume and the reduction of surface effective density. We simulated plumes with variable gas to oil ratios and a release flowrate similar to the IXTOC-1 plume in Southern Gulf of Mexico, which released about 30,000 barrels of oil per day from a source at 50 m water depth. The predicted buoyancy reduction near the surface varied from about 980-965 kgm^{-3} for gas to oil ratio variation of 1500-4000 scf bbl^{-1} and the dynamic plume extent varied from 110-140 m at the surface. Further development of the model is proposed to predict the initial unsteady surface wave created by the impinging plume at the surface.

Revisiting the Deepwater Horizon Spill: Effects of Oil Droplet Size Distribution and River Fronts

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An open source ocean trajectory framework, OpenDrift, is used to simulate the 2010 Deepwater Horizon oil spill. Metocean forcing data are taken from the University of Miami 1/50^{o} HYCOM ocean model with realistic river input and ECMWF global forecasts of wind and wave parameters with 0.125^{o} resolution. OpenDrift includes the fully fledged oil drift module OpenOil which is coupled to the NOAA oil chemistry database with nearly 1000 oil types. It allows for multiple choices of forcing data and parameterizations. Here, we look at the effect of using a newly developed oil droplet size distribution formulation of Li *et al*. (2017), which provides a higher fraction of larger droplets compared to previous formulations. We show that the choice of formulation has dramatic effect on the amount of oil stranded in the simulations, since the size of the droplets decides how much oil is present at the surface and hence subject to wind and Stokes drift. We also look at the effect of removing river outflow in the ocean model to investigate the effects of the river induced fronts on oil spreading. We found a consistent effect on the amount of stranded oil, and considerable impacts on the location of the surface oil patch.

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From Droplet Generation in a Turbulent Release to Final Loss through Biodegradation - SINTEF Contributions to the DROPPS I, II, and III Programs

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The DROPPS I, II and III programs at SINTEF Ocean focused on oil droplets: from droplet generation in a turbulent release to final loss through fate processes, such as biodegradation. Our goal was to improve the wholistic understanding of oil droplets in the environment and the DWH oil spill in particular. Response options, such as Subsurface Dispersant Injection (SSDI) and *in-situ* burn (ISB) are key techniques that were examined. Controlling droplet size distribution (DSD) allows control of where in the water column the oil will reside, so selection of this response option depends on the local natural Resources At Risk (RAR). Studying the effects of deepwater (higher) pressures on droplet and gas bubble formation allows more robust predictions. Droplet breakup leads to smaller droplets with the addition of chemical dispersant both within a well blowout and under surface wave action. Surfactants from the dispersant can remain on rising oil droplets, leading to increased dispersibility at the surface with wave energy. Aerosolization of oil droplets in being modeled now. A wider range of droplet and gas bubble diameters can be measured automatically, using a silhouette camera. Once released into the ocean, oil droplets begin to biodegrade. Water temperature was shown not to influence biodegradation rates when using local, acclimatized bacteria. However, by comparing the pristine water in Trondheim Fjord, as compared to the Gulf of Mexico, the propane jumpstart in biodegradation appears to be dependent on natural gas development activity occurring in the area. Biodegradation consumes dissolved oxygen (DO) during the breakdown process, leaving a trail of anomalously low DO water as a tracer of previous oil droplet contamination. Our future work will include continuing laboratory studies and examining other potential scenarios in the Gulf of Mexico that could lead different response questions. SINTEF is also examining other well blowout scenarios in the Gulf of Mexico that could have different trajectory, fate or effects that were seen in 2010.

The Vertical Distribution and Horizontal Dispersion of Buoyant Materials in the Ocean Surface Boundary Layer

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Spilled oil and other buoyant marine pollutants stay in the ocean surface boundary layer due to their preferred upward motion. Using solutions of Lagrangian buoyant particles advected by turbulent ocean surface boundary layer flows computed by a large eddy simulation model, we study how particle properties and meteorological conditions influence the vertical distribution and horizontal dispersion of those particles. We will also discuss how the result could be applied to parameterize sub-grid scale velocity in operational oil spill models.

High Resolution Simulations of Oil and Gas Blowouts

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We illustrate the potential role of rotation and crossflows in oil and gas blowouts using the MITgcm in a multiphase and non-hydrostatic configuration. We also present a new numerical package, "spoil",

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which can be used and coupled with chemical and biological models, to assess the different impacts oil and gas releases may have on the environment. An application to a Deepwater Horizon like deep oil release is described and compared to observations.

Effect of Hypoxia on the Bacterial Degradation of Oil Microdroplets Traveling through a Seawater Column

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Marine oil spills often result in the formation of microdroplet clouds in the seawater column. For instance, droplet clouds may be generated either at the sea surface during the breakup of an oil slick by waves, or at the seafloor during the atomization of live crude oil extruding from a natural crack or a broken wellhead. The concentration of oil microdroplets in seawater is positively correlated with the risk of toxic effects to many marine species. It is therefore imperative to quantify the impact of key factors on the persistence and residence time of oil microdroplets in a water column.

We have recently developed a compound particle model for the biodegradation of solitary oil microdroplets moving through a water column (Kapellos *et al*., 2018). The compound particle is of the core-shell type and consists of an oily core that is successively surrounded by a bioreactive skin of negligible thickness and another bioreactive shell of finite thickness. The thin bioreactive skin represents superhydrophobic microbes that uptake oil directly from the oily phase, whereas the bioreactive shell represents a distinct biofilm phase. The new model accounts for all three biodegradation modes, i.e. interfacial uptake and bulk bioreaction in the biofilm and aqueous phases. The theoretical analysis provides estimates for the shrinking rate, size evolution and residence time of oil microdroplets in the water column, as functions of the drifting velocity, microbial kinetics, biofilm thickness, diffusivity and solubility ratios. Numerical analysis is also used to examine the profound impact of hypoxic conditions on the aerobic biodegradation of oil droplets. Model predictions will be discussed along with observations from the bacterial degradation of hydrocarbons in microfluidic devices with varying availability of dissolved oxygen. **Funding**: EU Horizon 2020 MSCA Grant 741799 - "OILY MICROCOSM" **Reference**: Kapellos, G.E., Paraskeva, C.A., Kalogerakis, N., Doyle, P.S. "Theoretical insight into the biodegradation of solitary oil microdroplets moving through a water column," *Bioengineering*, 5:15, (2018).

Vertical Distribution and Shear Dispersion of Oil in a Wind and Wave-Driven Upper Ocean: Integrating Nonlocal Fluxes into a Langmuir Turbulence Model

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Langmuir turbulence-resolving Large Eddy Simulations (LES) of oil droplets in the wave and wind-driven ocean mixed layer show that accurate parameterization of the vertical flux of buoyant tracers cannot be achieved by a traditional down-gradient flux, i.e. an eddy diffusivity. This recognition confirms and extends other GoMRI LES findings bearing fundamentally on construction of physical oil spill models embedded within a regional-scale ocean simulation. This study addresses the problem by integrating nonlocal flux components into an otherwise single-point second moment closure model of Langmuir

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turbulence. The approach unifies convective and Langmuir-driven nonlocal fluxes, and applies to both buoyant tracers without any surface flux, and to non-buoyant tracers with nonzero surface flux.

Large-Eddy Simulations of Transport of Aerosolized Oil Droplets in Marine Atmospheric Boundary Layer

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In the aftermath of an offshore oil spill accident, the spilled crude oil can stay on the ocean surface for a long period of time before being restored. During this period, frequently occurring events at the sea surface, such as wave breaking and bubble burst, can generate considerable amount of small aerosolized oil droplets, which can then be further transported upward and downwind by turbulent wind in the marine atmospheric boundary layer. This process can induce serious threats for public health if it occurs over coastal ocean near high population urban cities. In this study, large-eddy simulations (LES) are performed to study the transport of aerosolized small oil droplets in wind over progressive sea-surface waves. The LES model uses a boundary fitted computational grid system that follows the instantaneous sea-surface geometry to capture the turbulent flow structures and transport phenomena near the sea surface. The LES model utilizes different spatial discretization methods for different aspects of the flow problem, i.e. a hybrid pseudo-spectral and finite-difference method for simulating the turbulent wind, and a finite-difference method with a combination of upwinding scheme and central difference scheme for simulating the oil aerosol transport. Using this LES model, a set of simulations with various wind and sea-surface wave conditions are performed to investigate their effects on the vertical and lateral transports of oil aerosols. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

023: Understanding Processes Associated with Chronic Hydrocarbon Releases from Natural and Accidental Sources

The Relative Importance of Submarine Seepage to Carbon Pools of the Gulf of Mexico

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Organic C pools in the GOM are unique compared other seas. In addition to modern surface production, one of their primary sources of organic matter is the microbial cycling of hydrocarbons. Our goal was to characterize $\delta^{13}C$ and $\Delta^{14}C$ signatures of suspended, sinking and sedimentary particulate organic C from seep and North Central Gulf non-seep (but DWH affected) sites. A 2nd goal was to determine the recovery of this C pool following the DWH event. We hypothesized that at sites removed from hydrocarbon seep sources, we would observe depletion of isotopic signatures following the spill and subsequent recovery of the isotopic signatures, shifting towards more background-like enriched values. We found extensive natural variability in both $\delta^{13}C$ and $\Delta^{14}C$ of suspended

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particulates. Depth, partitioned into euphotic (<300m) and deep (>300m), was the main driver of spatial $\delta^{13}C$ differences with deeper depths exhibiting ^{13}C depletion. Both deeper depths and proximity to the sources of natural seepage resulted in ^{14}C depletion. At deep-water non-seep sites in the North Central Gulf (NCG) we observed decreasing $\Delta^{14}C$ signatures from 2010-2012, followed by isotopic enrichment from 2012-2014, consistent with the hypothesis described above. At seep sites, we estimated that suspended particles could incorporate as much as 70% of their carbon from material ultimately derived and transformed from oil. Sinking particulates were collected 2010- 2016 in sediment traps. Near the spill site, changes in $\Delta^{14}C$ indicated a 3-year recovery period. $\delta^{34}S$ indicated 1-2 years. Under post-spill baseline conditions, carbon inputs to sinking particulates in the northern Gulf were dominated by surface marine production (80-85%) and riverine inputs (15-20%). At the seep site we observed the incorporation of naturally seeped oil into sinking particles, a natural MOSSFA event. Determination of post-spill baselines for these isotopic signatures allows for evaluation of anthropogenic inputs in future.

Deep-Sea *Callogorgia delta* Octocorals Closely Associated with Active Seepage Are in Significantly Better Condition than Colonies Found Far from Active Seepage

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The distribution and tissue stable isotope values for the deep-living coral *Callogorgia delta* indicate that unlike other corals, *C. delta* is often associated with active seeps (Quattrini *et al*., 2013) and obtains nutritional C and N from seep primary productivity. As part of a study to examine the effects of natural seepage on corals, we used imagery to compare the condition and growth of *C. delta* colonies near and far from active seeps. We identified aggregations of *C. delta* within meters of sources of seepage ("seep corals") and others at least 20 m away from visible signs of seepage ("non-seep corals") in three lease blocks in the Gulf of Mexico. Interaction, or lack of interaction, of these aggregations with active seeps was confirmed using tissue stable C and N values. Examination of the condition of the corals, using methods developed to identify impact from the DWH spill, indicated that the seep *C. delta* colonies were in significantly better condition than the non-seep colonies. On average, 6.5% (SD= 4.4%) of the branches of seep and 15.6% (SD=19.2%) of branches of non-seep corals were ranked as not healthy. Although our analysis of growth is still in progress, preliminary data indicates no significant difference between groups, perhaps because of the very large variability in growth rates measured among both sets of colonies. Yearly growth, as a fraction of total branch length, ranged up to 14% in seep associated and up to 25% in non-seep associated colonies. Overall, *C. delta* grew much faster than the deeper living species of *Paramuricea spp*. studied using the same method. Average yearly growth for *C delta* yielded 5% new branch length per colony compared to averages of 0.25 to 0.75% depending on site and species of *Paramuricea spp*. Moreover, yearly growth was detected in 87% of colonies of *C. delta* analyzed so far, while on average only 9 to 53% of *Paramuricea* colonies at the deeper sites showed detectable growth between 2016 and 2017.

Temporal Variability of Vertical Upwelling of a Natural Hydrocarbon Seep and Its Connection to the Ocean Surface

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Vertical upwelling measurements of hydrocarbon seeps in the Gulf of Mexico are limited due to the paucity of long-term measurements and due to the temporal variability of the bubble seeps and boundary layer dynamics. This work offers an unprecedented insight into a seafloor seepage, its movement through the water column and its fate on the sea surface. Through the initial phase of the study, a Kongsberg EM2040 multibeam mounted on an AUV was used to collect the acoustic signature of the active seeps in an ~2200x1600 m^2 area of lease block GC600 in the Gulf of Mexico. Further visual inspections carried out by a remotely operated unmanned vehicle (ROV) lead to the selection of Mega Plume (27° 22' 11.49" N; 90° 34' 15.99" W) for further investigations. Temporal variation of the vertical velocity induced by the seep was measured using acoustic scintillation flow meter (ASFM) at 20 mab. Underway measurements included a 600 kHz TRDI Workhorse Monitor acoustic Doppler current profiler (ADCP) and a vertical array of SeaBird conductivity-temperature-depth (CTD) sensors which were positioned in vicinity of the seep to measure the physical oceanography processes such as turbulent kinetic energy (TKE) production and dissipation, buoyancy flux, and tidal and near-inertial currents. On the recovery cruise, the Ocean ProHD TV camera on the ROV Millennium recorded detailed color movies of the seep source. Collected images were processed to obtain the vertical and horizontal speeds of bubbles and their size distribution at the source. Initial seep simulations using the Texas A&M oil spill (outfall) calculator (TAMOC) model approximated the surfacing mass fluxes and locations of oil for different bubble size classes released from the seep. Using these coordinates, surface images of Sentinel-1A C band slicks were obtained. After preliminary screening, a semi-automated image processing routine, the texture classifying neural network algorithm (TCNNA) was employed to delineate observed oil slicks within SAR images from which the oil discharge at the seep vent can be estimated. A custom-made funnel handled by the millennium ROV was used to measure the instantaneous MegaPlume discharge on Jan 30, 2018.

Comparison between NETL High Pressure Water Tunnel Experiment and Numerical Modeling for Analysis of Natural Gas Bubble Behavior in the Ocean

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In order to understand the fundamental behavior of natural gas bubbles in the ocean environment, the National Energy Technology Laboratory (NETL) conducted experiments for methane and mixture bubbles (methane/ethane/propane) in their high-pressure water tunnel (HPWT) under different circumstances (pressure, temperature, salinity and dissolved gas concentration). For each experiment, images of individual bubbles were recorded with a high-speed and high-definition camera to observe the morphological behavior of hydrate armored bubbles and the change of bubble size over time in simulated ocean conditions. We adapted our numerical model, the Texas A&M Oil spill Calculator (TAMOC), to simulate the experiments in the NETL HPWT and compared our results with their report by Levine *et al* (2015). Through this comparison, we were able to validate our numerical model for the mass transfer between the bubbles and water column. The simulation helps understand the effect of hydrate skins on the mass transfer rates during and after hydrate formation and dissociation. Also, these simulation results give us insight of 1) which mass transfer rate coefficients are appropriate before and after the transition due to gas hydrate, and 2) whether the concentration at the

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bubble/water interface in the mass transfer equation should be the solubility of methane gas or methane hydrate. Our results are that dirty bubble mass transfer rates are accurate with methane gas solubility at the bubble/water interface.

Application of Physical, Chemical, Biological and Geological Constraints on Petroleum Seepage at MC20

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In 2004 Hurricane Ivan induced a regional submarine slope failure that inundated block 20 of the Mississippi Canyon protraction unit. The flow transported and then toppled Taylor Energy's MC20 platform, which became partially buried by the 40-foot emplacement of new sediment, and came to rest 550 feet downslope from its original location. Prior to the Hurricane the platform was producing ~1000 barrels of oil per day, with >99.5% of production potential coming from nine wells; the remaining 16 wells had been produced in the preceding decades to the point they no longer flowed oil without stimulation. Following the Hurricane, oil freely leaked from a subset of wells, focused at two seafloor locations: the former location of the platform which retained the buried well heads, and near to the fallen platform where the conductor pipes (the pipes that connect the platform to well heads) had severed and become buried. By 2011 nine intervention wells had been completed for the producing wells mentioned above, which eliminated seafloor discharge at multiple locations including the site over the wellheads, but a persistent oil sheen remains in the vicinity of the platform. The contemporary surface sheen appears to emanate from the area near to the platform that overlies the severed conductor pipes. This area has developed into a large scour pit from which oil and gas seep. The focus of this talk is on placing holistic constraints on the processes active at this site, including biological, chemical, physical and geological processes that define the immediate source of seeping petroleum and the rates at which such processes occur.

A Chemical Contaminants Assessment of the Sediments, Water, Oil, and Gas from the Mississippi Block 20 Site, Gulf of Mexico

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A joint BSEE and NOAA project has obtained water, oil, and gas samples from the persistent hydrocarbon plume emanating from the MC20 site offshore South Pass LA, 1-7 September 2018. A unique sampling device (bubblometer) was deployed from an industry-class ROV in order to collect material from the plume near its seafloor origin and to recover pristine samples. Analysis will provide characterization and determination of the weathering of oil from within the water column and at the surface. Gas samples collected will determine the nature of the gas, biogenic vs thermogenic, being released at the site. Sediment samples collected from the ship by box and gravity cores are analyzed for a suite of over 290 chemical contaminants with a special focus on polycyclic aromatic hydrocarbons (PAHs). Raw oil and dissolved PAH samples are analyzed using multiple methods including PAH fingerprinting and biomarkers.

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Insights from the Long-Term Taylor Energy Response at the Mississippi Canyon Block 20: A Review of Several Decades of Chemical Data

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Following the 2004 toppling and burial of the Taylor Energy Company's platform in the northern Gulf of Mexico at Mississippi Canyon block 20 (MC-20) by a massive hurricane-induced submarine slide, the wreckage field has hosted a pervasive surface sheen. However, the immediate source feeding the sheens and the rate of release are uncertain and the focus of ongoing response activities. We conducted a forensic investigation of analytical data from 1986 to 2018 to assess the likelihood of a single dominant source (e.g., a leaking well) feeding the contemporary slick, which we compared to sediment samples and slick samples from the site. Our results show a plurality of biodegraded slick oils sufficiently complex that a single source is excluded. A forensic comparison of sheens collected at different times with sediments indicates multiple oils feeding the sheens with contributions that vary in space and time. Collectively, the heterogeneity in surface sheen, the degree of biodegradation in both surface sheens and sediment oils, and the extent of sediment oiling indicate the contemporary sheen at the MC20 site derives primarily from a plural assortment of residual oil from the saturated sediments near the downed jacket. These results are inconsistent with surface sheens being from an ongoing release and are difficult to reconcile with recent remote sensing-based reports that claim flow rates in excess of 39.71 to 110.83 cubic meters per day. The distinction between residual oil in sediment and active ongoing discharge is important because it dictates response options that are viable and appropriate for the site, a topic of active consideration.

Measuring Oil Residence Time with GPS-Drifters, Satellites, and Unmanned Aerial Systems (UAS)

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During accidental oil spills, the assessment of the magnitude of oil releases is crucial for the planning and implementation of counter-measures for oil spill response operations. For decades (since 1930) operational response procedures have been focused on the identification of floating oil extents and thicknesses classification from aerial observation and from available remote sensing platforms. These procedures have evolved and have been eagerly adapted as advancements in remote sensing technology have become available. In this study we have examined a comparison of oil spill volume calculations using the most current industry standards from the Bonn Agreement, NOAA, and the ASTM-F2534. Coupling a surface oil resident time study using GPS tracked drifters, we have developed oil volume estimates to calculate a flux rate from the chronic oil slicks observed around the Gulf of Mexico MC20.

Two Decades of *In-Situ* Observation Guiding MC20 Response Operations: What We Have Learned and Why It Matters

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Forensic analysis of the MC20 platform's destruction indicates that the hurricane-induced turbidity flow which toppled it was unlike anything previously encountered or contemplated by US regulatory policy. The unusual characteristics of this disaster, combined with the natural complexity of this shelf break region, have required careful planning and execution of response operations in order to minimize environmental impact and safety risks. Over the past two decades numerous *in-situ* surveys have been conducted at the MC20 site to inform these response operations using an array of advanced in-situ technologies operated from surface ships, remotely operated vehicles, autonomous underwater vehicles, seafloor tethered platforms, and saturation divers. Under the auspices of the Unified Incident Command, results from these operations have been used to develop a composite 4-dimmensional model of the site in order to aid situational awareness, with particular emphasis on understanding the persistent oil sheen, along with the potential utility, risks, and consequences of specific response actions. This talk presents an overview of the in-situ technologies and methods used to inform response operations, examines the 4D model developed from these studies and its use in guiding response operations, as well as the physical and chemical evolution of the MC20 site over the past 14 years.

Surface and ROV-Based Acoustic Mapping of the MC20 Oil and Gas Leak in the Northern Gulf of Mexico

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In 2004, Hurricane Ivan swept through the northern Gulf of Mexico and toppled the MC20 Taylor Energy oil and gas platform. Following initial surveys to locate the downed platform jacket and discovery of the plume and surface sheen, in 2018 NOAA and partners conducted a comprehensive assessment of the MC20 site. Using a combination of acoustical and optical techniques, as well as direct capture of gas and oil samples, the team provided concrete evidence of oil and gas discharging from the seafloor to the surface sheen expression. Our presentation will focus on the ship-based surface hydroacoustic surveys characterizing the spatial structure of the plumes. Inspection of the acoustic backscatter indicates multiple plumes emitting from more than one origin on the seafloor rising to the surface. Broad-band acoustic signal processing discriminated backscatter into indicators of oil and gas plumes within the water column. Closer inspection using ROV-integrated echosounders and multibeam sonars confirm the presence of at least 4 seeps emitting from the seafloor with acoustic signatures indicating oil separated from gas as well as oil and gas mixtures. The separation of oil from gas from each of the seep sources was further verified using *in-situ* optical and direct capture methods. The assessment provides further evidence of an oil and gas leak that has likely occurred since the original toppling of the MC20 platform.

Character and Dynamics of Surface Sheens at MC20

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An underwater mudslide during hurricane Ivan sheared the legs of the MC20 platform, moved the platform approximately 550 feet, bent well piping, and buried damaged wells below newly deposited mud. This unforeseen event and associated extraordinary damage to the MC20 structure has resulted in the presence of a persistent surface sheen at the site. Under the Unified Command, a workgroup was chartered to "assist in identifying the seabed location(s) of the hydrocarbon source(s) causing the continue sheening in MC20". Data collection included: water column velocity measurements (profiles); time-stamped, georeferenced aerial observations of sheen origination(s); forensic analysis of discrete samples of recently surfaced residual oil (rosebuds); time-stamped, georeferenced locations of surface observations of rosebuds and dry gas bubbles at the origin of the sheen and locations along the surfacing trajectory; conductivity, temperature, and speed of sound depth profiles; and acoustic multi-beam imagery of water column anomalies and bathymetry. This talk presents information on characteristics of surfacing material and dynamics of surface expressions including models of upward trajectory of hypothetical releases and subsequent comparison of model output to observations at the surface and multibeam imagery of acoustic water column anomalies.

Quantitative Imaging of Oil and Gas Bubbles Discharged at MC20

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Prominent plumes of hydrocarbons in the water column and oil slicks on the surface have been reported from independent surveys in MC20 lease block, located approximately 15 km offshore South Pass, LA. Plumes emanate from the near the wreckage of the Taylor Energy platform, toppled by a mudslide during Hurricane Ivan in 2004. A unique sampling device (bubblometer) deployed from the Comanche ROV and R/V Brooks McCall during 1-7 September 2018. Acoustic surveys identified two groups of smaller bubble streams, at least five in total, emanating from erosion pits at the NW corner of the well jacket. Comanche entered the streams near the seabed (~130 m depth) to quantify this material. Bubbles of oil and gas passed through a 30x30 cm wide, 20 cm high visualization chamber. They were imaged by a calibrated HD video camera with high-intensity lamps that resolved 4 pixels per mm. Separate streams ranged in composition from gas bubbles discolored by oil, to dark spheroids of liquid oil, to oblate blobs that appeared weathered. This indicated differences among the separate bubble streams. Vigorously rising oil and gas bubbles were also observed above the well jacket (~110 m and higher) as the individual streams merged into larger plumes. After passing through the chamber, discrete samples of oil and gas were collected into pressure cylinders for laboratory analysis. Measurement of bubbles will provide size frequency statistics, bubble density samples, and qualitative gas to oil ratios from the plume.

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