Abstracts for Poster Presentations

Organized by Session

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

Historical Dispersant Use in U.S. Waters

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Dispersants are a rarely used response tool in the U.S, but the public and scientific controversy over their use may lead the public and policy makers to conclude otherwise. Over the past 40 years and over 400,000-reported potential spill incidents, we are aware of only 26 incidents in the United States where dispersants have only been utilized, and no-instances since the Deepwater Horizon Spill. This presentation will summarize the known cases where dispersants have been used.

Fluxes between River, Estuary and Coastal Ocean: State of the Art and Future Challenges

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Fluxes of water, sediment, nutrients, carbon, oil and other constituents between rivers, wetlands, estuaries, and coastal areas are critical components of ecosystems functioning, which are also influenced by interactions with the open ocean. Most flux studies have addressed some specific aspect of interactions within one or two of these units, but only a few have focused on the integrated system. To the extent of our knowledge, no study has yet produced a synoptic picture of the fluxes for the entire riverine-wetland-estuarine-coastal-open ocean continuum in the Gulf of Mexico. The difficulties of performing such a study can be partially attributed to the compartmental structure of research funding as well as the historic separation of different areas of study, such as blue and brown water, fresh and saline areas, riverine and coastal settings. In addition, logistics limits the ability to perform flux studies during storms, biasing the results toward fair weather conditions. For example, little is known about fluxes between estuaries and coastal ocean during both moderate (e.g., frontal passages) and extreme (e.g., hurricanes) weather events. This synthesis aims to 1) summarize the state of the art in terms of the understanding of fluxes of water, sediment, nutrients, carbon, oil and other constituents between river, wetland, estuary, coastal ocean and open ocean; 2) assess the specific contributions of GoMRI-funded research to the advancements in this field, and, 3) identify some critical but currently missing research component, which could provide a blueprint for the future.

P-002: Turbulent Behavior of Deepwater Blowouts

Eulerian Large Eddy Simulations of Bubble-Driven Plume with Finite Bubble Void Fraction

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The discharge of bubble-driven hydrocarbon plumes from subsea oil spills can cause severe adverse effects to the ocean ecosystem. Accurately modeling the characteristics of the plume structure and material dispersion has become a crucial task for supporting decision making in oil spill response and remediation. In recent years, the Eulerian-Eulerian large eddy simulation (EE-LES) approach has become a valuable numerical tool for simulating the detailed dynamics of the bubble-driven multiphase plume. Despite its recent successful applications in oil spill modeling, EE-LES models often make the approximation of very low void fraction for the dispersed phase (e.g. bubbles and droplets) so that the carrier flow can still be treated as a single-phase incompressible flow for the sake of reducing computational cost. This approximation may become inappropriate under high plume discharge rate in regions close to the plume source, where the dynamics of the plume can be strongly affected by the finite void fractions of the dispersed phase. In this study, an EE-LES model for bubble-driven plume with finite bubble void fraction is developed. Preliminary tests for lab-scale cases are conducted to simulate the plume structure and dye dispersion in a stably stratified fluid with a constant cross-plume current. The results are compared to those obtained from an EE-LES model with a low-void-fraction approximation. The new model is shown to efficiently capture the effects of bubble void fraction on the plume characteristics, which is found to be vital for accurately determining both the main plume structure as well as the vertical/lateral dispersion of dye concentration towards the downstream of the cross flow. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

Observed High Frequency Internal Wave Accompanied by Symmetrical Unstable Fronts

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A marine X-band doppler radar observed a series organized bands with interval ~150 m near the submesoscale front (SF) in the northern Gulf of Mexico during the Lagrangian Submesoscale Experiment (LASER). Analysis of the characteristics of these bands excluded the possibility that they were Langmuir cells or the surface footprint of atmospheric boundary layer rolls. Vertical profile of potential vorticity indicated that the dynamics satisfied the symmetric instability condition. However, the bands propagated away fronts at speeds of ~ 0.2 m/s as observed in continuous radar images, which was consistent with high frequency internal waves (HIW). Further analysis showed that HIWs were likely generated by the symmetric unstable SF. These observations captured the surface signature of HIWs radiated from symmetric unstable fronts for the first time, which represents a new mechanism for energy cascade in the upper ocean.

Experiments on Multiphase Plumes in a Rotating Environment

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A crucial component for the dynamics of a multiphase plume, such as the Deepwater Horizon oil plume, is the slip velocity of oil droplets and gas bubbles. Due to this slip velocity, oil and gas can escape from the entrained seawater plume and, in particular, from the subsurface lateral intrusions. Although the dynamics of a multiphase plume have been previously studied in a non-rotating

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environment, there is a lack of experimental research on the effects of the system rotation on a multiphase plume. We conducted small-scale experiments in the laboratory to investigate the influence of a rotating environment on the dynamics of multiphase plumes. Bubble plumes, produced using electrolysis, were released into the saline rotating environment. We studied how the rotation rate, the source buoyancy flux and, specifically, the slip velocity of bubbles affect the plume characteristics such as its rise velocity and the temporal evolution of its width. Of particular interest is the question how the rotation rate modifies the area on the water surface which is affected by the plume after its rise through the water column. This can be, for example, important for modelling the spreading of the oil on the ocean surface after an accidental oil spillage. In the near-source region, multiphase plumes also exhibit anticyclonic precession of the plume axis, similar to single-phase plumes. In this talk, we present our experimental results and develop simple theoretical models to explain the observed plume behaviour.

The Effects of Bubbles on Oil Transport During High Wind Conditions

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Bubbles in the ocean environment are generated by breaking waves and the entrainment of these particles into the ocean enhances the air-sea fluxes. In the ocean, local air-sea fluxes affect the transportation of materials as petroleum. Understanding how the bubbles will behave in high wind conditions is still poorly understood, and it is a relatively new area of research. The chaotic nature of boundary turbulence makes the study of the bubbles more difficult. As part of the Gulf of Mexico Research Initiative (GoMRI) this study is intended to establish a high-fidelity computational framework for the interactions among wind, waves, and currents in upper oceans. This study is performed using the Air-Sea Interaction Salt Water Tank (ASIST) at the Rosenstiel School of Marine and Atmospheric Science (RSMAS). This experiment is conducted in two parts (1) without oil, and (2) with oil added to the surface. Gulf-surrogate Sweet Petroleum Crude Oil from British Petroleum (BP) is applied into the tank. Six runs for wind conditions from 15-25 m/s each, with fresh and salt water are studied. Images of bubbles are taken with a high speed camera. Analysis is done with the image processing toolbox in Matlab®. Properties of bubbles including concentration, radius, and centroid are recorded and analyzed. Wave phase, local slope and height were also measured using optical imaging methods and conductivity wave probes. The analysis provides a way to understand the characteristics of these bubbles, primarily their distribution as function of depth, bubble size and wave phase. Results from this experiment will establish an advanced simulation tool for the modeling and prediction of oil transport in both water and air under a variety of wind and wave conditions.

Modeling of Multiphase Plumes in a Stably Stratified Environment

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The plumes released in the course of underwater oil spills such as the Deepwater Horizon accident produce one or several intrusion layers in the water column. In such events the oil-water mixture is lifted primarily by gas bubbles and, secondarily, by oil drops. The momentum imparted to the liquid mixture by the bubbles causes it to rise above the neutral density level. However, the continuously falling ambient density gradually robs the plume of its momentum: the plume mixture, with a

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negligible momentum, finds itself surrounded by lighter liquid and slumps downward close to its neutral height where it forms the intrusion. The details of this process are incompletely understood. This work is based on the numerical solution of the pertinent equations and attempts to obtain a detailed understanding of the fluid mechanics of the rising and falling liquid, with an eye toward the development of simplified models of the process.

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Experimental Investigation of Oil Droplet-Turbulence Interactions under Breaking Waves

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After initial breakup of surface oil slicks or subsurface plumes, the interaction between crude oil droplets and turbulence plays a major role in their transport, weathering and biodegradation. The relative motion between droplets and the surrounding flow is affected by buoyancy and by the Stokes Number, i.e. the droplet response time relative to time scales of the surrounding turbulence. This laboratory study investigates the trajectories of 2µm-1mm slightly buoyant MC252 crude oil droplets located within a cloud generated as breaking wave entrain an oil slick. The size distribution of these droplets, with d_{95} varying between 30 to 800µm, is controlled by premixing the oil with Corexit 9500 at dispersant to oil ratios of 0, 1:500, 1:100, and 1:25. The droplet trajectories are recorded using cinematic digital inline holography at varying magnifications, starting from the initial entrainment up to 6 hours later. Particle Image Velocimetry is used for characterizing the time evolution of the flow field and turbulence. Immediately after entrainment, the droplet Stokes numbers (St) range from 10^{-4} to 10^{1}. While small droplets nearly follow the flow, large ones begin to rise, but their rise velocity is modulated by the turbulence, consistent with Friedman and Katz (Phys. Fluids, 14, 2002), as confirmed by analyzing the droplet trajectory statistics and the time evolution of their size distribution. As the turbulence generated by the breaking wave decays, larger fractions of the droplets size spectrum rise at the quiescent rate, while small ones continue to be dispersed by the turbulence and remain suspended. The data analysis follows the time evolution of the droplet rise rate and dispersion, as well as their impact on the size distribution of the remaining droplets as a function of the initial droplet statistics and evolution of turbulence dissipation rate. These findings have direct implications to droplets statistics under varying oceanic conditions.

Dynamic Coupling of Near-Field and Far-Field Models

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Deep-water spills pose a unique challenge for reliable predictions of oil transport and fate, since live oil spewing under very high hydrostatic pressure has characteristics remarkably distinct from oil spilling in shallow water. It is thus important to describe in details the complex thermodynamic processes occurring in the near field, meters above the wellhead, and the hydrodynamic processes in the far

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field, up to kilometers away. However, these processes are typically modeled separately since they occur at different scales. Here we directly couple two oil prediction applications developed during the Deepwater Horizon blowout operating at different scales: the near field Texas A&M Oilspill Calculator (TAMOC) and the far field oil application of the Connectivity Modeling System (oil-CMS). A new oil-CMS "near-field module" was developed to read TAMOC output consisting of distinct droplet types, each of different sizes and pseudo-component mixtures, which enter at a variable mass flow rate at a given time and position into the far field, relative to the wellhead. These variables are transformed for use in the individual-based framework of oil-CMS, where each droplet type' size (mean diameter, d_50) is transformer into a log-normal droplet size distribution (DSD). Here we used 19 pseudo-components representing a large range of hydrocarbon compounds, each varying within X droplet types. Simulation results show that the dispersion pathway of different droplet types varies significantly, some remaining in suspension in the subsea, others accumulating at the surface. In addition, the decay rate of the pseudo-components alters significantly the oil transport. These results denote the critical importance of both DSD parameterizations and of additional biodegradation/dissolution studies of naturally and chemically dispersed petroleum compounds under changing pressure and water temperature. This innovative dynamic coupling has the potential of improving the accuracy of oil transport and fate forecasts, advancing impact assessment and response during a deep-water spill.

Predicting Hydrocarbon Volumes and Pathways from Subsurface Formations to the Sea Floor During Blowouts in Gulf of Mexico Offshore Settings

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Although natural hydrocarbon seeps constitute a normal occurrence in the Gulf of Mexico (GoM), it is a catastrophic event like an offshore oil well blow out, that discharges high volumes of hydrocarbons within a short span of time into the environment. This presentation focuses on recent research that couples the subsurface formations with the wellbore system to compute blow-out rates, volumes and pathways into the subsea environment. To understand possible pathways of seabed contamination, in particular those from a bottom-up through the subsurface perspective, numerical models of GoM specific stacked geologic sequences have been developed and relevant spill volumes determined for underground blowout scenarios. A combination of near wellbore, multiphase flow models (no broaching), and coupled fluid flow, geomechanical models are constructed to simulate possibility of subsea broaching for GoM specific subsurface configurations (geology and reservoir pressures). Discharge volumes and rates for various lengths of time - 90-120 days for blowouts (current practice) and years (leaky wellbores) are determined as boundary conditions for seabed contamination models. Results from this research are 1) the development of a workflow that couples subsurface fluid flow with wellbore flow models to compute blowout rates and volumes, 2) determination of geologic conditions that affect blowout rates and 3) determination of parameters and conditions for the different pathways that the hydrocarbons take during such an event through the subsurface and onto the seafloor. Acknowledgement: Research reported in this publication was supported by an Early Career Research Fellowship from the Gulf Research Program of the National Academies of Science, Engineering and Medicine. Disclaimer: The content is solely the responsibility of the author and does not necessarily represent the official views of the Gulf Research Program of the National Academies of Science, Engineering and Medicine.

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

High-Resolution Photoluminescence Approach for the Isomeric Analysis of High-Molecular Weight-Polycyclic Aromatic Hydrocarbons in the Gulf of Mexico

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The multidimensional nature of photoluminescence phenomena provides fluorescence techniques with unique potential for the analysis of complex matrixes. The simplicity of experimental procedures makes room-temperature fluorescence techniques the most popular approach. The main limitation of room-temperature techniques is the broad nature of excitation and emission spectra. The diffuse character of such spectra limits the information content for the selective analysis of target compounds in complex matrixes. Herein, we present significant improvements we have made to line-narrowing fluorescence techniques. The full dimensionality of photoluminescence is obtained with the aid of a pulsed tunable laser for sample excitation, a spectrograph and an intensifier-charged coupled device (ICCD). Because of the spectrograph and the ICCD, wavelength time matrices (WTMs) and time-resolved excitation-emission matrices (TREEMs) are efficiently recorded in short analysis time. These data formats are applied to the environmental analysis of high molecular weight polycyclic aromatic hydrocarbons (HMW-PAHs) in the Gulf of Mexico. Similar chromatographic behaviors and almost identical mass fragmentation patterns make separation and identification of HMW-PAHs via GC-MS and HPLC-MS difficult. Since the carcinogenic properties of those pollutants differ significantly within isomers of the same molecular weight, it is of paramount importance to determine the most toxic isomers even if they are present at much lower concentrations than their less toxic isomers.

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Chromatographic Optimization for the Chemometric Determination of High-Molecular Weight Polycyclic Aromatic Hydrocarbons via Photodiode Array Detection

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This presentation focuses on high-molecular weight-polycyclic aromatic hydrocarbons (HMW-PAHs) of extreme environmental and toxicological interest that challenge state-of-the-art gas chromatography-mass spectrometry (GC-MS) methodology. Individual isomers of MW 302Da are not routinely identified or quantified in oil contaminated samples. Difficulties arise from their similar GC behaviors and almost identical mass-fragmentation patterns. Herein, an optimization of normal phase liquid chromatography (NPLC) parameters is presented for the determination of MW 302Da isomers via ultraviolet-visible photodiode array detection (PAD). The NPLC optimization allows for the determination of co-eluting isomers with overlapping absorption spectra. When coupled to multivariate chemometric algorithms such as parallel factor analysis 2, NPLC-PAD provides accurate qualitative and quantitative information in relatively short analysis time.

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Chemometric Analysis of High-Molecular Weight Polycyclic Aromatic Hydrocarbons under Normal Phase Liquid Chromatography Conditions

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Environmental monitoring of polycyclic aromatic hydrocarbons (PAHs) is an important step to prevent human exposure to oil contaminated sites. Classic examples are the sixteen PAHs included in the priority pollutants list of the US Environmental Protection Agency (EPA). A popular approach to the routine monitoring of EPA-PAHs is based on high-performance liquid chromatography (HPLC) coupled to ultraviolet and visible (UV-VIS) absorption detection. The research presented here tackles a different aspect of PAH analysis as it focuses on high molecular weight - polycyclic aromatic hydrocarbons (HMW-PAHs) with MW 302Da. One of the problems that confronts HPLC methodology for the analysis of HMW-PAHs arise from the large number of MW isomers with co-eluting retention times and overlapping absorption spectra. Herein, we compare the performance of two multi-way calibration algorithms - namely parallel factor analysis 2 (PARAFAC 2) and multivariate curve resolution-alternating least-squares (MCR-ALS) - for processing tri-linear data consisting of retention times and UV-VIS absorption spectra. Comparison of their performance provides the basis of a new method of analysis for the quantification of HMW-PAHs in samples of unknown composition with signal-overlapping constituents. **Acknowledgements**: The authors acknowledge financial support from The Gulf of Mexico Research Initiative (Grant 231617-00). The views expressed are those of the authors and do not necessarily reflect the view of this organization.

Determination of Benzo[b]naphtho[2,1-b]thiophene in NPLC Fraction on the Basis of Excitation Emission Low Temperature Phosphorescence Data Coupled to PARAFAC

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The large volume of crude oil released into the Gulf of Mexico by the Deepwater Horizon (DWH) accident has raised considerable concerns over potential ecosystem impacts. To fully understand the environmental implications of the DWH accident, analytical methods should be able to determine a wide variety of polycyclic aromatic compounds (PACs). These include polycyclic aromatic hydrocarbons (PAHs), alkylated-PAHs (APAHs) and sulfur containing PAHs (PASHs). A new strategy for the analysis of PAHs, methyl-derivative PAHs (Me-PAHs) and PASHs in standard reference materials (SRMs) combines sample fractionation via normal-phase liquid chromatographic (NPLC) followed by gas chromatography-mass spectrometry (GC/MS) analysis of NPLC fractions. [1] PAC identification is based on two qualitative parameters per compound, namely NPLC and GC retention times. Unfortunately, many cases exist where PAHs, Me-PAHs and PASHs have overlapping retention windows and common mass spectral ions, making their chromatographic identification even more difficult for risk assessment and toxicological purposes. The research presented here explores the potential of low temperature phosphorescence spectroscopy for the analysis of PASHs in NPLC fractions at liquid nitrogen temperature (77K). A PASH with molecular mass 234 Da and known chromatographic behavior - Benzo[b]naphtho[2,1-b]thiophene (BbN21T) - is used as the model compound. The application of 0.04 ms time delay after the excitation pulse and gate time (sample window) of 9 ms were found to minimize the fluorescence interference of PAHs co-eluting in the NPLC fraction. 77K excitation-

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emission phosphorescence matrices (EEPMs) were recorded at the optimum gate and delay times of BbN21T and data were subjected to parallel factor analysis (PARAFAC) for the determination of BbN21T. The successful analysis of BbN21T with relative error of prediction (REP) of 5.5% provides a solid foundation to pursue the determination of PASHs isomers in NPLC fractions via 77K EEPMs and PARAFAC. [1] W. B. Wilson, H. V. Hayes, A. D. Campiglia and S. A. Wise, *Analytical and Bioanalytical Chemistry*, 410, 4177 - 4188, 2018.

Stable Oxygen Isotopes as a Novel, Sensitive Tracer of Petroleum Hydrocarbon Oxidation at the Sunlit Sea Surface

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Several lines of evidence indicate that partial oxidation by sunlight was a critical environmental fate of Deepwater Horizon surface oil, transforming over half of the floating oil mass within days of surfacing. Here we build on this mounting evidence using a combined field and laboratory approach to show that sunlight likely drove substantial shifts in the stable oxygen isotopic composition ($\delta^{18}O$) of oil floating on the sea surface. In less than one week, $\delta^{18}O$ of Deepwater Horizon surface oil increased by 7‰, an enrichment comparable to 25% of the known dynamic range of $\delta^{18}O$ of organic matter on Earth. By exposing oil to sunlight in the presence and absence of molecular oxygen in the laboratory, we demonstrate that nearly 90% of photochemical O-incorporation is sourced from enriched molecular O_2 (24‰) rather than more depleted water (0‰). Mass-dependent isotopic fractionation was also measured in the laboratory. Fractionation factors, ε, were similar for two widely different oil types (Louisiana Sweet Crude and Alaskan North Slope), suggesting a similar reaction pathway(s) governs partial photo-oxidation. To close the isotopic mass balance, roughly 20% of total O-incorporation would have had to exchange with water after production. This hypothesized isotopic exchange is consistent with several studies reporting surface oil photo-products are comprised of exchangeable functionalities (e.g., ketones, carboxyl, aldehydes), shedding additional light on the chemical composition of the transformation products. Collectively, $\delta^{18}O$ is a novel, sensitive tracer of the partial photo-oxidation of petroleum hydrocarbons, with potential applications for alternative reduced hydrocarbon sources such as lipids, black carbon, and pollutants.

Where Did it All Go? Fate and Distribution of PAHs on *Avicennia* and *Spartina* in Barataria Bay, LA

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Since the Macondo oil spill in 2010, there have been many efforts to rehabilitate affected shoreline including those with vegetation. Significant data gaps exist on the interaction of crude oil with vegetation surfaces and how these surfaces influence system recovery. This study will present 3 sets of measurements on the distribution and fate of crude oil components, in particular polycyclic aromatic hydrocarbons (PAHs), on wetland plant leaves. Studies were conducted on *Avicennia germinans* (black mangrove) and *Spartina alterniflora* (smooth cordgrass) which are widely abundant and geographically widespread in areas impacted by Macondo oil. These halotolerant plants have different cuticle thicknesses as well as differing leaf ultrastructure that potentially affects PAH distribution. The first study presented will be a series of isotherms for the PAH and the cuticle using different concentrations

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of a water accomodated fraction (WAF) of crude oil. This will establish a partition coefficient on the cuticle, the passageway for the PAHs to reach the leaf tissue. The PAH isotherm is hypothesized to be linear because, the organic waxy cuticle will likely continue to sorb PAHs without meeting a maximum capacity. The second study is a field measurement of the fate of isotopically labelled PAHs (naphthalenes, phenanthrenes and chrysenes), painted onto the leaves in plant's natural habitat of the Caminada Headlands marshes in Port Fourchon, LA. This experiment was conducted by spiking the plant leaves with PAHs and extracting PAHs over time in both the cuticle as well as the leaf tissue. After spiking, it is hypothesized that PAHs will decrease over time in both the tissue and the cuticle within the span of a few weeks. Finally, the third study is using 2-laser confocal microscopy to visualize the phenanthrene distribution on the leaf surface. Visualization results showed higher concentrations of phenanthrene around salt gland structures on *Avicennia germinans*. These 3 studies will be discussed in context of long-term oil fate in marshes and the role vegetation surfaces play in that process.

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

The Development and Implementation of the Foram-AMBI for the Gulf of Mexico

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Various monitoring methods and indices have been developed to quantify the ecological quality status (EQS) of aquatic ecosystems. One such index commonly associated with ecological health is the AZTI Marine Biotic Index (AMBI), which pairs species abundance with environmental stressors. This has been shown to be the ideal index for the identification of disturbance gradients as well as the detection of new impact sources. This index has been used to assess EQS in the NE Atlantic and Arctic (Alve *et al*. 2016), and in the Mediterranean Sea (Jorissen *et al*. 2018). Benthic foraminifera are especially well adapted to populate this index due to their high diversity and abundance in nearly all marine environments, varying environmental sensitivities among species, and preservation potential in the sediment record. To calculate Foram-AMBI, species are assigned to one of five groups ranging from sensitive (1) to first order opportunists (5) based on their correlation to total organic matter and grain size. The Gulf of Mexico (GoM) is an economically important region (e.g. oil and gas, fisheries) and with the expansion of oil drilling, harmful algal bloom events, oil blowouts, dead zones, anthropogenic eutrophication and contaminant loading, it is important that the EQS of different localities in the Gulf is closely monitored. This study seeks to construct a Gulf-wide Foram-AMBI that will provide decision-relevant knowledge about baseline EQS for the GoM and will satisfy the need for widespread geospatial coverage in the case of unforeseen future impacts. The construction of a GoM Foram-AMBI will provide managers with benthic habitat suitability for economically important, benthic dependent fish (e.g. groupers, snappers) and simultaneously encourage collaborative partnerships between academic scientists and living resource managers throughout the GoM to operationalize, refine and implement AMBI as a decision support tool.

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The Utility of Benthic Foraminifera for Gulf of Mexico Oil Spill Science and Resource Management

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Benthic foraminifera (BF) have proven to be useful tools for the assessment of impacts, response, resilience and long-term sedimentary preservation of marine oil spills. BF provided one of the first records of seafloor impact and the first record of resilience (3-5 years) following the Deepwater Horizon (DWH, 2010) oil spill. The stable carbon isotope composition of BF shells (tests) has also provided a robust and recalcitrant record of the DWH and Ixtoc-1 (1979) oil spills in the sedimentary record. These results have implications for determining the long-term preservation of oil spills, assessing petroleum carbon mineralization and burial, and contributing to overall oil spill budgets. Expanding the utility of BF in the context of oil spills, Gulf-wide (US, Mexico, Cuba) baseline measurements of BF density, diversity and stable isotope composition have been developed to provide means to quantitatively determine impact, resilience and recovery following future oil spills. In a broader perspective, these baseline measurements also allow for inter-regional spatial connectivity assessments, trophic connectivity assessments (habitat, BF, macrofauna, benthic dependent fishes) and have implications for the calibration of paleoceanographic proxies (stable isotopes, transfer functions) along depth (T,S) and latitudinal gradients. Finally, the development of internationally recognized BF marine biotic indices (e.g. AMBI) for the Gulf of Mexico will allow for benthic habitat suitability assessments with implications for management of living marine resources.

Assessing eDNA Degradation Rates in Deepwater Marine Environments to Determine Persistence Controls and Viability for Species Identifications

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In the past decade, the collection and identification of environmental DNA (eDNA) in aquatic systems has become an important tool for measuring biodiversity. It is especially useful for detection of species that prove difficult to locate or collect. Aquatic eDNA research thus far has largely focused on freshwater and surface marine ecosystems, but deepwater marine environments remain largely unexplored. We seek to address two weaknesses in the application of eDNA techniques to marine systems. First, the temporal persistence of eDNA in deep and mesophotic ocean environments must be determined. It is not yet understood how varying ocean conditions, such as pH, redox state, and temperature, impact the degradation rate of eDNA. The first phase of this new project, funded by the NOAA Office of Exploration and Research, will focus on conducting a series of experiments to construct a general kinetic model of deepwater marine DNA persistence that can be applied to any natural field sample. Next, we aim to develop an open-access bank of DNA metabarcodes for corals and bony fishes in the Gulf of Mexico (GoM). This reference database will increase the efficiency of taxonomic identification and enhance biodiversity exploration in the GoM. Species detection through eDNA sampling will supplement visual exploration and prove especially valuable in deep-water environments where in-person and video observations are difficult. An improved knowledge of biodiversity in the GoM will also aid in the management and monitoring of conservation areas such as the Flower Garden

*Student Presenter

Banks National Marine Sanctuary. This presentation will outline a project that seeks to fill gaps in effective eDNA research and propose improvements to this promising method of marine species detection and identification. Preliminary results from planned eDNA persistence experiments will also be discussed.

Re-Occurring Patterns of Stratification and Hypoxia in Chandeleur and Breton Sounds in Southeast Louisiana

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The Lake Pontchartrain Basin Foundation has been monitoring hypoxia in Chandeleur Sound since 2010 and in Breton Sound since 2013. LPBF collects a top, middle and bottom data at sites along established transects with a YSI unit (temperature, salinity, and D.O.). Stratification and hypoxia tend to occur annually in both areas from May to August, but can persist until September. Cumulative data indicates two patterns. In Chandeleur Sound, the pycnocline is 10 to 20 feet deep with Gulf seawater (30 to 35 ppt) intruding below "mixed" sound water (15 to 25 ppt). In Breton Sound, the pycnocline is generally 2 to 8 feet deep with fresh Mississippi River water intruding above the "mixed" sound water (15 to 25 ppt). Therefore to the north, mixed- normoxic water is above and to the south mixed sound water with reduced D.O. is below. The Chandeleur Sound hypoxia probably first develops in the Gulf in the Mississippi Bight, but then moves through the deep channel between Chandeleur and Ship Islands. Once in Chandeleur Sound, it may spread westward toward Mississippi Sound and southward toward Breton Sound. The Breton Sound hypoxia seems to move northward from the Mississippi River and toward Chandeleur Sound. In some years, the two stratified areas may converge forming nearly continuous areas of stratification and hypoxia that can extend from Ship Island to the Mississippi River. These two patterns suggest genesis of the two hypoxic areas being driven by differing dominant influences. In Chandeleur Sound the low-energy, high salinity reservoir of Gulf water in the Gulf of Mexico may dominate due to its residence time. Whereas, in Breton Sound the high-nutrient, freshwater discharge plumes from the Mississippi River is likely the dominant driver due to eutrophication.

Foraminiferal Bio-Monitoring as an Effective Tool for Marine Ecosystem Quality Observations in the Persian Gulf

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Hydrocarbon pollution and contaminations caused by mariculture are two important environmental issues in the Persian Gulf. The whole body of water is heavily influenced by long-term oil and gas exploitations on both northern and southern coasts. Recently number and size of floating cage fish farms has exponentially risen in this important body of water. Environmental monitoring is a major part of an integrated coastal and marine habitats management program. Benthic foraminifera are well-known environmental bio-indicators because of their short lifespan and quick response to environmental changes. These bio-indicators are abundant in bed sediments of the Persian Gulf. Contact with hydrocarbons can induce growth deformities in benthic foraminifera. Foraminiferal assemblages also can be used as excellent indicators for environmental changes caused by floating fish

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farms. This study tests foraminferal bio-monitoring method for evaluating the impacts of cage fish culture and oil leakage on the northern coast of the Persian Gulf. An interface sampler has been used for surficial soft sediment sampling in a number of fish cage localities. Samples then stained using rose Bengal at a concentration of 2 g/l. Foraminifera separated from fine bed sediment using 125 µm test sieves. Foraminiferal assemblages then studied under binocular microscope. High salinity of the Persian Gulf is a restricting factor in Foraminifera diversity. Genus *Nonion* and *Amonnia* are the most abundant in the study area. Preliminary results show a significant reduction in number and diversity of living foraminifera near fish cages comparing to control samples collected in distances of 50 and 1000 m from the cages. This change is plausibly related to organic enrichment by Fish culture. Our results suggest a clear impact of cage fish culture on nearby marine ecosystems in addition to impacts of hydrocarbon pollution in the Persian Gulf.

A Comparison of Scleractinian Corals Occurring in the West Florida Shelf and the Florida Keys

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The ledge habitats of the West Florida Shelf (WFS) support a diverse assemblage of invertebrates and fishes, including commercially important species and scleractinian corals. However, the benthic community of the WFS is relatively unstudied compared to other marine habitats in Florida, such as those in the Keys. WFS corals can experience similar stressors as Keys corals (e.g. temperature related bleaching), and periodic local stressors such as harmful algal blooms (HABs); this may mean WFS corals are uniquely resilient in comparison to conspecifics elsewhere. We conducted demographic surveys of corals on ledges offshore from the Tampa Bay area, following the same Coral Reef Evaluation and Monitoring Program protocols used in long-term monitoring at sites in the Keys, to make condition comparisons among corals in these disparate habitats. We surveyed two, 10m x 1m transects parallel to the ledge and two, 10m x 1m transects perpendicular to the ledge at each survey site, to document changes in assemblages with distance from the ledge. We conducted photo transects alongside of the demographic transects, to estimate benthic percent cover across sites, and to compare results of this study with a similar assessment performed following a 2005 HAB event, and between the WFS and Keys. Coral cover and diversity were lower at ledges than at Keys sites, but species such as *Siderastrea siderea* and *Stephanocoenia intersepta* were common in both habitats, many Mussidae family corals were more common at some ledges than at Keys sites overall, and some species are Gulf of Mexico (GOM) specialists. This project will provide valuable insight for future conservation or regulatory needs for the WFS. Because of the spatial overlap of some coral species across the GOM and the Florida Reef Tract (FRT), an update on the multi-year coral disease outbreak in the FRT will be presented, to inform GOM stakeholders of coral disease signs, should this outbreak spread from the FRT into the GOM.

Local Hydrocarbon Rich Accumulation in Sediments from the Upper Slope of the Southern Gulf of Mexico

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We present some preliminary evidence on the sedimentation of oil-associated particles on the slope of the southern Gulf of México. We evaluated sedimentation processes and organic carbon degradation in four sediment cores collected from the upper continental slope (217-523 m) in the southern Gulf of Mexico (sGoM). Sediment cores were split along their depth axes and scanned with an XRF system. Total organic carbon (TOC) and short-lived radionuclides were determined for the upper few centimeters at high resolution (2-4mm). Sediment accumulation rates and bioturbation rates were calculated using excess ^{210}Pb and ^{234}Th ($^{210}Pb_{ex}$, $^{234}Th_{ex}$) profiles in each core. In the four cores, we observed $^{234}Th_{ex}$ in the first 0.5 cm and a monotonous decrease of $^{210}Pb_{ex}$ in the 2 cm section below. The OC fluxes at the sediment-water interface range between 5-8 $gm^{-2}yr^{-1}$. In general, higher burial rates are controlled by higher sedimentation rates. In all cores, we observed a brown layer (1-2 cm), with a subsurface peak of Mn and a peak of Fe usually 10-15 cm downcore. However, core B8E22, located in the deeper area, shows a dark brown sediment layer extending down to 2 cm below the sediment-water interface, punctuated by a significative change in redox conditions, underscored by an Mn peak right on top of the dark brown carbon-rich layer and a peak of Fe 2 cm below. Moreover, on top of this layer, we found a peak of ^{226}Ra (measured by ^{214}Pb and ^{214}Bi), probably remobilized from the suboxic layer right below and reprecipitated close to the sediment-water interface. We consider that this core-top is recording a high carbon sedimentation event, associated with a local source of hydrocarbons from a nearby seep. The sedimentation of this hydrocarbon-rich layer may have temporarily impacted benthic fauna, which would have inhibited bioturbation processes and allowed for the observed enrichment of carbon and altered the redox profile, moving it much closer to the sediment-water interface.

Expanded Footprint of the Deepwater Horizon Oil Spill on Deep-Sea Benthic Communities

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An extensive deep-sea benthic survey was conducted in the aftermath of the Deepwater Horizon disaster to study the effects of the crude oil release on macrofauna and meiofauna communities of the northern Gulf of Mexico. Initial reports were based on 58 stations, but recently added data brings the total to 120 stations, ranging in distance from the wellhead between 0.3 km and 265 km. Physical and geochemical sediment qualities and zoobenthos abundance and diversity were measured at all stations. In a principal component (PC) analysis, PC1 was related to water depth, whereas PC2 was strongly correlated to PAH and barium concentrations, which are both indicators for oil spill effects. PC2 was negatively correlated with macrofauna and meiofauna diversity, and positively correlated to meiofauna abundance and nematode to copepod ratio. This means that the released oil impaired meiofauna and macrofauna communities by excluding sensitive taxa through its toxicity, while at the same time causing an increase in the abundance of more tolerant taxa through an enrichment effect. The most severe impacts of the hydrocarbon pollution were found in a radius of approximately 10 km, particularly at stations located to the northeast and southwest of the wellhead. Severely and moderately impacted stations were found on the upper continental slope and the continental shelf to the north and northwest of the wellhead in shallower depths than previously known. The footprint of the oil spill is now much larger. It is hypothesized that the shallow stations received hydrocarbons from the mid-water plume and oiled marine snow deposition, but possibly from Mississippi River outflow.

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REDIRECT: Evidence for Recent Gravity Flow Deposition Down-Slope of DWH: Re-Sedimentation of MOSSFA?

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The REDIRECT group is testing the hypothesis that upslope oil-residue contaminated sediments were resuspended and deposited in deeper waters. Towards that end, we collected sediment cores at 31 sites downslope of DwH during a May 2018 GoMRI-supported cruise. Most cores exhibit intact detailed stratigraphy, contain numerous primary sedimentary structures, with little evidence of bioturbation. Structures are indicative of sediment re-deposition and include: 1) thin, mm-scale, sub-parallel laminae and wavy bedded units interpreted as being deposited by low-density, fine-grained turbidity currents, 2) inclined and/or contorted beds indicative of re-deposition by slides or slumps, and 3) fine-grained, homogeneous units displaying cm- to dm-scale color banding interpreted to represent fine-grained turbidites. Interpretations are consistent with those resulting from a 1983 DSDP cruise to the Mississippi Fan. Short-lived radioisotope analyses reveal exceptionally high activities of $^{234}Th_{xs}$ and $^{210}Pb_{xs}$ in surface layers, consistent with high rates of sediment input and accumulation indicative of the high preservation potential of underlying units. Sediment texture/composition, isotopic, hydrocarbon, foram, flume resuspension analyses are in progress, but the well-preserved stratigraphy, excellent detail of primary sedimentary structures representing re-deposition, lack of bioturbation, and documented high sedimentation rates provide evidence that sediments collected within the project area have been re-deposited from upslope depocenters and thus may carry the signature of DwH oil residues.

Spatial and Temporal Sediment Distribution and Accumulation Patterns: NW Cuba

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Sediment cores collected along the coastline, shelf and slope of northwest Cuba were analyzed for sediment texture/composition and short-lived radioisotope (SLRad) chronologies to investigate sediment sources, distribution/transport, and depositional mechanisms over the past ~100 years. Coastal cores consist primarily of carbonate sands/muds near the base, transitioning upcore to organic-rich muds. Some contain surficial overwash deposits. This pattern reflects an initial regressive sequence followed by a transgressive sequence indicating shoreline instability. Offshore cores (~300-1500 m water depths) yielded good stratigraphy, consisting dominantly of carbonate silts, with robust SLRad chronologies. An east to west pattern is evident in sediment accumulation rates and texture/composition over the past ~100 years. In the westernmost sampling area, offshore pristine coastline, cores reflect consistent accumulation of carbonate silts at lower rates, and accumulation rates increase to the east, with recent changes in texture/composition. Sediments offshore of Habana recorded the highest accumulation rates, variability in composition (changes in accumulation of island-derived sediments), and an increase in grain size over the past ~100 years. $^{234}Th_{xs}$, reflecting active

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deposition within ~5 months, was detected in the surfaces of all offshore cores, to ~10 mm depth in easternmost cores compared to 2-4 mm in westernmost cores, consistent with an increase sediment accumulation off the four studied coastal bays. Few siliciclastic sediments were found on the shelf between the coastline and ~300 m water depths, reflecting little sediment exchange between the nearshore and offshore. Offshore of Habana is the exception, potentially due to the narrow shelf and/or increased anthropogenic activities.

REDIRECT: Spatial and Temporal Sedimentation Patterns in the NEGoM: Short-lived Radioisotope Records of Sediment Focusing and Downslope Transport of MOSSFA

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A suite of sediment cores was collected to investigate the potential down-slope redistribution of MOSSFA related sediments in the NEGoM. Short-lived radioisotopes are utilized to identify areas of, short-term and long-term, sediment focusing of remobilized MOSSFA sediments. Excess ^{234}Th ($^{234}Th_{xs}$) indicates short-term sedimentation with $^{234}Th_{xs}$ Inventories reflecting sedimentation and $^{234}Th_{xs}$ mass accumulation rates (MAR's) reflecting sedimentation and potential influence of bioturbation. In the northwestern portion of the study area, high $^{234}Th_{xs}$ Inventories and MAR indicate high sedimentation likely associated with Mississippi River input and downslope transport of sediment in this region and low influence of bioturbation. This indicates a higher potential for this area to contain redeposited MOSSFA sediments that were remobilized from upslope areas and a higher preservation potential in the sedimentary record. In the southeast portion of the study area $^{234}Th_{xs}$ Inventories decrease reflecting a lower sedimentation rate and lower potential for accumulation of remobilized MOSSFA, their subsequent burial and preservation in the sedimentary record. Higher MAR's in the southeast portion of the study area may also reflect an increased potential for bioturbation. Excess ^{210}Pb ($^{210}Pb_{xs}$) also reflects higher sedimentation in the northwest portion of the study area as compared to the southeast area. $^{210}Pb_{xs}$ will also identify areas of sediment focusing over the past ~100 years as well as provide age control for investigating the presence of oil-residue contaminated sediments in downslope regions from the DwH site. This will assist in constraining the potential remobilization of MOSSFA, redistribution and secondary sedimentation leading to modification of the spatial extent and fate of oil-residue contaminated sediments.

Evolution of Sedimentary Redox Conditions following Deepwater Horizon Blowout: Geochemical and Ecological Implications

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Following the Deepwater Horizon blowout event, marine sediment cores reveal a regional organic rich sedimentation pulse, which resulted in significant changes in sedimentary redox conditions. We use a time series of redox sensitive metals (Mn, Re, Cd) in four different sediment cores near and at the well head to constrain the temporal evolution of reducing conditions for seven years after the event.

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Microbial respiration of carbon-rich marine snow deposited to sediments resulted in decreased pore-water oxygen concentrations and a shoaled redoxcline. The shoaled redoxcline produced a second Mn oxide peak, at 5-10 mm, shallower than the original Mn oxide peak at 20-30mm. Rhenium (Re) enrichment is associated with anoxic sediments. Sediment Re concentrations at 40-50 mm increased 3-4 times the pre-event Re levels two years after the event. More reducing (anoxic) conditions may have limited bioturbation, which may have then prolonged the reducing conditions in surface sediments. After 2-3 years, subsurface Re concentrations no longer increased, and returned to steady state conditions. This is consistent with a return of bioturbated sediments, as indicated by short lived radioisotopes (Larson *et al*., in review).

The subsurface Re enrichment increased 3-4 times for the first two to three years following the event, then leveled off, indicating a return of bioturbation and to pre-impact conditions. A dramatic (80-93%) reduction in benthic foraminiferal density is coincident with reducing conditions, demonstrating the important consequences of changing redox conditions on benthic organisms. An increase in sedimentary PAH concentrations could also be responsible for the reduction.

Extended, multi-year time series with multiple stations are fundamental in understanding the impact of changing redox conditions on benthic ecosystems.

Water Column Prokaryotic Communities at the Flower Garden Banks National Marine Sanctuary after the 2016 Mass Mortality Event and Hurricane Harvey

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Approximately 200 km off the Texas-Louisiana coast lies the Flower Garden Banks National Marine Sanctuary (FGBNMS), underwater mounds associated with salt domes that lie at the edge of the continental shelf. A unique coral reef community grows on the banks; they are geographically isolated and their northerly position classifies them as marginal reefs since they live near the environmental limits (low light and temperature) for coral reef growth. We collected water column samples to study microbial community composition after two extreme events at FGBNMS: a mass mortality of corals, sponges, and other invertebrate metazoa in August 2016 and Hurricane Harvey in September 2017. Follow up samples were also collected during August and October 2018. We describe here overall prokaryotic diversity within the FGBNMS and what that can tell us about both the mortality event and the ecosystem response to Hurricane Harvey. Microbial community composition and structure was predominantly structured by water depth in 2016. Shallow samples were dominated by Cyanobacteria and clustered into two separate groups, located in the East and West Flower Garden Banks respectively. Variations in microbial community structure between these two groups was primarily due to differences in salinity. EFGB surface waters were enriched with *Synechococcus* relative to the WFGB, which instead harbored larger abundances of *Prochlorococcus*. Fourteen OTUs (operational taxonomic units), many of which belonged to taxa commonly associated with oxygen minimum zones, were found to be strongly correlated with low dissolved oxygen concentrations. Half of these OTUs classified as MGI Thaumarchaeota, ammonia-oxidizing archaea which thrive in and have been implicated in the creation of hypoxic conditions. The results from 2016 will be compared with those of 2017 to determine how two different extreme events at the FGBNMS shaped the microbial community in the water column there.

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

Environmental DNA Assay for Detection of the Rare Gulf of Mexico Bryde's Whale

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The Gulf of Mexico Bryde's whale is the only resident baleen whale species in the Gulf of Mexico (GOMx). Recently, this population in the GOMx has been identified as a unique taxonomic unit, likely at least a new subspecies of *Balaenoptera edeni*. Population size is very low (N=33) and it is currently being considered for listing as Endangered under the ESA. Furthermore, this population was significantly impacted by the BP oil spill. Currently, these animals appear to be restricted to waters of the northeastern GOMx; however, historical whaling records suggest they may have inhabited the north-central GOMx, and recent acoustic data have detected calls that are unique to this population near the Flower Garden Banks in the northwestern GOMx. Recently, molecular genetic methods have been developed to detect the presence/absence of species through the use of environmental DNA (eDNA), DNA that is shed or excreted by animals into their surrounding environment. We have developed an assay to collect, concentrate and detect eDNA shed by GOMx Bryde's whales. During a summer 2018 RESTORE research cruise, water samples (~3L) were collected in the "flukeprint" of whales. On the ship, samples were filtered through 0.445µ filters and stored in Longmire's lysis buffer until they could be processed in the laboratory where total DNA was extracted. We identified several small fragments (< 120 base pairs) of the mitochondrial DNA control region that distinguish this species from all other cetaceans in the GOMx and designed primers to target these regions. The primers were used to develop a PCR-based (polymerase chain reaction) assay to amplify and detect the targeted fragments in the eDNA samples. In future studies, with use of autonomous environmental water samples, this assay could be applied to gridded water sampling in the GOMx to fill a significant data gap and improve our understanding of distribution and habitat use and of these rare whales.

Integrative Modelling of Marine Mammal Populations Impacted by the Deepwater Horizon Oil Spill

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We describe the integrative modeling project of the Consortium for Advanced Research on Marine Mammal Health Assessment (CARMMHA), which runs from 2018-2019. The ultimate goal of the CARMMHA is to provide a comprehensive understanding of the health impacts of oil-associated chemicals on cetaceans, with particular focus on the recovery of cetacean stocks after the Deepwater Horizon oil spill. The consortium is pursuing thematic and field projects aimed at furthering our understanding of ongoing cardiac, immune and indirect (i.e., prey-related) effects of the oil spill on Bay,

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Sound and Estuary (BSE) common bottlenose dolphins, as well as the Northern coastal stock. The integrative modelling project will bring this information together, along with new research findings from outside the consortium, to update and refine the marine mammal population models created for the Deepwater Horizon Natural Resources Damage Assessment (NRDA). We will produce improved estimates of the recovery trajectory of BSE dolphin stocks, as well as stocks of coastal dolphins and key offshore species. Formal expert elicitation will be used to derive distributions on recovery of individual health, and on transferability of information gained by field studies of BSE animals to the other stocks. Modeled trajectories will be compared with those from independent estimates of population size derived by the ongoing GoMAPPs project. This updated assessment comes at a crucial time, when the NRDA models predicted the impact (in terms of reduction in population size) would be most severe.

Gulf of Mexico Dolphin Identification System (GoMDIS) - A Collaborative Effort to Better Understand Bottlenose Dolphin Movements

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The 2010 Deepwater Horizon oil spill and Unusual Mortality Events in the northern Gulf of Mexico demonstrated the need for additional information on bottlenose dolphin movements and ranges. No mechanism existed for detecting range shifts in response to these events. To address this issue, a collaboration was formed in 2012, involving federal and state agencies, non-profits, and academia with NMFS-permitted photographic-identification projects, as well as stranding programs and international partners. The Gulf of Mexico Dolphin Identification System (GoMDIS) provides a venue to house dolphin identification data from collaborating research groups Gulf-wide, including Cuba and Mexico. The objectives are to: 1) maintain a compilation of dolphin identification data, 2) build and maintain a repository for identification images and 3) facilitate data sharing among colleagues to examine dolphin movements through the Gulf. The Chicago Zoological Society's Sarasota Dolphin Research Program (SDRP) curates GoMDIS. Data are provided by our contributors and stored both offline on our secure server at SDRP, and on Duke University's OBIS-SEAMAP, which is accessible via an online portal, allowing collaborators to browse catalogs of interest, and go through animal matching workflow. Access to the portal allows the contributors to download match lists and contact others for additional animal sighting data. GoMDIS is constantly updating, currently including 30 catalogs, 19,192 animals and 32,855 images, yielding >1,000 matches between projects (current and archived) to date. We expect GoMDIS to grow and evolve as a conservation decision-making tool. To ensure success, it will be necessary to 1) find funding for continuing operations (funded into 2019 by NFWF), 2) incorporate new research and stranding programs, 3) receive and process catalogs with an improved data processing framework, and 4) maintain communication between the curator and collaborators.

Can You See or Hear Me Now? Evaluating the Distribution, Abundance and Detectability of Ziphiid and Kogiid Whales in the Gulf

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Detecting deep diving whales during line-transect surveys can be challenging for several reasons. Deep diving cetaceans, such as beaked whales (Ziphiidae) and dwarf and pygmy sperm whales (Kogiidae) are cryptic by nature and spend a large proportion of their time underwater. Visual detection of these species can be further compromised by environmental parameters, such as rough seas. Similarly, the acoustic detection of these whales is impacted by the depths at which they produce acoustic signals, the signal frequency, and their behavioral state, as well as sound propagation and ambient noise conditions (including vessel noise). Despite these challenges, ziphiid and kogiid whales are regularly encountered during SEFSC research cruises in the Gulf of Mexico (Gulf) and Atlantic Ocean. Data collected since the early 1990s indicate a patchy distribution concentrated in deep waters around the continental slope, including submarine canyons. Sightings of beaked whales in the Atlantic show higher predicted mean densities than in the Gulf while sightings of the dwarf and pygmy sperm whales (recorded singularly under *Kogia* spp.) yield higher densities in the Gulf when compared to the Atlantic. Since 2017, the SEFSC has been conducting line-transect surveys in the Gulf as part of the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS). A total of 16 visual sightings including 33 individuals and 43 acoustic detections of beaked whales and *Kogia* spp. have been documented and, with a survey ongoing and scheduled to be completed by October 2018, these values are expected to increase. This study will evaluate trends in distribution and abundance of Ziphiidae and Kogiidae whales in the Gulf, incorporating data collected in the recent years during the GoMMAPPS. Developments in data collection techniques will also be discussed in light of detection probabilities of these cryptic whales across both ocean basins.

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

Addition of Microbial Community Composition in the Evaluation of Habitat Suitability for Tidal Marsh Restoration Projects: A Case Study from the Lake Hermitage Marsh Creation Project, Plaquemines Parish, Louisiana

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Tidal marsh construction projects in Louisiana are being completed under the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) program. Objectives for these interagency projects are to combat land loss and erosion, restore critical habitat for fisheries, and counteract ecosystem injuries after the Deepwater Horizon oil spill. In natural marsh systems, ecological communities form through long-term interactions with the habitat, and community structure is directly affected by salinity, tidal inundation, sedimentation, hydrology, and nutrient cycling. In created marshes, sediment is typically hydraulically dredged from “borrow areas,” or introduced from nearby riverine diversions, to build-up land. Dewatering of the introduced sediment over time should result in a marsh elevation that is conducive to recruitment and colonization of native marsh flora and fauna. However, it is

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unclear when (or how long after sediment introduction) ecological conditions within a created marsh reflect those of natural systems. At present, monitoring restoration project success includes evaluating aboveground biomass, survival/mortality of planted vegetation, and percent cover of invasive species. From study sites near Bay Batiste (natural marshes) and Lake Hermitage, West Point a La Hache (created marshes), we analyzed sediment and water physicochemical conditions, and microbial, plant, and macrofaunal communities along 100-m transects. Created marsh soil profiles in 2018 were composed of coarse riverine sand that originated as fill from 2012 to 2014. Despite comparable recruitment of native flora and fauna, the created soil profiles did not have a well-developed rhizosphere comparable to natural marsh sites, likely indicating that soil microbial communities and nutrient cycling are also dissimilar. Therefore, the appearance of a marsh, and presence of aboveground vegetation, may not be an accurate measure of created tidal marsh long-term habitability and sustainability.

P-007: Organismal Responses to Oil Exposure: from Individuals to Ecosystems

Novel Silica-Based Nanoparticles Reduce the Toxicity of Crude Oil WAF to Fathead Minnow Juveniles After 96h of Exposure

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To remediate crude oil spills, the usual solution is to apply a dispersant such as Corexit. However, there are concerns regarding whether the dispersant makes the crude oil more bioavailable to organisms. As such, new materials are being developed that may be more effective and less hazardous to wildlife. In this study, an engineered nanoparticle (NP) was tested as a substitute oil dispersant. This NP is based on a silica core coated with amphiphilic branches that can disperse the oil by adsorbing it into the tethered chains in the corona. Here, a hyperbranched poly(ethylene glycol) (HPG) coated silica NP was assayed to evaluate the capacity to capture oil components from the water accommodated fraction (WAF) thus making the oil less bioavailable to exposed juvenile fathead minnows (FHM). WAF was prepared after weathering a mixture of crude oil (3 mL) in 3 L 20% Hanks Media for one week. Three different concentrations of HPG-NP (2, 10 and 50 mg/L) were added to a solution of WAF/20% Hanks (1:1). FHM juveniles (10 days post hatch) were exposed for 96 h with 50% water change every day. The expression of the CYP1a gene was selected as a biomarker of oil bioavailability. Total RNA was extracted from the whole animal and quantified by RT-qPCR. Although not statistically significant, exposition to WAF tended to increase the mean expression of CYP1a by 6.33 fold, indicating that PAHs in the oil were bioavailable. However, when NPs (10 mg/L and 50 mg/L) were mixed with the WAF, the expression of CYP1a returned to levels seen in unexposed fish, suggesting that the NPs reduced the bioavailability of the oil (Control = 2.58, WAF+10 mg/L= 3.01 and WAF+50 mg/L= 2.90). Further analysis will be done to compare the composition of the WAF before and after mixing with NPs using GC MS/MS. These preliminary studies suggest that HPG-NP effectively captured the components of WAF and made them less bioavailable to fish.

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Effects of Nitrogen Availability on the Diatom Thalassiosira pseudonana in the Presence of Oil and Surfactant

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The Deepwater Horizon oil spill released millions of barrels of crude oil into the Gulf of Mexico (GoM). In the coastal zone of the GoM, phytoplankton are known to be nitrogen limited for most of the year, including the post spill period. Little is known about the phytoplankton response to nutrient availability in the presence of oil and chemical dispersants. The purpose of this study was to investigate if the availability of nitrogen affects the diatom *Thalassiosira pseudonana* resilience to these contaminants. Diatom cultures grown with replete (100%) and 25% nitrogen were inoculated into five treatments: a control (f/2), a water accommodated fraction of oil (WAF), a chemically enhanced (with surfactant) WAF (CEWAF), a 1/3 and a 1/10 dilute CEWAF (DCEWAF and DDCEWAF). Diatom responses to each treatment were followed in a nitrogen replete, quarter nitrogen, and nitrogen deplete counterpart. Samples were taken daily to monitor changes in cell densities, concentration of oil, the macromolecular composition of cells, and their photosynthetic efficiency using fluorescence induction and relaxation. Results showed growth rates were more affected by contaminants than photosynthetic efficiency, and nitrogen limitation enhanced those responses. While protein content per cell was lowered by nutrient limitation, carbohydrate and lipid increased; this in turn enhanced production of extracellular polymeric substances. Changing nutrient availability may be an important trigger for marine snow formation. This study could help us better predict how the GoM phytoplankton may respond to any future oil spills, and the role of nutrient enhancement as occurred with the release of Mississippi River waters.

The Effects of Crude Oil and Corexit on the Diatom *Phaeodactylum Tricornutum* Under Nutrient Stress

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The Deepwater Horizon oil spill of 2010 released four million barrels of crude oil into the Gulf of Mexico. In response, a chemical dispersant was applied to fragmentize the oil slick as means of remediation. *Phaeodactylum tricornutum* is a marine diatom that has previously been found to be resilient in the presence of water accommodated fraction of oil (WAF) and chemically enhanced water accommodated fraction of oil (CEWAF) treatments. This diatom has a silica frustule, serving as a shell, and is dependent on a variety of nutrients, including nitrate as a nitrogen source. In this study, we investigated the role of the silica frustule in protecting *P. tricornutum* against WAF, CEWAF, and diluted CEWAF (DCEWAF) treatments as well as the effect of nutrient stress in lowering its resilience to these pollutants. *P. tricornutum* were cultured in F/2 media with and without silica (Si) and with and without nitrate (N) for five weeks and subsequently inoculated into WAF, CEWAF, and DCEWAF treatments. Growth rates showed that CEWAF treatments inhibited growth the most compared to WAF and DCEWAF, which had the highest growth rate. Photosynthetic activity was not affected during Si limitation but N limitation was important. This may be because the macromolecular composition of the cells was not altered by the Si limitation but N limitation lowered protein production. The latter resulted in a more “sticky” exopolymeric substance produced which lead to the cells clumping. Results also found that *P. tricornutum* protect their photosynthetic apparatus against harmful conditions under

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Si stress but not N stress, suppressing growth until ideal conditions are again reached. For the latter, growth does not recover without the resupply of new nitrogen. Further research is needed to better understand how diatom physiology is being modified by these pollutants.

The *Sargassum* Abundance under Oil Contamination Stress

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Pelagic Sargassum is critical marine habitat for various marine fauna in the Gulf of Mexico and they are potentially under the oil contamination impacts. Preliminary studies have used Landsat statistics to determine the aerial coverage of *Sargassum* within the cumulative oil spill footprint. However, there are two main issues to be resolved: 1) how much *Sargassum* biomass is associated with these aerial coverage estimations; 2) whether these *Sargassum* are in contact with oil during their time differences of observations. Using field measured *Sargassum* biomass per area and corresponding reflectance spectra, the first issue can be resolved through building a remote sensing-based biomass model. The second issue would be better diagnosed with more frequent, finer-resolution observations from satellites of both *Sargassum* and oil features. With these, a better estimation of the *Sargassum* abundance or biomass under the oil contamination stress could be derived and help understand the oil impacts to the marine ecosystem within the Gulf of Mexico.

The Effects of the Deepwater Horizon Oil Spill on Bottlenose Dolphin Diets

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The Deepwater Horizon oil spill (DHOS) had significant negative effects on dolphin populations in the northern Gulf of Mexico (GoM). The DHOS adversely impacted fish and invertebrate populations, leading to altered trophic interactions and community dynamics that would have changed dolphin food supplies and may have contributed to the poor health of these dolphin populations. To define how the DHOS affected the diet of bottlenose dolphins in the northern GoM, we compared stable isotope ratios in live and stranded dolphins and available prey species from different locations and time periods relative to the DHOS. We analyzed tissue samples from animals in Barataria Bay, LA and along the Alabama coast during 2011 (acute DHOS effects), 2013-2015 (recovery from DHOS), and 2017 (putative post-recovery). Dolphin diets will be quantified using stable isotope mixing models for each of the three time periods (acute, recovery, post-recovery) at each location. To further establish a rate of diet change within individuals during acute and recovery time periods, we will analyze up to three tissue types with different turnover rates (liver and skin, 2-4 weeks; muscle, 2-3 months) from dolphins along the Alabama coast. Our study will quantify diets of dolphins more thoroughly than has been done in the northern GoM, a region which we have sparse data on dolphin diets. These results will help us determine if changes in diet contributed to the poor health of dolphins following the DHOS and will broaden our understanding of how major events like the DHOS affect communities, from the base of the food web to a common top predator.

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Early Life-Stage Effects of Deepwater Horizon Crude Oil Exposure on the Developing Zebrafish Kidney

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Much has been learned with respect to the developmental toxicity of crude oil exposure to teleost fish in the years following the Deepwater Horizon oil spill. Among the key findings are several lines of evidence that specific crude oil constituents, namely polycyclic aromatic hydrocarbons (PAHs), impair the function and proper development of the teleost heart. The resulting reduction in cardiac output is believed to elicit a characteristic suite of downstream effects (e.g., pericardial and yolk sac edema) and likely impairs the proper development of other organs, such as the kidney. While there is some evidence that exposure to individual PAHs impairs development of the early stage kidney (i.e., pronephros), little is known regarding the effects on the pronephros following exposure to complex crude oil mixtures at environmentally relevant concentrations. Furthermore, it is unknown whether early life stage (ELS) effects arising from short-term exposures result in long-term or latent effects on kidney function. To address these knowledge gaps, time-course and dose-response exposures to zebrafish embryos were performed using high energy water-accommodated fractions (HEWAFs) of DHW slick oil. Transcriptional changes in genes with various structural, functional and signaling roles specific to different regions of the developing pronephros (e.g., glomerulus, pronephric tubule and pronephric duct) were assessed by QPCR and whole mount in situ hybridizations. Results demonstrate transcriptional changes in key genes involved in early kidney development and function and that early stage impairment of normal kidney development might translate into long-term impairment of teleost kidney function. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

Synergistic Effects of Oil Exposure, Temperature, and Hypoxia on Two Economically Important Sciaenidea Fishes in the Gulf of Mexico

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Aerobic scope, the difference between an animal's basal metabolic requirements and their maximum metabolic capacity, is considered to be a particularly important metric influencing ecological success in fishes. Crude oil exposure has been shown to impair cardiorespiratory function in fishes, which consequently reduces maximum metabolic rate, aerobic scope, and likely impairs ecological performance. Yet, oil exposure is not the only environmental stressor that can affect aerobic scope, especially in areas affected by crude oil spills (e.g. the Gulf of Mexico). Hypoxia (low dissolved oxygen) is known to constrain maximum metabolic rate in fishes, while high temperature raises basal metabolism and constrains maximum metabolic rate. Despite this knowledge, there has been little effort to explore how these environmental factors may influence the magnitude of metabolic injury following oil exposure. Therefore, the goal of this study was to investigate the synergistic effects of acute oil exposure, hypoxia, and temperature on the metabolic performance of two sciaenid fishes common to the Gulf of Mexico - red drum (*Sciaenops ocellatus*) and Atlantic croaker (*Micropogonias undulates*). Here, sub-adult red drum and croaker were acclimated to a series of 4 wk species-specific temperature acclimations before a subset of individuals were exposed to crude oil for a 24 h period. Following exposure, each individual's aerobic scope, post-exercise oxygen consumption, and hypoxia tolerance were quantified before each individual was assessed for a suite of morphological and

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physiological characteristics that could drive differences in aerobic performance (e.g. hematocrit, relative ventricular mass, mitochondrial enzyme content, and blood binding affinity). These comparative data will offer insight into metabolic constraints facing fishes exposed to oil while concurrently subjected to increased temperatures and hypoxia, two notable climate change stressors.

Decline and Recovery of Horse Fly Populations in Louisiana Marshes following the Deepwater Horizon Oil Spill

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In the aftermath of the Deepwater Horizon oil spill in April 2010, which had unprecedented impact on the Gulf of Mexico, we established the greenhead horse fly (*Tabanus nigrovittatus* Macquart) as a bioindicator of marsh health. Immediately after the oil spill (2010-2011), horse fly populations declined in oiled areas of Louisiana marshes with significant impacts on genetic structure. Five years after the catastrophic event (2015-2016), populations in formerly oiled areas showed signs of recovery. Fly numbers increased compared to those immediately after the oil spill. Previously detected genetic bottlenecks in oiled populations have disappeared. Migration into oiled areas began to replenish formerly depleted horse fly populations in impacted regions with populations from non-oiled areas as an important source of migrants. Parameters of family structure that had been negatively impacted by the oil spill (number of breeding parents, effective population size, number of family clusters) rebounded to levels similar to or exceeding those in non-oiled control areas.

The Marsh Periwinkle (*Littoraria irrorata*) as an Indicator of Deepwater Horizon Oil Spill Effects

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The Deepwater Horizon oil spill resulted in varying degrees of oiling in the salt marshes of northern Barataria Bay, Louisiana, USA. This study examines the effects of moderate and heavy marsh oiling compared to reference (without visible oiling) stations, and recovery, on *Littoraria irrorata*, the salt marsh periwinkle, from 2.5 to 8.5 years after the spill. After an initial population decline associated with oiling, the population density of *L. irrorata* increased at all oiling categories with the highest density of *L. irrorata* at moderately-oiled sites compared to both reference and heavily-oiled stations. *Spartina alterniflora* stem density recovered within two years after the spill at the moderately-oiled stations facilitating recovery of *L. irrorata* density approximately one year later. *L. irrorata* average shell length and length-frequency distributions are potentially sensitive indicators of the health and recovery of the marsh. Average shell length increased linearly from 16.5 mm at the beginning of the study to 19.0 mm at 7.5 years at reference sites. However, snails at both the moderately-oiled and heavily oiled sites increased in average shell length through year 4 of the study, but then decreased. The difference between the oiling categories is associated with a decline in the relative abundance of the larger adults (shell size 21-26 cm) at oiled sites. This discrepancy This discrepancy could mean that either *L. irrorata* individuals are not surviving to these larger sizes, are growing more slowly than expected, or that adults leave the oiled area prior to growth to these larger sizes. Larger *L. irrorata* may be emigrating from the oiled areas.

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The Effect of Oil-Exposure on Ammonia and Urea Excretion in Mahi-Mahi (*Coryphaena hippurus*) Early Life Stages

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The timing and location of the 2010 Deepwater Horizon (DWH) incident within the Gulf of Mexico coincided with the spawning of many commercially and ecologically important fish species, such as mahi-mahi. Early life staged mahi exposed to environmentally-relevant crude oil concentrations have displayed increased oxygen consumption suggesting an increased metabolic rate which is mainly fueled by protein catabolism from yolk sac. In teleosts, protein is usually metabolized into ammonia or urea. Recent studies by our lab revealed that, similar to other teleosts, mahi avoid the toxic build-up of ammonia by being largely ureotelic during the embryonic stage and gradually switch to being ammonotelic for less ATP cost at the time of hatch (42-48 hpf). The nitrogenous waste excretion happens mostly at the gills, where Rh protein family (Rhag, Rhbg, Rhcg1 and Rhcg2) works as ammonia transporters and UT works as urea transporter. In this study, mahi embryos and larvae were exposed to 2%, 4% and 6 % HEWAF (6.4, 14.2, 20.7 μg l^{-1}∑50 PAH) to investigate the impacts of crude oil on ammonia and urea excretion by examining gene expression changes of related transporters over the initial 102 hpf of life. Crude oil was found to significantly increase mRNA levels of ammonia transporters around the time of hatching but not urea transporters. The upregulated mRNA levels of ammonia transporters support the increased metabolic demand fueled by protein metabolism, especially during hatch when any physiological change could impact larvae survival. Our results contribute to understand the underlying mechanism of toxicity from crude oil in early life staged pelagic fish. Measurements of ammonia and urea excretion rate is currently ongoing and will also be presented. This research was made possible by a grant from The Gulf of Mexico Research Initiative. Grant No: SA-1520.

Towards a Petrochemical Vulnerability Index for Gulf of Mexico Marine Species: Comprehensive Collection of Body Burden and Toxicity Data

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The overall goal of this project is to provide a variety of resource managers representing government, non-profit, corporate and other stakeholders, with comprehensive population, extinction risk and petrochemical vulnerability estimates for more than 2,000 marine species, including all marine vertebrates and complete clades of select plant and invertebrate groups, in the Gulf of Mexico Large Marine Ecosystem. In this first phase, all available information on species-specific polycyclic aromatic hydrocarbon (PAH) body burdens and/or measured toxicological responses to PAHs or petrochemical exposures were systematically collected from a number of databases, including Web of Science and the GoMRI GRIIDC database. To date, more than 360 studies have been identified to contain species-specific information on PAH body burdens and/or toxicological responses, representing primarily more well-known commercial or commonly tested species across the Gulf. From these preliminary data, general trends across different species groups representing relative toxicities and likelihoods of

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exposure were evaluated, in addition to identification of major gaps in exposure and toxicity data for key species groups.

Interactions of Microbes and *Spartina alterniflora* Growing in Oiled Mesocosms

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The 2010 Deepwater Horizon oil spill is being heavily investigated to understand the effects of the spill on communities of macro- and microorganisms. In particular, the foundational salt-marsh grass, *Spartina alterniflora*, is studied with regards to the effects of oil pollution because of the central role it plays in salt-marsh function. However, the response of the plant has never been studied in conjunction with the microbial associates of the plant. We hypothesize that the microbiome of *S. alterniflora* is integral to the persistence of the grass in oiled environments and propose that the microbiome should be considered in management of oiled salt marshes. Here we report our preliminary results from a greenhouse experiment in which *S. alterniflora* was grown in mesocosms contaminated with naturally weathered oil recovered from the oil spill. We examine changes in the microbial communities of *S. alterniflora* and plant morphology through time and between the rhizosphere, root, and leaf tissues. Additionally, we describe how oil constituents are changing through time and as they infiltrate the plant tissues, depending on the presence or absence of the plant and select microbial taxa. Effects of the oil are slow to manifest, supporting the idea that long-term research is necessary after an oil spill. The response of these communities, and the ecosystem they support, is key to understanding the oil spill and developing efficient management and for management strategies in affected salt marshes.

Altered Gene Expression in Developing Mahi-Mahi Embryos Exposed to Chemical Dispersant and CEWAF

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Following the Deepwater Horizon oil spill, nearly 2 million gallons of the chemical dispersant Corexit 9500 were deployed at both the well-head and surface waters to prevent slick formation. Previous studies have shown that dispersant application may enhance the acute toxicity of oil by altering PAH composition and increasing PAH availability via increased oil surface area. To assess the transcriptomic impacts of Corexit on oil toxicity during embryonic development in mahi-mahi (*Coryphaena hippurus*), recently fertilized embryos were exposed to Corexit alone (2.5, 5, or 10 mg/L) or Corexit in combination with oil (CEWAF, ∑PAH 2.21 ± 0.6 µg/L + 2.5, 5, or 10 mg/L Corexit) for 48 hours post fertilization. Surviving embryos were collected for whole-transcriptome analysis with RNASeq. All Corexit alone concentrations induced fewer than 50 differentially expressed genes compared to controls, embryo survival was unaffected, and Corexit exposures and controls formed a tight cluster in a principal component analysis, suggesting that dispersant alone may not have a significant effect on mahi-mahi development. CEWAF preparations induced ~2500 differentially expressed genes at all Corexit concentrations, and percent survival was not affected by dispersant concentration. Pathway analysis indicated mitochondrial dysfunction, oxidative phosphorylation, and calcium signaling were the most affected pathways in all CEWAF preparations, and toxicity pathways for cardiac malformations were also highly enriched, similar to previous findings in oil exposed mahi-mahi without dispersant. These data suggest that the addition of Corexit did not have a large impact on oil-induced transcriptional

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responses in mahi-mahi embryos, and increasing Corexit concentrations did not impact oil toxicity. 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).

Fiddler Crab Burrowing and Oil Pollution Alter Greenhouse Gas Fluxes from Salt Marsh Soil

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Coastal wetland soils are important sites of carbon burial that can mitigate the intensity of carbon-induced climate change. However, soil microbial processes produce potent greenhouse gases, such as carbon dioxide and methane, which can then be released into the atmosphere and offset some of the climate benefit provided by carbon burial. A great deal is known about the influence of seasons, tides, and salinity on salt marsh greenhouse gas emissions, but little effort has been devoted to determining their responses to natural and anthropogenic disturbances. In this study, we specifically evaluate how fiddler crab (*Uca longisignalis*) bioturbation and oil pollution affect the fluxes of carbon dioxide and methane from Louisiana salt marsh soil. This study included three burrow treatments (no burrow, artificial burrow, and crab-made burrow) and four oil treatments with oil concentrations of 0 mg cm-2, 0.85 mg cm-2, 8.52 mg cm-2, and 25.55 mg cm-2. Soil microcosms were incubated for five days after which carbon dioxide and methane fluxes were measured using a field gas analyzer and the microcosms were extruded to quantify burrow size and depth. Oil concentration did not affect carbon dioxide fluxes, but methane fluxes were significantly lower in the high oil treatment than in the other treatments. We found a linear relationship between the mass of burrowed material and the carbon dioxide flux, but burrow size did not influence the methane flux. Instead, we determined in a follow-up experiment that burrows of any size were sufficient to drive an enhanced methane flux. Our study demonstrates the potential of both natural and anthropogenic disturbances to alter salt marsh soil greenhouse gas fluxes, but more work is required to determine their influence on the ecosystem scale.

Population Dynamics and Disease Prevalence in the Marsh Rice Rat (*Oryzomys palustris*) following the 2010 Deepwater Horizon Oil Spill

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The marsh rice rat (*Oryzomys palustris*) is a semi-aquatic small mammal native to Louisiana coastal saltmarshes impacted by the 2010 Deepwater Horizon oil spill. Its use of intertidal habitats and dependency on fossorial invertebrates make it a good candidate to examine long-term exposure to persistent oil residues. The marsh rice rat is also the reservoir species of Bayou Virus (BAYV), a hantavirus which is potentially fatal when contracted by humans. This system provides an opportunity to investigate the relationship between oil exposure in a free-ranging species and immune system response. The objectives of this project are to determine whether marsh rice rat population abundance, survival, and BAYV prevalence differed between oiled and unoiled sites. From 2013-2017, marsh rice rats were trapped and tagged as part of mark-recapture sampling at oiled (n=4), unoiled (n=3), and control (n=2) sites for a total of n=9,996 trap nights. Blood sera were collected from live animals via the retro-orbital sinus and screened for antibodies using immunofluorescent assays. RT-

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PCR was used to detect viral RNA (vRNA) in lung samples collected from a subset of rats that were sacrificed at the end of each field season. Huggins' closed capture models were developed in Program MARK to derive estimates of marsh rice rat abundance. These estimates were used to compare population size, inter-annual growth, and demographic differences between oiled and unoiled sites. Cormack-Jolly-Seber models were used to determine whether apparent survival differed between oiled and unoiled sites. Rate of seropositivity, antibody titer level, vRNA presence/absence, and vRNA load were compared across years, sites, and individual covariates such as sex, age, and weight. Results from this study will help elucidate the long-term impacts of oil exposure on near-shore vertebrate populations as well as the effects on immune system response, as measured by disease prevalence.

Hydrocarbon Toxicity to the Shallow-Water Coral *Porites divaricata*: Modeling and Evaluating the Effects of Macondo Crude Oil

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Shallow water coral reef ecosystems in close proximity to urbanized coastlines have an elevated risk of exposure to petroleum. Previous research evaluating hydrocarbon toxicity to corals has generally focused on community level effects. That, and variability between studies, leaves a significant data gap on the toxicity thresholds of hydrocarbons to individual coral species making targeted toxicity studies important to accurately assess coral resilience in case of spills. In response, we developed standardized toxicity testing protocols for corals that utilize multiple high-resolution assessment metrics. Previous experiments individually evaluated toxicity of 1-methylnaphthalene, phenanthrene, and toluene to the scleractinian coral *Porites divaricata*, and determined the critical target lipid body burden using experimentally derived LC50s and the target lipid model. This was then used to model the impacts of crude oil using the Petrotox model. Estimated impacts were verified by assessing the effects of passively-dosed Macondo surrogate oil (MC252) in a 48 h constant exposure multi-concentration toxicity test with *P. divaricata*. Acute and sub-acute effects (color, polyp retraction, mucus production, tissue loss/mortality, and PAM fluorometry) were evaluated during exposure and post-exposure recovery periods. Threshold estimates were based on sub-acute and acute effects at the end of the exposure period. Exposure to oil concentrations from 15 to 960 mg/L loading resulted in no mortality, preventing calculation of an LC50 and verifying the Petrotox prediction of an LC50 > 1000 mg/L. The comparison of predicted versus observed toxicity is a key focus of this work and thresholds determined in this study provide data for modeling of potential impacts of *in-situ* hydrocarbon exposures. This information is important for Net Environmental Benefit Analysis (NEBA) or Spill Impact Mitigation Assessment (SIMA) of predicted impacts and response options in coral reef environments.

Behavioral and Physiological Responses of Bicolor Damselfish and Mahi-Mahi to Olfactory Cues following Crude Oil Exposure

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In fishes, olfactory cues provide information about predators, prey, and conspecifics that is crucial to survival; however, olfactory sensory neurons are directly exposed to the environment and are

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susceptible to damage from aquatic contaminants such as crude oil. The 2010 Gulf of Mexico oil spill overlapped with the habitat of pelagic and reef fishes, including mahi-mahi (*Coryphaena hippurus*) and bicolor damselfish (*Stegastes partitus*). To date, within the marine teleost group, nothing is known about how crude oil exposure affects the detection of olfactory cues or if crude oil can be detected as an olfactory cue and avoided. To address these questions, we used a two-channel flume choice system to assess behavior and an electroolfactorgram (EOG) technique to examine olfactory acuity of oil exposed and control juvenile bicolor damselfish and mahi-mahi. Control bicolor damselfish avoided a conspecific chemical alarm cue (CAC) in the flume choice system, while oil exposed conspecifics did not avoid the CAC ($p<0.001$). Control mahi-mahi did not distinguish between seawater and crude oil in the flume choice system; however, oil exposed mahi-mahi spent a greater proportion of time in crude oil than the control fish ($p<0.01$). Preliminary bicolor damselfish EOG data suggests that controls detect the CAC as an olfactory cue while oil exposed conspecifics do not. Preliminary mahi-mahi EOG data suggests that controls can detect crude oil as an olfactory cue. While preliminary, these data suggest that crude oil may be detected as an olfactory cue while a 24-hour exposure may inhibit the detection of biologically relevant olfactory cues. 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).

Acute and Subacute Toxicity of Polycyclic Aromatic Hydrocarbons 1-methylnaphthalene and Phenanthrene to Five Atlantic Scleractinian Coral Species

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Coral reefs are key tropical ecosystems of significant ecological and economic value that are at risk worldwide due to a broad range of environmental stressors, including potential impacts from oil spills. Previous research evaluating hydrocarbon toxicity to corals and coral reefs has generally focused on community-level effects and results are often not comparable between studies due to variability in exposure characterization and coral health assessment metrics during exposure. This represents an important knowledge gap in oil spill preparedness and response as it relates to the potential impacts of oil spills to corals. The central objective of the CoralTox project is to provide new data on lethal and sub-lethal thresholds of hydrocarbon exposure for five Atlantic coral species in order to support more effective decision-making and response should a spill occur near coral reefs. Modeling the toxicity of individual hydrocarbons permits prediction of the toxicity of any complex hydrocarbon mixture. This study therefore assessed the toxicity of 1-methylnapthalene and phenanthrene to shallow-water coral species *Acropora cervicornis, Porites astreoides, Siderastrea siderea, Stephanocoenia intersepta* and *Solenastrea bournoni*. Acute and sub-acute effects (mortality, coral condition, photosynthetic efficiency, growth and cellular changes) were evaluated in 48 h constant exposure, multi-concentration toxicity assays utilizing a passive dosing system. For 1-methylnaphthalene, 48-h EC50s ranged from 2774 µg/L for *A. cervicornis* to 12049 µg/L for *S. siderea*, and 48-h LC50 of 3518 µg/L for *A. cervicornis* and 12138 µg/L for *P. astreoides*; <50% mortality was observed in the other tested coral species. Results of phenanthrene tests will also be presented. While the threatened species *A. cervicornis* is the most sensitive of those tested thus far, acute endpoints indicate that corals may be more resilient to hydrocarbon exposure compared to other species. These toxicity thresholds are key to modeling impacts of oil exposures to scleractinian corals, and in Net Environmental Benefit Analysis (NEBA) of predicted impacts and response options in coral reef environments.

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Hepatic and Biliary Accumulation of PCBs, OCPs, and PAHs in Snappers and Groupers from the Northwest Coast of Cuba

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Understanding the presence and impact of contaminants is an integral part of maintaining a healthy fishery and ecosystem, however there is currently little known about the contaminate loads affecting Cuban fish populations. In 2017, the Center for Integrated Modeling and Analysis of Gulf Ecosystems (C-IMAGE) in conjunction with the Center for Marine research at the University of Havana, conducted a demersal longline survey along the northwestern coast to gather baseline contaminant data. The objective of this study is to assess the health of fish populations by quantifying contamination loads of polychlorinated biphenyls (PCBs), organochlorine pesticides, and polycyclic aromatic hydrocarbons (PAHs) present in fish. Bile and tissue (liver and muscle) were collected from grouper and snapper species. Biliary PAHs were quantified using HPLC-FLD, and tissue concentrations of the organics (PAHs, PCBs, OCPs) quantified using gas chromatography tandem mass spectrometry (GC-MS/MS). Species differences, spatial patterns, and size/sex comparisons will be provided and interpreted for these samples. The data from this study will provide insights into the presence and possible impacts of three key groups of environmental contaminants in Cuban coastal ecosystems across a human impact transect from the urbanized area around Havana City to the rural extreme west of the country.

Acute Toxicity of 1-methylnapthalene and Macondo Surrogate Crude Oil to the Peppermint Shrimp, *Lysmata boggessi*

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The potential impacts of hydrocarbons to marine crustaceans are an important consideration in a more complete understanding of ecosystem effects resulting from oil spills. Toxicity benchmarks for the marine environment are often based on estuarine species, which are tested at lower salinities, and the results may not be directly applicable to the higher salinity marine environment. Current studies, such as the Deep-sea Risk Assessment and Species Sensitivity to WAF, CEWAF and Dispersant project (D-TOX), focus on the data collection of ecologically important pelagic crustaceans. However, these experiments are also accompanied with complications, such as collection stress, that may compromise results. To improve the accuracy and validity of the data, a model organism is required. The peppermint shrimp, *Lysmata boggessi*, which occurs in shallow coastal marine environments throughout the western Atlantic, Caribbean and Gulf of Mexico, may be a suitable representative species. This study thus compares new petroleum hydrocarbon toxicity endpoints for *L. boggessi* to previously determined thresholds for other crustacean species.

The effects of 1-methylnaphthalene and crude oil on *L. boggessi* were assessed in 48-h constant-exposure multi-concentration toxicity tests utilizing a passive dosing protocol. Acute effects were evaluated both during exposure and at the end of the 48-h exposure period, and were used to estimate median lethal concentrations (LC50s). A critical target lipid body burden (CTLBB) was determined using the target lipid model and the calculated LC50 for 1-methylnaphthalene. The 24-h LC50s for 1-methylnapthalene and crude oil were estimated at 452.5 µg/L and 199.2 µg/L, respectively, and the

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calculated CTLBB was 24.8 µmol/g. The sensitivity of *L. boggessi* to petroleum hydrocarbons is similar to other coastal, epi-, and mesopelagic crustaceans, suggesting that *L. boggessi* may be a suitable surrogate species.

From Individuals to Ecosystem: The Use of Biomarkers as Risk Indicators for Operational Discharges of Oil and Gas Activity in the North Sea

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Oil and gas companies operating on the Norwegian Continental Shelf are required to carry out environmental monitoring to obtain information on the environmental impacts of their activities and to give authorities a better basis for regulation. A multidisciplinary approach (e.g. chemistry, biology, modelling and risk assessment) is in use at present to monitor discharges and reduce risks. Aiming to integrate biomarkers into probabilistic risk assessment for oil-based discharges, biomarker data from the 2017 Water Column Monitoring (WCM) program have been used as risk indicators in the procedures for Environmental Risk Assessment of PW discharges. In 2015, new guidelines were published and the requirements have been applied for the first time in the 2017 Water Column Monitoring program. This holistic approach shows a significant improvement in the scientific outcomes of the monitoring, in a cost-efficient way. The surveys included the use of species from various trophic levels and the analysis of both chemical and biological parameters. Three regions were selected: Tampen, Southern North Sea, and Egersundbanken (reference area) and in additional the near platform effect (Statfjord A) was assessed. The study design included the use of a predictive discharge model (Dose-related Risk and Effect Assessment Model, DREAM). This model calculates the fate of the discharge in 4 dimensions (including time) to predict environmental concentrations, risk and effects. Biological and chemical data confirmed the accuracy of the study design and provided information on the actual impact of the discharge on the ecosystem. Data showed a general decrease in the actual impact in comparison to previous years. It is worth to notice that while developing the Water Column Monitoring program, scientists in Norway prioritise a RRI (Responsible Research and Innovation) approach.

Responses of Sulfate-Reducing Bacterial Communities to Hydrocarbon Contamination

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Oil spills have shown to stimulate the activity of hydrocarbon-degrading bacteria and lower oxygen concentrations due to respiration of microorganisms. Some sulfate-reducing bacteria (SRB) can degrade hydrocarbons and may play significant roles in anaerobic oil degradation. We hypothesize that the addition of hydrocarbons to subtidal sediments will decrease oxygen concentrations and change microbial communities in favor of anaerobic oil degradation. High-throughput 16S rRNA gene sequencing, dissimilatory (bi)sulfite reductase gene sequencing, and microelectrodes were used to investigate the microbial responses of sediment cores exposed to water-accommodated fractions (WAF) of crude oil. 16S rRNA analysis showed that hydrocarbon-degrading sulfate reducers, *Desulfosporosinus* sp. (Clostridia) and *Desulfotalea* sp. (Deltaproteobacteria) dominated in Estero Bay

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sediment while facultative anaerobes, *Christensenella* sp. (Clostridia) and *Marinilabilia* sp. (Bacteroidia) dominated in Chandeleur Island sediment in response to WAF exposure. Microbial diversity as measured with the Shannon index in both 16S rRNA and dissimilatory (bi)sulfite reductase genes decreased in most cores exposed to WAF. Microsensor profiles of oxygen and hydrogen sulfide in control cores and cores exposed to WAF varied depending on the differences between sediment cores (i.e. sampling location, sediment type). Overall, we confirmed the microbial population shifts from aerobic to anaerobic respiration along with the reduction of microbial diversity in response to WAF exposure.

Southern Flounder DWH Oil Sediment Induced Oxidative Stress and DNA Damage

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In coastal areas impacted by the Deepwater Horizon spill, benthic species, like the southern flounder (*Paralichthys lethostigma*) are at risk for biological damage, reduced fitness and ultimately mortality because of their continued long-term exposure to polycyclic aromatic hydrocarbons (PAHs) in oiled sediments. This exposure occurs via multiple pathways; dermal contact, across the gill membranes and through ingestion of prey and incidental ingestion of associated contaminated sediments. These exposure routes ultimately result in internal exposure to PAHs, potentially creating reactive oxygen species giving rise to oxidative stress and DNA damage. A 30-day laboratory based oiled sediment exposure study was carried out using juvenile southern flounder. South Louisiana crude oil was mixed with clean sediments at a 3 g/kg (w/w) ratio and placed in three raceways with six replicate tanks to a depth of 5 cm of oiled sediments and three tanks with clean sediments. Sediment samples were collected weekly and analyzed for ∑50PAHs. At the end of the 30-day exposure, all fish were sacrificed and evaluated for ∑50PAHs body burden, evidence of oxidative stress and DNA damage. There was a significant increase in PAHs in the liver and a decrease in blood intracellular antioxidant defense (GSH/GSSG), which may be a result of increased oxidative stress in the fish. Concurrent with this reduction evidence of oxidative damage to cellular components was also apparent. There was a significant increase in lipid peroxidation and increased levels of DNA single strands breaks detected using the COMET assay in the liver and blood cells of exposed fish. In conclusion exposure to fish to chronic low levels of oiled sediments resulted in persistent biological perturbations and damage consistent with PAH exposure that could have implications for the health and fitness of resident organisms.

Succession Pattern and Phylotype Analysis of Microphytobenthic Communities in a Simulated Oil Spill Seagrass Mesocosm Experiment

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Microphytobenthic communities play a significant role in nutrient modulation, sediment stabilization, and primary production in seagrass beds, which are imperative habitat and nursery for commercially

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important fish and shellfish species and provide various ecosystem services. During August to October in 2016, 19-liter seawater mesocosms were prepared, each containing one 15 x 10 cm PVC pipe core of sediment and seagrass (*Ruppia maritima*) collected from the Chandeleur Islands, Louisiana, and Estero Bay, Florida. They were exposed to 50% WAF and diluted by 50% with seawater daily over the course of 8 days to simulate tidal dilution. Two mesocosms were created from each location, with one from each site used as a control. Regular microsensor monitoring of oxygen and hydrogen sulfide was conducted during oiling and for 6 weeks afterwards to monitor changes that may be attributable to microphytobenthic metabolic activity. Bottom water oxygen concentrations decreased in all samples, with oiled samples often containing slightly lower concentrations than their unoiled counterparts. High-throughput sequence analysis based on the chloroplast 23S rRNA gene was conducted on extracted DNA from sediment to assess the impact of oiling on microphytobenthic communities. Distinct succession patterns were detected in benthic algal communities between naïve (Florida) and chronically oil exposed (Louisiana) sediments. The impact of oiling in microphytobenthos across all samples showed that benthic diatoms dominated all algal communities with sample percentages ranging from 43 to 98%, followed by cyanobacteria, which ranged from 0.6 to 48%. Pennate diatoms (32 to 98%) occupied a larger fraction than centric diatoms (0.7 to 28%). Within pennate diatoms (Pennales), Bacillariophyceae (30 to 97%) were more abundant than Fragilariophyceae (0.3 to 10%). The dominance of pennate diatoms and cyanobacteria was also confirmed by microscopy. The observed succession patterns and detailed phylotype analysis may provide a firm base for future research on microphytobenthic response to oiling.

Role of Micron-Scale Aggregates in Hydrocarbon Oxidation

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The Deepwater Horizon oil spill in April 2010 introduced an estimated 650,000-780,000m^3 of crude oil into the Gulf of Mexico (GoM). To mitigate the impact of this oil to the coastal environment, dispersant was applied to the surface oil slick, promoting the incorporation of oil droplets into the water column. During the spill, the formation of oil associated flocculants was observed within the contaminated surface waters which aggregated and sank over time, leading to the sedimentation of oil-rich marine snow. Mesocosm experiments were conducted to better understand the role of such microbial aggregates in hydrocarbon degradation and transport. Using GoM coastal water, three mesocosm treatments were set up consisting of a seawater only control, seawater amended with the water accommodated fraction of oil (WAF), and seawater with dispersed oil. It was observed that, in addition to the formation of marine oil snow, smaller micron-scale microbial aggregates were also present in all treatments. Visual inspection of these microaggregates revealed that within the WAF and dispersant amended treatments, ≥90% were associated with oil droplets. The abundance of these aggregates was greater in the WAF and dispersant treatments as compared to the control and their peak abundance occurred on day 3, followed by a gradual decline. This peak abundance coincided with the maximum rates of biological hydrocarbon oxidation as estimated by the mineralization of ^{14}C labeled hexadecane and naphthalene. To elucidate the potential of these microaggregates to serve as hotspots for hydrocarbon degradation, the microbial assemblages within the aggregates was characterized via 16S rRNA gene sequencing, revealing a large and diverse population of potential hydrocarbon degrading taxa. The presence of some of these taxa with the microaggregate structure was further validated using fluorescent in situ hybridization (FISH).

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Maternal Offloading of PAHs and Relationship to Hepatobiliary Changes in Gulf of Mexico Golden Tilefish

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Through a series of Gulf-wide demersal longline surveys, 2012-2017, the Center for Integrated Modeling and Analysis of Gulf Ecosystems (C-IMAGE) collected tissues (liver, gonad) from Gulf of Mexico Golden Tilefish (*Lopholatilus chamaeleonticeps*). Golden Tilefish were selected as a target species due to their strong association with clay sediments, leading to elevated and chronic exposure to sedimented oil residues. Tissues were analyzed for polycyclic aromatic hydrocarbons (PAHs) and alkylated homologs via QuEChERS EMR extractions and gas chromatograph tandem mass spectrometry (GC-MS/MS). A subset of liver tissues was processed via histological analysis by a board-certified veterinary pathologist. Ninety nine percent of Golden Tilefish exhibited one or more hepatobiliary change, and preliminary data analysis indicated a relationship between frequency of certain hepatic lesions and accumulation of PAHs in liver tissue. Preliminary data analysis also revealed male Golden Tilefish have higher mean total PAH (TPAH) concentrations in their liver (μ= 31,900 ng/g wet wt.) compared to female fish (μ= 20,300 ng/g wet wt.), suggesting that maternal offloading of PAHs may be a route of elimination for females worth investigating. Total PAH levels in gonadal tissue will be quantified and compared to TPAH levels in liver tissue in male versus female fish. The expected trends are that females will have elevated TPAH concentrations in their gonads, and lower TPAH concentrations in their liver compared to males, and thus lower frequency of hepatocellular abnormalities detected. TPAH concentrations in gonadal tissue will also be analyzed by gonad stage and percent lipid. The data from this study will provide insight into the offloading of petrogenic contaminants by female Golden Tilefish, with the potential for harmful impacts on eggs, larvae and juveniles of this commercially important benthic species.

Path to “Dirty Blizzard” from Deep-Sea Oil Plume: Bacteria Form Streamers on Rising Droplets to Increase Drag

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During the Deepwater Horizon oil spill, wellhead injection of dispersant caused a large pool of micro-droplets to be entrained in the 400 m thick deep-sea plume spanning over a hundred kilometers for months. To date, apart from transport by buoyancy or currents, the perceived fates of these suspended droplets are metabolic degradation by microbes or sedimentation via marine oil snow formation. However, both fates are contested on the grounds that droplets rise too fast to allow microbes to encounter, adhere, and grow at the oil-water interface to initiate biotic processes. For instance, a 200 μm oil droplet traverses the microbe-laden plume in ~48 h, while processes leading to both fates require weeks to complete. Using a microfluidic platform capable of investigating a single oil droplet rising through a microbial suspension at ecologically relevant length (0.5 μm - 1 mm) and time scales (1 ms - 1 d) with well-controlled physicochemical environments, we discover that within minutes immediately after the droplet encounters Pseudomonas suspensions, long polymeric streamers are extruded behind it and are bundled into a large tail extending up to 10 drop diameters downstream within hours. Flow measurements show that droplet drag is increased by at least 60% with only a few streamers. Increase in drag by streamers slows the drop and consequently lengthens its residence time to surrounding microbes. Short formation time scales compounded with impacts on hydrodynamics

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provide a creditable missing link in pathways to biodegradation and sedimentation, and significant implications in droplet transport models.

Acute Toxicity of Oil and Dispersant on Deep-Sea Crustaceans

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This study is part of the DTOX (Deep-sea Ecotoxicology) project tasked with understanding the impacts of chemically enhanced water accommodated fraction (CEWAF) of oil on deep-sea crustaceans. The targeted crustaceans for this study (Euphausids, *Systellaspis* sp., *Sergestes* sp., and *Sergia* sp.) represent an important trophic linkage between deep- and shallow-water ecosystems due to their diurnal vertical migrations. Commercially important fish species are dependent on these deep-sea crustaceans for food, and impacts from oil spills and the use of chemical dispersants on these organisms must be addressed. Deep-sea crustaceans collected from the Gulf of Mexico during a cruise aboard the RV Point Sur were stored in the dark (at 7-8 degree C) for 24 hours prior to toxicity experiments. Crustaceans were exposed to multiple concentrations (0-1000 mg/L oil loading) of CEWAF in a temperature controlled, 48 h flow-through toxicity system constructed in a dark room. Estimated oil equivalents (EOE) and petroleum hydrocarbons were monitored at three time points; 0, 24, and 48 h to verify aqueous concentrations of constituents, and to be used in determination of acute toxic thresholds using generalized linear modeling. Treatments above 130 mg/L loading resulted in 100% mortality within 12 h of exposure. Lethal loadings (LL50s) were calculated using the mortality data and nominal loading: LL50's range from 49-169 mg/L at 12 h to 14-71 mg/L at 24 h. Further characterization of impacts using measured aqueous concentrations of hydrocarbons is underway.

The Hydrodynamics of Swimming Bacteria at a Clean Oil-Water Interface

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Bacteria exhibit interesting behaviors at oil water interfaces. If the bacteria remain active swimmers, a variety of distinct swimming trajectories arise including nearly straight lines, tight circles, and sharp reversals of direction. Moreover, bacteria can interact with other bacteria or passive colloids at the interface to generate even more interesting paths of motion. Here, we present a theoretical investigation of the hydrodynamics of microswimmers attached to an oil-water interface with the goal of furthering the fundamental understanding of this rich, active system. We consider a flat, clean interface and an arbitrary oil-water viscosity ratio. Unlike a swimmer in a bulk fluid, a swimmer attached to an interface may exert a net force and/or torque on the fluid owing to capillary forces that pin it to the interface. Using a multipole expansion of the flow field on either side of the interface, we show that this leads to the production of net attractive (repulsive) hydrodynamic interactions between swimmers in the interfacial plane, assuming that the swimmers are pushers (pullers). An addition, we compute the trajectories of individual swimmers using the spherical squirmer model adapted for use on the interface. We show that circular trajectories arise whose radius is a function of viscosity ratio and the torque produced by the swimmer in the direction parallel to the interface. This finding is similar to that for swimmers found near but not attached to interfaces. Our theoretical results are compared to experimental measurements of the trajectories of the bacteria *Pseudomonas aeruginosa* at a hexadecane-water interface.

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Impacts of the Deepwater Horizon Oil Spill on the Population Structure of the Southern Ribbed Mussel (*Geukensia granosissima*)

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This study documents the long-term impacts of Deepwater Horizon (DWH) oil exposure on the southern ribbed mussel (*Geukensia granosissima*), an ecologically important species that facilitates salt marsh function and stability through plant-invertebrate mutualism. During the 2017 growing season, we conducted five mussel surveys at salt marsh sites in northern Barataria Bay, Louisiana, that were exposed to either heavy, moderate, or no visible oiling. At each site, all *G. granosissima* within a 0.25-m^2 quadrat placed at random within 1 m of the marsh edge were harvested, classified as either adult (> 60 mm) or juvenile, and the effects of oiling assessed on each size-class individually by determining mussel density, approximate volume, and average mussel biomass. Our results show that adult mussels were significantly smaller and tended to be less massive at moderately oiled sites. In contrast, juvenile mussels tended to be larger at heavily oiled sites, but their density, as well as total mussel density, followed a decreasing trend with increasing oil intensity. Observed long-term negative impacts on *G. granosissima* communities at oiled sites indicate that recovery was not complete seven years after initial DWH oiling, and suggest possible lingering alterations to ecosystem structure and function, which may ultimately influence salt marsh stability.

Evaluating Dolphin Serum Fatty Acid Profiles as Indicators of Ecosystem Change and Dolphin Health following the Deepwater Horizon Oil Spill

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Cetacean research following the Deepwater Horizon (DWH) oil spill primarily focused on the direct toxic effects of oil exposure. Yet the oil spill affected many components of Gulf of Mexico (GoM) ecosystems, with adverse and beneficial effects observed in lower trophic species. These observed changes may have indirect effects on the body condition, nutritional status, growth, and reproductive success of bottlenose dolphins (*Tursiops truncatus*). Fatty acid and stable isotope signatures are indicative of bottlenose dolphin diet, and thus available prey species, and shifts in dolphin serum fatty acid profiles may reveal the nutritional and disease state of the dolphins. Bottlenose dolphins sampled in heavily oiled Barataria Bay, LA during the year following DWH had high serum iron and anemia in addition to a higher prevalence of poor body condition and lung disease compared with dolphins sampled from a reference site with no evidence of contamination from DWH (Sarasota Bay, FL). Available data were not sufficient to determine whether the poor condition was due to disease states directly related to oil toxicity, a decrease in prey availability or quality, or some combination of these factors. We aim to determine whether changes in prey fatty acid content following DWH directly influenced dolphin serum fatty acid profiles, and whether negative effects observed in dolphin iron metabolism and hemoglobin are related to these environmental changes. In this study, we evaluate the

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use of bottlenose dolphin serum fatty acid signatures to assess changes observed in GoM ecosystems and evaluate the effect of such changes on bottlenose dolphin health parameters. This research will contribute to our understanding of how dolphins are affected by ecosystem changes that occurred in GoM bays and sounds during and after DWH.

The Effect of Deepwater Horizon Crude Oil on DNA Methylation Patterns in Wild-Caught Red Drum (*Sciaenops ocellatus*) in Louisiana Estuaries

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Epigenetics is the study of heritable changes in gene expression mediated by a wide-range of modifications to chromatin/DNA, one of which is DNA methylation. This addition of a methyl group to cytosine can be induced by environmental change, such as exposure to environmental contaminants, and maintained through cell lines and/or being passed from parent to offspring. As a result of this gene-environmental interaction, the tissue specific epigenetic landscape of cells can be altered and thereby the regulation of functionally important genes, but there still remains a lack of information about the pattern of epigenetic response to oil exposure. This study aims to assess differences in DNA methylation patterns on wild-caught juvenile red drum (*Sciaenops ocellatus*) residing in chronically oil-impacted and low-oil Louisiana estuaries. Using reduced representation bisulfite-converted sequencing, we will identify methylation patterns of wild fish exposed to differently oiled environments and compare them to acutely exposed laboratory-raised fish. Bioinformatic analyses, mapping reads to a previously sequenced draft of the red drum genome, will be used to quantify total methylation across the genome and patterns in specific gene regions, looking for an oil-induced epigenetic signal. Overall, this project will contribute to our understanding of epigenetics, specifically DNA methylation, and its relationship with acute and chronic oil exposure in red drum. The ability to detect changes at the molecular level is crucial in understanding potential negative impacts of oil exposure for economically and ecologically important food fish and can further be incorporated into future oil spill recovery monitoring and public health risk assessment efforts.

In-situ Spectroscopy of Cycloclasticus pugetii to Monitor Degradation of Polycyclic Aromatic Hydrocarbons

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Cycloclasticus pugetii is a ubiquitous marine bacterium that degrades polycyclic aromatic hydrocarbons (PAHs) contained in crude oil, a property beneficial to bioremediation efforts during an environmental spill. In contrast to classical reductionist approaches that study the function of highly purified proteins in dilute solutions, we have adopted a new systems approach for studying the responses of *C. pugetii* cells to soluble PAHs in situ, using the OLIS CLARiTY UV/Vis spectrophotometer. The CLARiTY utilizes a novel integrating round-cavity cuvette that allows collection of accurate absorbance data using turbid cell suspensions under noninvasive and physiological conditions. *C. pugetii* was grown to a high density

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and collected by centrifugation. The pellet was washed and suspended at $3.1x10^7$ cells/mL in a minimal, synthetic media (ONR7a). The addition of phenanthrene + 1% DMSO to the observation cell induced the rapid appearance of a colored product/intermediate with a broad absorbance maximum at 395 nm. The initial velocity of the absorbance change at 395 nm was directly proportional to the concentration of the cells in the suspension when the concentration of phenanthrene was 12.5µM. The V_{max} under these conditions was calculated to be 2.2 absorbance units 395nm x 10^{-12}/min/cell. Efforts to determine whether the observed reaction obeyed Michaelis-Menten kinetic behavior were hampered by the apparent rapidity of the reaction and the limited aqueous solubility of phenanthrene. We have observed the rapid appearance of similar spectral intermediates (395-455 nm) for other PAHs (chrysene, anthracene, naphthalene, fluorene, fluoranthene, pyrene). We hope to utilize this systems approach to elucidate both the PAH preference of *C. pugetii* and to deduce differences in PAH degradation among the wide variety of PAH degraders present in the natural environment.

A Synthesis of Toxicology of Oil in Vertebrates: Lessons from the Deepwater Horizon Oil Spill

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In the eight years since the Deepwater Horizon (DWH) oil spill, scientists have conducted an unprecedented number and variety of laboratory and field studies that documented the toxic effects of oil on Gulf of Mexico resources. The natural resource damage assessment (NRDA) studies alone included testing across multiple vertebrate taxa including fish, turtles, birds, and mammals, covering a wide range of exposure and stressor scenarios. A variety of Gulf of Mexico Research Initiative studies have provided further analyses of the impacts of oil and dispersants on vertebrate species, and the National Institutes of Health, Army Corps of Engineers, Centers for Disease Control and Prevention, and their partners have evaluated the impacts of the spill on response workers and the population along the Gulf coast. Scientists have found that many of the toxic effects were consistent across several vertebrate taxa. This 'constellation of toxic effects' guides our comprehensive understanding of oil impacts to multiple resources indigenous to the Gulf and beyond.

On October 23-25, 2018, the Toxicology of Oil in Vertebrates Synthesis Workshop was held to review the information derived from the studies during and after the spill to advance the field of oil toxicology at the level of specific physiological systems, so that we can better support the planning for, response to, assessment of, and recovery from future oil contamination events. The workshop participants reviewed scientific findings across vertebrate taxa to identify common pathways of exposure and injury. The group discussed how interactions among these pathways could cumulatively affect individual health, including intergenerational effects. Finally, workshop participants identified data needs that if addressed could better inform response decisions and resource assessments of future oil spills.

*Student Presenter

Transcriptomic Responses to Oil Exposure in Estuarine Fish Across Developmental Stages and Taxa

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Oil spills often occur in fish spawning and nursery habitats, therefore characterizing the effects of oil exposure in fish models bears economic and environmental importance. The timing of the 2010 Deepwater Horizon oil spill coincided with the spawning period of many fish species in the northern Gulf of Mexico, and exposed early life stages of several commercially important species to oil contamination. Although exposure to crude oil and its constituents are known to affect developing fish, few studies have addressed how responses to oil change across life stages. Additionally, despite known differences in sensitivity to oil across species, it is unclear whether transcriptional responses to oil vary substantially across fish taxa. To address differences in responses to oil across developmental stages and taxa we compared transcriptional effects 1) across life stages of a single species (*Cyprinodon variegatus*) and 2) across two similar species at the same developmental stage (*C. variegatus* and *Fundulus grandis*, immediately post-hatch). Embryos and larvae were exposed to high energy water accommodated fraction (HEWAF) from DWH source oil for 48 hours, followed by RNA sequencing to identify transcriptional responses. To examine biological impacts resulting from gene expression changes, transcriptomic data were subjected to pathway and gene network analysis using Ingenuity Pathway Analysis software. Our results strongly demonstrate that *C. variegatus* embryos are transcriptionally less sensitive to oil exposure than later developmental stages, and that post-hatch and post-larval groups exhibit similar responses to oil, both in number of dysregulated genes and in the type of functions altered. Disruption of cholesterol biosynthesis was the dominant effect of oil exposure in larval *C. variegatus*, followed by dysregulation of cardiac processes. Comparison of transcriptional responses between *C. variegatus* and *F. grandis* revealed marked differences in gene expression, and opposing responses with regard to cholesterol metabolism. Our results suggest that future studies should include examination of multiple life stages to fully assess the impacts of oil exposure during development, and caution against assuming that ecologically similar fish species will react comparably to oil exposure.

PAH Exposure in Red Snapper Collected Around Natural and Artificial Reef Systems in the Northwestern Gulf of Mexico

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In 2016, a total of 88 Red snappers (35 female/53 male) were collected from natural and artificial reefs located in the northwestern Gulf of Mexico (GoM) to assess their exposure to PAHs. Polycyclic aromatic hydrocarbons (PAHs) are environmentally persistent pollutants that are both anthropogenically and naturally derived. PAHs are found in natural fuel deposits (e.g. crude oil), volcanoes, and forest fires as well as the incomplete combustion or burning of organic substances (e.g. coal, oil, diesel, wood, garbage, tobacco). These pollutants are known to be associated with oilrigs with potentially negative effects due to increased exposure to the organisms that utilize these structures. While there are still natural reefs found throughout the GoM, artificial reefs (eg. standing, toppled, or cutoff oilrigs) seem to be increasing as natural habitats decrease from destruction or degradation through pollution or

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overexploitation. Red Snapper (*Lutjanas campechanus*) are commonly recognized as an important part of fisheries across the bordering states and their high abundance throughout these areas is a contributing factor in the economy. This study measures and compares PAH concentrations between gender, tissue matrices (liver, gonad, muscle, and bile samples), and habitat type (natural vs. artificial reef systems) from Red Snapper collected in the GoM in 2016. Preliminary results were analyzed using a semi-quantitative method of high performance liquid chromatography with a fluorescence detector (HPLC-FLD), which suggest there are no significant differences in the individual concentration of PAHs (naphthalene, phenanthrene, benzo-(a)-pyrene) in Red Snapper bile among sites, structure type (cutoff, natural, standing, toppled), or by habitat type (artificial v. natural). Standard length and total weight of the Red Snappers collected near the natural banks sites were significantly higher than the other site structures ($p>0.0001$). A significant difference could still be seen after examining the other extracted tissue samples (liver, gonad, muscle). Since some Red Snappers were caught during the spawning season, some gonads could be enlarged with eggs, increasing the lipid content found in the ovaries or testes, leading to a higher chance of bio-concentration of pollutants. Knowing the level of PAH exposure on Red Snapper matrices will help gain a better understanding of how other demersal fish may also be facing this level of exposure. This study could also be used to better understand the amount of PAH exposure that other fish could be experiencing in other places with high concentrations of oilrigs in an area.

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

A Novel Exposure Device to Assess the Health Impacts of Airborne Particulate Matter on the Human Respiratory System

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Aerosolization of oil by wave splashing on crude oil slicks may pose a respiratory health threat to oil-spill workers and communities nearby. However, the health effects of inhaling oily aerosols remain mostly unknown. Exposure systems for testing the toxicity of aerosols are crucial in understanding the airway disease pathogenesis. This study focusses on the design and implementation of a novel Real-Time Examination of Cell Exposure (RTECE) system for assessing the toxicity of airborne particles. A major advantage of this system over available commercial devices is the ability to observe the cells in situ throughout the exposure, enabling direct assessment of physiological changes, e.g., cell morphology and migration as well as changes to the Ciliary Beat Frequency (CBF) of the Human Bronchial Epithelial (HBE) cells. The latter could be used for assessing toxicity. Initially, the performance of the RTECE is compared with the commercial Vitrocell system, which does not allow *in-situ* observations, by exposing HBE cells to cigarette smoke. Measurements of mass deposition, monolayer permeability, and CBF after the exposure show agreement. Subsequently, the cells are observed while being exposed to 2 cigarettes twice, separated by a rest period of 60 min. Time evolution of CBF is continuously monitored by calculating the Fourier transform of the images. The data reveals that the

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CBF decreases gradually during the first exposure but recovers to the initial level following a rest period. A similar gradual decrease occurs after the second exposure, but after a short recovery period, the CBF decreases rapidly and never recovers. Furthermore, imaging of fluorescently-stained cell culture is used for measuring the effect of the smoke on the cell motility during and after the exposure. Results show that smoking causes a reduction in motility. Following ongoing tests focus on the paracellular permeability, protein abundance, and CBF to assess the toxicity of aerosolized oil.

Sand Adherence Estimated through Hand Press Trails for Children at Beaches

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Marine oil spills and the resulting environmental contamination is common along coastal areas; however, information is lacking about the safety of impacted beaches for public use, especially for the most vulnerable population: children. One route of exposure for children at oil impacted beaches is through dermal contact with impacted beach sands. The purpose of this study was to evaluate beach sand skin adherence for children under the age of seven, where sand adherence values are critical factors in the assessment. Each of the 122 children participated in a hand press trial conducted at one of four different beaches (two in Miami, FL and two in Galveston, TX USA). During the hand press trials, hand conditions of the children were randomized (dry, wet, or with sun-screen), and the maximum force applied and the sand loading (i.e., mass of dry sand adhering) was measured. Soil loading values were converted to sand adherences using surface area of hands. Results showed that the average sand adherence for both hands across the 122 children was 10.65 mg/cm^2 (std. 11.82 mg/cm^2), with boys (11.54 mg/cm^2) showing slightly higher means than girls (9.95 mg/cm^2), however these differences were not significant ($p = 0.23$). Among the three conditions evaluated, the highest loading was measured for children with wet hands (18.19 mg/cm^2), followed by hands with sun screen (7.39 mg/cm2). Dry hands (mean 6.58 mg/cm^2) had the lowest loadings. The difference between the loadings for wet hands versus dry hands was statistically different ($p<0.001$). The loading was also influenced by the force applied with overall pressure of contact of 0.24 psi. Study results will also be presented on the influence of soil size and environmental conditions on soil adherence. Overall results from this study can be utilized to look at dermal exposure and health risk to oils spill chemicals and other contaminants found in beach sands.

What are Nanoparticles Emitted from Seawater after an Oil Spill Made Up of?

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The health impacts of exposure to marine airborne particulate matter (PM) aerosolized after an oil spill depends on the particle size and the fraction of their toxic content. There is some evidence that application of chemical dispersant onto a crude oil slick increases the concentration of nanoparticles (particles smaller than 1 μm) aerosolized due to the natural oceanic processes. Although, finer PM generally intensifies the health impacts due to effective penetration and larger surface area

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interactions with alveolar region of the human respiratory system, toxicity assessment of the exposure strongly depends on chemical composition of the PM. In this study, we determined the chemical constituents of the nanoparticles emitted from seawater covered with a crude oil (MC252 surrogate) slick of 0.5 mm, before and after mixing with dispersant (Corexit 9500A, dispersant to oil ratio of 1:25). Aerosol generation was facilitated through the bursting of air bubbles injected at controlled diameter of 0.6 mm into a vertical seawater column. A 12-stage low-pressure cascade impactor (LPCI) collected the particles with size bins to be with cut off diameters of 9.5, 6.2, 4.2, 2.9, 1.8, 0.95, 0.51, 0.38, 0.30, 0.20, 0.13, and 0.056 µm onto 81-mm filters. Then, particles were extracted from the filters using pentane as the solvent and chemical composition of the particles was analyzed using a gas chromatography/mass spectrometry system. Based on the results, we recognized dodecane as an identifier compound for crude oil and 1-(-2-butoxy-1-methylethoxy)-2-propanol (BMEP) as an identifier compound for dispersant. Use of quartz filters provided the highest extraction efficiency (> 90% of the collected content). Both dodecane and BMEP were detected on the filters collected from multiple stages of the LPCI. Size-specific proportions of dodecane and BMEP, changes in dodecane contents at each stage compared to the case without dispersant, and anticipated health impacts will be presented.

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

Eastern Oysters (*Crassostrea virginica*) as Retrospective Bioindicators to Detect Oil Contamination in the Marine Environment

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Bivalves are useful biomonitors because they assimilate particles from their environment into tissue and shell. To determine if bivalves assimilate oil-derived elements into their shells as a possible retrospective bioindicator of exposure to oil or other contaminants, we conducted a controlled laboratory experiment exposing juvenile oysters to various oil types and concentrations during a 4-month period. Oysters were exposed to one of six possible treatments: Macondo 252 source oil; weathered oil from surface water; highly weathered tarballs from local beaches; water collected from an industrialized area in the Mobile River, Alabama; spiked oil of known elemental concentration (positive control); and filtered artificial seawater (negative control). Trace element profiles from the shells of a subset of exposed oysters were obtained using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). To incorporate the effects of multiple stressors, oysters were exposed to locally relevant low salinity stress (14) or standard estuarine salinity (25). Biological response to oil exposure and salinity conditions was monitored by measuring oyster survival and growth throughout the experiment. Preliminary data suggest oil exposure during the study did not have a significant effect on oyster growth or survival. This research tests a new technique to improve detection and tracing of oil and other contaminants in coastal waters and could be applied to enhance existing monitoring programs for damage and recovery assessment.

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Effects of Beached Weathered Oil May Depend on Shoreline Exposure History

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Oil released at sea can undergo significant weathering prior to beaching, with a loss of the lighter hydrocarbons due to evaporation, dissolution and degradation. Beached oil differs from freshly released oil in composition, which may lead to different fates and effects. An intermediate fuel oil (IFO40) representing a potential source from shipping, mixed with seawater, was weathered for three days on an orbital shaker, then added to replicate outdoor artificial beaches to characterize leaching hydrocarbons due to tidal flux. Water was drained and replaced daily (July) or every 2-3 days (February) for 5 to 7 days and analyzed to determine total petroleum hydrocarbon (TPH) concentrations, impact on microbial activity (Microtox) and changes in the abundance and diversity of microbial communities. In February, TPH increased gradually over 7 days to 1 ppm, with a concurrent increase in light inhibition to 20%, but no change in the abundance of prokaryotes. In July, one experiment showed rapid increase in TPH to 3 ppm corresponding to light inhibition of 60% and a tenfold increase in prokaryotes. Prokaryotes also increased in the control beaches. In the second July experiment, both control and oiled beaches started with TPH at 2.3 ppm and an average light inhibition of 44%, indicating pre-contamination of the sand. For control beaches, TPH decreased over time to 0.2 ppm, while light inhibition decreased to 6% before increasing in 2 of the replicates. For oiled beaches, TPH increased to 3 ppm and light inhibition increased to 61%, similar to the other July experiment. Prokaryotes were over tenfold higher initially in both treatments, but decreased over time. Even after days of weathering, beached oil can still release hydrocarbons into the water with tidal flushing. The increase in TPH and light inhibition in the pre-contaminated sand was significantly less than pristine sand, suggesting that the microbial community in the pre-contaminated beaches may have been primed to respond to the addition of oil. Thus, natural attenuation of oil on primed beaches may occur faster than on pristine beaches.

Applicability of a New Green Dispersant Based on the Hydrolysis of Shrimp Waste

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Oil dispersants can break oil into small droplets, and further enhance oil dispersion in marine environments. A new green dispersant based on the hydrolysis of shrimp waste (HSW) was developed and modified by removing oil and solid residues. Its applicability was further evaluated in terms of the effectiveness and toxicity, as well as the biodegradability of the dispersed oil in seawater. The influencing factors were examined including oil types (crude oil, marine fuel oil, and dilbit), temperature, icy conditions (frazil and packed), concentration of dispersed oil, and dispersant-oil-ratio (DOR). The results showed that the effectiveness of HSW ranged from 40-80%, compatible with that of commercial chemical dispersants, with/out breaking waves, temperature variations, and ice cover. The acute toxicity of new dispersants was evaluated through standard protocol for the Microtox basic test using luminescent bacterium *Vibrio fischeri*. The 5 min and 15 min EC_{50} ranged from 15-21 g/L, and 17-23 g/L, respectively. No inhibiting effect were observed on biodegradation of oil dispersed by the new dispersant. Although further testing is ongoing, the current results indicated a potential, ecofriendly option of marine oil spill response.

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Determination and Evaluation of Relative Response Factors of Alkylated PAH Homologs Using Gas Chromatography/Triple Quadrupole Mass Spectrometry

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Alkyl-PAHs are abundant in crude oils and weathered oil residues. They can be more toxic and persistent than their parent-PAH compounds and, thus, represent an increased threat to the environment. However, alkyl-PAHs are not EPA listed priority pollutants, which is primarily due to the lack of reliable analytical technique to accurately identify and quantify alkyl-PAH homologs in complex environmental samples and weathered oil residues. In comparison to the widely used GC-MS SIM method, multiple reaction monitoring (MRM) in GC-MS/MS effectively separates interfering ions and more accurately quantifies target alkyl-PAHs in complex environmental samples. However, the lack of certified analytical standards for alkyl-PAH isomers and consequently the historic use of relative response factors (RFs) obtained from parent-PAHs to quantify alkyl-PAHs can significantly affect such MRM analyses, when compared to SIM-based analysis. With an aim to develop a more accurate quantitative approach for analyzing alkyl-PAHs, we used commercially available alkyl-PAH homolog standards for optimizing a MRM method to measure and compare RFs of alkyl-PAHs to their respective parent-PAHs, in both SIM and MRM methods. The optimized MRM method was also utilized to analyze MC252 crude oil and weathered oil residues. The results showed that the traditional approach of using parent-PAHs' RFs for their alkyl-PAHs underestimates 1.2-6.4 (2.2±1.2), and 1.2-6.7 (3.4±2.0) times of their actual concentrations, respectively for SIM and MRM analyses. The results also showed that the application of MRM with individual RFs for alkyl-PAH isomers can be a very powerful analytical approach to significantly remove interfering ions and more accurately determine the actual concentration of alkyl-PAHs in environmental matrices and weathered oil residues. Such accurate quantification of alkyl-PAHs should be essential in determining their transport, fate and environmental health impacts for next generation of oil spill data.

Degradation of Sand Oil Agglomerates in a Sandy Florida Beach

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We report results from a time series study that quantified the degradation of sediment oil agglomerates that were buried in Gulf of Mexico sandy beaches after the Deepwater Horizon accident. Compositional changes and weight loss of standardized MC252 sediment oil agglomerates (sSOAs) that were buried in the dry beach sand at Pensacola Beach were compared to the degradation of the same sediment oil agglomerate material exposed on the beach surface and control samples, kept at constant temperature and in the dark in the lab. After three years, the buried sSOAs had lost 63% in their petroleum hydrocarbons. sSOAs at the sediment surface decayed faster than buried sSOAs, but buried sSOAs degraded faster than those kept under constant conditions in the lab. Time series of sSOA weight and carbon content allowed the assessment of the duration of the complete decomposition of the petroleum hydrocarbons in the beach. The results indicate that petroleum compounds of golf-ball-size SOAs are likely to persist in the dry beach sands for approximately three decades.

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Microbial Degradation of Polycyclic Aromatic Hydrocarbons at Ambient Near-Surface Coastal Conditions

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Polycyclic aromatic hydrocarbons (PAHs) comprise a vast family of compounds found in crude oil. These compounds can be highly toxic, and negatively impact biological processes such as DNA replication and transcription. PAH congeners that possess a 'bay' or 'fjord' region are particularly susceptible to partial oxidation and subsequent intercalation with double-stranded DNA, inducing cell death by precluding access to the affected sequences. Therefore, it is vital to understand the environmental fate of these molecules after oil spill events, particularly in coastal environments where flora, fauna, and humans may be exposed. Benzo[a]pyrene (B[a]P) is a high molecular weight pentacyclic molecule with a prominent bay region that has been shown to be degraded by microbes under specific conditions; however, little attention has been paid to its next larger siblings, the dibenzopyrenes. This group of congeners is hexacyclic, and, depending on conformation, may have one or multiple bay regions. These isomers are of particular interest as recent technology has enabled the resolution of individual congeners from a mixed solution, heretofore an infeasible proposal. In this study, a particular microbial species (*Mycobacterium vanbaalenii* strain PYR-1) was exposed to the more labile PAH, phenanthrene to develop analytical methods and optimal growth conditions for higher-order PAH degradation. Using these optimal growth conditions, *M. vanbaalenii* was then incubated with the higher molecular weight dibenzopyrenes to determine degradation kinetics and byproducts. Cyrofluoresence spectroscopy was used to analyze fractions collected by HPLC separation. Additionally, bacterial isolates collected from sediment from the Chandeleur Islands were screened for PAH degradation in order to find novel hydrocarbon degrading microbial species.

Weathered Crude Oil from the Deepwater Horizon Oil Spill was Rapidly Biodegraded but Altered Nutrient Cycles in Permeable Nearshore Sediments

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An estimated 22,000 tons of weathered crude oil from the Deepwater Horizon blowout contaminated Gulf coast beaches in 2010 and deposited an unknown amount into nearshore environments. In this study, the fate and transport of oil contamination in nearshore sediments of the northern Gulf were investigated in the field and in the laboratory. Specific objectives were to: (1) quantify potential rates of oil degradation and transformation attributable to microbial biodegradation, (2) examine the controls on biodegradation activity, and (3) determine oil-induced disruptions to carbon and nitrogen biogeochemical cycling processes. In both the field and the lab, the majority of GC-detectable petroleum hydrocarbon compounds were degraded within a 4-month period, and measured biodegradation rates were linked to an increased oxygen consumption. 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. Furthermore, there was a large-scale disruption to the marine nitrogen cycle, due to the inhibition of nitrification and increased inorganic nutrient demand in oiled sediments. This disruption can be linked to the microbial

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populations that mediate nitrification along with other nitrogen cycling processes, offering direction for environmental monitoring programs to assess ecosystem health and recovery. 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.

Dynamics of Surfacing Oil Droplets in the Presence of Dispersants

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Dispersants are used to mitigate the effects of oil spills by causing oil to fragment into smaller droplets whereby microbe consumption becomes quicker and more effective. In laboratory experiments, oil droplets of various composition and sizes were injected into seawater. Trials were conducted with crude and weathered oil, with and without dispersants. These observations were compared to numerical simulations using a computational fluid dynamics model. The effect of dispersants was simulated with a multi-phase, volume-of-fluid method including realistic interfacial tensions. Laboratory experiments and numerical simulations were generally in agreement, providing verification for the model performance in the presence of dispersants (though some model limitations exist). After verification, the model was applied to the case of dispersant application at a well outlet. Simulation results show that dispersant application at the source is more effective at fragmenting oil than dispersant application at the sea surface, providing a more effective way of mitigating oil spill disasters. Numerical simulations performed here confirm that the responders of the Deepwater Horizon incident were correct in applying dispersants, not at the surface, but directly at the source of the leak.

Amphiphilic Grafted Nanoparticles as a Platform for Dispersants with Improved Efficiency and Biocompatibility

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The current and primary methodology for oil spill remediation involves the use of small molecule surfactants that facilitate the formation of oil microdroplets. This thermodynamically unstable process requires constant energy input to emulsify the oil droplets. Furthermore, this route only slows down the coalescence of oil, it does not prevent it. These small molecule surfactants also contain charged particles that can retard bioremediation and exhibit a dependence on concentration and environmental conditions. Amphiphilic grafted nanoparticles (NPs) show promise as a more efficient platform both from an economical and a toxicological standpoint. Our general design is to use poly(caprolactone) as the oil-soluble polymer and hyperbranched poly(glycidol) (HBPG)as the hydrophilic polymer to provide steric stabilization. In preliminary studies, these nanoparticles have been shown to have limited solubility for the HBPG component. As a result, poly(ethylene glycol) was added to the HBPG portion of the nanoparticle to improve water solubility. These particles have been tested for toxicological effects as well. Finally, we have explored an alternative route in sugar-based

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nanoparticles derived from sucrose or maltose. These particles offer a safer core degradation alternative than the silica-based NPs, which require hydrofluoric acid to digest the core.

Differences in the Compositional and Functional Responses of Marine Microbial Communities to Oil, Dispersant, and Chemically Dispersed Oil

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Marine microorganisms play a central role in degradation and removal of petroleum from the environment after an oil spill. However, the poor solubility of many components within crude oil limits their susceptibility to microbial attack and depresses crude oil biodegradation processes. As such, responders often turn to chemical dispersants, which results in smaller droplets that more readily mix into the water column. However, the use of dispersants and whether their effect on hydrocarbon degrading bacteria is beneficial or detrimental has remained controversial. Here we present our findings of a laboratory experiment to examine biodegradation of undispersed crude oil and chemically dispersed crude oil at various concentrations. Offshore water was collected from the Gulf of Mexico at a depth of 500m and used to prepare microcosms at 10°C with oil, dispersed oil, and dispersant only to simulate environmental conditions comparable to the underwater plumes of oil and dispersed oil during the Deepwater Horizon spill. Microbial community composition and structure was monitored over a course of 6 weeks while alkane and polycyclic aromatic hydrocarbon oxidation rates were estimated with ^{14}C-radiolabeled hexadecane and naphthalene assays. Degradation of the amended oil and dispersant within each treatment was measured via GC/FID, GC/MS, and LCMSMS. The results of this study will be valuable for determining how the concentration of oil and dispersant affects biodegradation rates and estimating the lifetime of oil spill hydrocarbons in the marine environment.

Fate of Eroding Crude Oil Asphalt and Emulsion in Shallow Marsh Embayments

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Marshes affected by the DWH spill actively erode, allowing the movement of crude oil in the form of a soft asphalt or emulsion to adjacent embayments. This process moves weathered oil from the marsh profile to comparatively high energy shallow open water systems where geochemical and microbiological conditions may stimulate additional weathering. We hypothesize that movement of crude oil asphalts and emulsions to a higher energy oxic environment can quicken biodegradation. Sediment cores (12-inch depth) were taken July 2017 across transects on a contaminated marsh in Barataria Bay near Bay Jimmy where oiling occurred on the marsh surface. Cores were analyzed by GC-MS for total PAHs (ug/g sediment) and weathering ratios constructed from less recalcitrant over very recalcitrant PAH compounds. Total PAH concentrations (ug/g sediment) range from 200 to 1200 in cores samples from the contaminated marsh edge with the majority in the top 6 inches. In core sections from nearshore and offshore, measure PAHs were often below or close to detection limits. Total PAHs ranged from 1 to 4 ug/g sediment which indicates that secondary deposition of crude oil derived PAHs is not occurring uniformly across these embayments. Microbial populations were assessed using *Iliumina* MiSeq sequencing. Quality analysis of MiSeq data by mothur software produced 2.8M sequences for 43 core sections. The microbial diversity (inverse Simpson index) rose

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from marsh (18-71) to marsh edge (52-109) and was at a maximum in the offshore sediments (23-189). Data was normalized by subsampling 10,000 sequences in each sample. Analysis by linear discriminant analysis of effect size of communities revealed 410 OTUs at statistically elevated levels in offshore sediments, followed by 366 OTUs in marsh edge sediments and 192 OTUs in marsh sediments. Offshore dialysis samplers were used to measure nutrients in porewater. Concentrations (mg/L) were observed for NH_4^+(1 - 24), NO_2^- (0.05-0.15), SO_4^{2-} (25-200), and P (0.1 - 0.3).

Fate of Eroding Crude Oil Asphalt and Emulsion in Shallow Marsh Embayments Lab Experiment

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Sediment was collected in summer 2018 across a contaminated marsh located in Barataria Bay in the vicinity of Bay Jimmy/Bay Batiste where heavy oiling occurred on the marsh surface during the Macondo oil spill. Three distinct oil types; eroded pieces of soft emulsion or "pebbles", oil-water emulsion, and oiled marsh soil were identified at the sampling location. Erosion and reworking of the soft emulsion on the surface produced the pebble-like oil pieces sampled from the shoreline. A layer of emulsified oil was deposited below the layer of soft asphalt at the surface of the marsh. Oiled marsh soil was located through the marsh shoreline in areas without the emulsion and asphalt layers. Each oil type was incubated in a 5-1/2 gallon aquaria along with bay water from the sample location for 140 days. A total of 9 tanks were set up with 3 tanks for each oil type. Effort was made to mimic the natural environment by conducting daily mixing events and measurement of dissolved oxygen. Periodic measurements of nutrients (N and P) and sulfate were performed throughout the incubation period. Furthermore, representative oil samples were taken from each of the aquariums and were quantified for alklyated PAHs by GC-MS and microbial community structure using Ilumina sequencing. Samples were taken after 0, 60, and 140 days of incubation. The day 0 average total PAH concentrations (ug/g sediment) for pebble, oiled marsh soil, and emulsion were 89+/-3, 129+/-40, 503+/-186 respectively. The average day 0 nutrient concentrations (mg/L) for sulfate P, ammonium, and nitrite were 863+/-23, 0.07+/-0.03, 0.04+/-0.01, 0.02+/-0.002, respectively. Relative PAH weathering, microbial community structure, and porewater geochemistry will be discussed to draw conclusions on ongoing weathering of Macondo oil after erosion.

P-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

Oil Behavior in Turbulent Flows under the Effects of Dispersants

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A laboratory experiment using EPA baffled flask was conducted to investigate the oil behavior in turbulent flows, by adopting different dispersant application methods: surface release, premixed, and dispersant in water. High-speed and high resolution cameras were used to visualize the droplet formation process and studied the mechanisms of oil behavior under the effects of dispersants. Two types of crude oils with high and low viscosity were used, along with the dispersant COREXIT 9500 at different dispersant to oil ratio. Droplet size distribution was analyzed from the images taken from the cameras, integrated with the data from LISST (Laser in situ scattering and transmissometry), to cover a full range of droplet size distribution. Cases without the application of dispersants were also studied in comparison to the ones with dispersants. Results from this study enhance the knowledge of the fundamentals of droplet formation in the presence of dispersants, which would provide insights in the development of oil remediation strategies during oil spill events.

The Effects of Crude Oil and Corexit on Silica-Replete and Silica-Limited *Phaeodactylum Tricornutum*

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The Deepwater Horizon (DwH) oil spill of 2010 released four million barrels of crude oil into the Gulf of Mexico. In response, the dispersant Corexit 9500A was applied to fragmentize the oil slick as means of remediation. *Phaeodactylum tricornutum* is a marine diatom that has a silica frustule, serving as a shell. *P. tricornutum* has previously been found to be resilient in the presence of water accommodated fraction of oil (WAF) and chemically enhanced water accommodated fraction of oil (CEWAF) treatments. This study aims to investigate the role the silica frustule has in protecting *P. tricornutum* against WAF, CEWAF, and diluted CEWAF (DCEWAF) treatments. *P. tricornutum* were cultured in f/2 media with and without silica for five weeks and subsequently inoculated into WAF, CEWAF, and DCEWAF treatments. Growth rates showed that CEWAF treatments inhibited growth the most compared to WAF and DCEWAF, which had the highest growth rate. Photosynthetic activity was found to be highest in the WAF treatment and lowest in the CEWAF treatment. Silica-limited *P. tricornutum* results consistently deviated lower than their silica-replete counterpart, with the exception of the photosynthetic activity in the DCEWAF treatment. Samples analyzed for estimated oil equivalents (EOE) showed that the oil concentration declined over time in all treatments. Results suggest that *P. tricornutum* protect their photosynthetic apparatus against harmful conditions, suppressing growth until ideal conditions are again reached. Further research is needed to better understand how diatom physiology is being modified by these pollutants to protect the cells.

Half-Lives of Petroleum Hydrocarbons in Controlled Mesocosm Studies

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A total of five separate Mesocosm (~90L tank) experiments (numbered M2 to M6) each having 3 to 7 replicates per treatment using surface coastal or surface open-ocean seawater from the Gulf of Mexico were performed. The water accommodated fractions (WAF) and chemically enhanced WAF (CEWAF) were produced using Macondo surrogate oil with and without Corexit. Experimental treatments were different with M2, M3 and M6 enriched with microbes, M3 and M4 enriched with nutrients and M5

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not enriched. Experiments ran from 3 to 16 days. Estimated oil equivalents (EOE) were determined on a fluorescence spectrophotometer calibrated with Macondo surrogate oil. Environmental half-lives were determined from EOE concentrations which decreased exponentially following first-order decay rate kinetics. The EOE concentration at time 0 days for the WAF, DCEWAF (a 10X CEWAF dilution), and CEWAF for the 5 mesocosm experiments ranged from 2.26 to 5.24 mg/L, 2.62 to 8.31 mg/L and 39 to 81 mg/L, respectively. Higher oil concentrations were achieved using higher mixing energies. WAF, DCEWAF and CEWAF treatment half-lives ranged from 0.9 to 3.2 days agreeing with estimates from other mesocosm studies and field studies reported in the literature. Taking into consideration uncertainty between replicates, there were no significant differences in the half-lives for WAF, DCEWAF or CEWAF. There was no correlation between EOE concentration and half-lives. In addition, there was no difference in half-lives for mesocosms enriched with nutrients or microbes, or Corexit. Additional oil analyses by GC/FID and GC/MS indicate that biodegradation was an important removal mechanism based on ratios of specific aliphatic, isoprenoid and aromatic hydrocarbons. The heterogeneity observed in all treatments was likely due to the hydrophobicity of oil and weathering processes (e.g. biodegradation, sedimentation, etc.) occurring at different rates and times.

Oil Uptake Efficiency of Amphiphilic Grafted Nanoparticles for Oil Spill Remediation

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The synthesis of amphiphilic grafted nanoparticles (AGNs) has been reported using a combination of surface-initiated ring opening polymerization (SI-ROP) and atom transfer radical polymerization (SI-ATRP). The AGNs to be presented herein are systems with grafted poly(caprolactone)-*b*-poly(oligo ethylene glycol mono-methyl ether methacrylate) (PCL-*b*-POEGMA). These copolymers are grafted from SiO_2 nanoparticles (NPs), but other more biodegradable cores have also been investigated. The polymer segment can be cleaved from the surface of the NPs and characterized using traditional techniques (e.g. NMR, MALDI-ToF MS, GPC) to confirm purity and determine molecular weight information. The grafted NPs can be characterized using additional techniques, such as TGA and IR, to determine the presence of specific functional groups, as well as the polymer weight percent relative to the NP cores. Such AGNs have demonstrated ability for uptake of oil in an aqueous media. As such, these AGNs have been systematically modified to study the effects of grafting density and polymer composition on oil uptake and stability. It is the goal of this ongoing research to determine the mechanism of oil uptake into the polymer bottlebrushes, and also to optimize oil encapsulation to achieve high efficiency. [ds1]

The Changes of Energy Dissipation and Temperature Dissipation Rate through Surface Boundary Layer in Grid-Generated Turbulence Flow

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The ocean and atmosphere are in direct contact with each other and create a complex system: thus, forming oceanic turbulence boundary layer near the interface. The turbulence boundary layer plays a crucial role in the heat flux (HF), momentum flux, gas transfer and biogeochemical processes. The details of the near-surface (Top 20 cm) turbulent processes are not well understood. As controlling the condition in the ocean field is difficult, the experiment was conducted in the ASIST tank of the

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University of Miami where we generated turbulence by placing an upstream grid in the flume. Our approach is to study experimentally the terms in the turbulent kinetic energy (TKE) and the turbulent temperature variance (TV) balance equation. As the large-scale terms (such as TKE or TV) of the balance equation are readily measured, the small-scale components such as the turbulent kinetic energy dissipation (TKED) and the turbulent temperature variance dissipation are difficult to obtain. More specifically, the aim of this study is to investigate how TKED rate and TD rate vary when approaching the surface in a turbulent flow. By approaching to the surface, a boundary layer with an approximate thickness of a solid wall turbulent boundary layer (δ) was created and the magnitudes of and increased and decreased at the depth z/δ~1 up to the z/δ~0.34, respectively. The changes of between depth z/δ~1-0.34 follow the law of the wall theory. The HF created due to temperature difference between air and water causes that the increased. The value of suddenly enhances at the depth about z/δ~0.34 and then, displayed a comparable uniform value up to the surface. The sudden increase is due to convection and the orbital motion of short waves at the surface. Also, the convection and short waves cause the value of to have a sudden increase at the depth z/δ~ 1 and a comparable uniform value up to the surface. The effects of HF rate on were investigated through the streamwise direction (x). By decreasing the humidity and temperature of the air along the channel through M/x ~3.8 to 4.8 (is mesh length of grid), the value of increased about 27 percent that it showed the effects of HF was more than heater. The values of n and m, the power law exponent of the mean TKE (< >~) and temperature variance (< >~) were measured between 1.01<n<1.18 and 1.25<m<1.68.

Oil-Microbe Interactions in the Gulf of Mexico (GoM) Modeled with the Genome-Based EmergeNt Ocean Microbial Ecosystem Model

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Shortly after the discovery of the first cold seep ecosystem on the Florida Escarpment in the GoM, similar sites were found among various geological settings within the region. Microbial chemo-organotrophs form the basis for the food web around these cold seeps. The ecosystem involves complex processes mediated by diverse microbial taxa that convert hydrocarbons into biomass, carbon dioxide, and refractory forms of organic carbon. How best to model the biologically mediated degradation of hydrocarbons on a regional scale has been a lingering interdisciplinary question. In contrast to traditional oil models that attempt to parameterize biodegradation of hydrocarbons, the new Genome-based EmergeNt Ocean Microbial Ecosystem Model (GENOME Model) includes 75-100 modeled organisms, some of which will be able to explicitly degrade hydrocarbons. Genes encoding for hydrocarbon degradation processes relevant to the region are expressed, and hydrocarbon degradation is simulated as a function of the biomass and availability of limiting nutrients and substrates to the microbial community in the model. This emergent, trait-based model will allow us to assess the role of natural seep sites in priming the ecosystem, and to understand the impacts of multiple types of hydrocarbon releases (e.g. methane and n-alkanes) on the overall ecosystem structure and function. Microbial community structures associated with local environmental conditions will be compared with *in-situ* observations.

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Marine Oil Dispersion—Insights into Dispersant Efficacy from Phase Equilibria and Nanostructure

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Recently, questions about the environmental toxicity of commercial dispersant formulations (e.g. Corexit) have led to the development of new dispersants composed of the food-grade surfactants phosphatidylcholine (lecithin) and polyoxyethylenated sorbitan monooleate (Tween 80). Individually, neither surfactant is as effective at dispersing crude oil as a mixture of the two, suggesting that lecithin-Tween 80 (LT) blends work synergistically for effective dispersion. Likewise, LT blends do not generally exhibit characteristics expected of effective dispersants (*viz*. a high interfacial tension compared to commercial formulations), and it is thought that other interfacial phenomena are involved in effective dispersion. Thus, we hypothesize that 1) the thermodynamic phase equilibria of a given LT dispersant blend correlates with that blend's dispersion effectiveness and 2) the nanostructures created at the oil-water interface (OWI) on a dynamic timescale by the LT system play a key role in its oil dispersion effectiveness. Specifically, there is some evidence in cryo-TEM and -SEM micrographs of the attempt to dynamically create microemulsion-like structures at the OWI, and this evidence will be discussed and explored. This work focuses on understanding the connection between LT ternary phase behavior and dispersion efficacy as well as characterizing the nanostructures of LT blends at the OWI. Further, this research will elucidate the effectiveness and synergy of the LT dispersant system, both of which will provide insight on how the current LT system works and how to optimize this dispersant formulation for future use in oil spill remediation.

Diurnal Cycling of Submesoscale Dynamics: Lagrangian Implications in Model Simulations of the Northern Gulf of Mexico

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The imprinting of diurnal variations in submesoscale circulations on the statistics of surface Lagrangian tracers is investigated through numerical simulations with different set-ups, forcing and resolution. In all cases, the region of interest is the northern Gulf of Mexico, offshore the continental shelf (i.e. where the water column is deeper than 200 m). The analysis focuses on the months of February, representative of winter, when the mixed-layer is deep and the inertial wave contribution due to the diurnal cycling of the wind forcing is limited, and August, when submesoscale circulations are fueled by density gradients associated to the riverine discharge and the inertial contribution is strong. The submesoscale diurnal cycling follows changes in short-wave radiation and thus vertical mixing, and affects dynamical quantities such as lateral divergence, relative vorticity and strain in the Eulerian fields. Horizontal divergence increases whenever vertical mixing decreases, while the cycling of relative vorticity is inversely proportional to that of the mixed-layer depth, with a delay of about two hours with respect to changes in horizontal divergence. The cycling is amplified in the Lagrangian statistics.

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The impacts of seasonal and interannual variability is investigated through an analysis of simulations representative of 2015 and 2016.

Bioaccumulation Potential of Oxygenated Oil Photo-Products Relative to Non-Polar Compounds under Laboratory Conditions

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The persistence of oil photo-products in the environment necessitates a closer investigation into their impact on marine organisms. Little is known about the biological uptake of polar heterocyclic and oxygenated hydrocarbon compounds during exposure to the water-accommodated fraction (WAF) of weathered oil. In this study, we assess the solubility, bioavailability and uptake of these compounds, especially when compared to the commonly analyzed non-polar polycyclic aromatic hydrocarbons (PAHs). To this end, WAFs were created with artificial seawater and weathered Macondo well oil. The dissolved compounds were extracted, the extract was fractionated into a non-polar and polar fraction, and the fractions (as well as unfractionated extracts) were re-dissolved in artificial seawater. Solid-phase microextraction (SPME) and GC analysis were subsequently used to assess the bioaccumulation and toxicity potential of polar and non-polar oil compounds. The experiment was also repeated with model compounds representing significant compound classes within weathered oil. WAFs with the model compound mix were similarly fractionated into polar and non-polar fractions, and added to fish embryos (Atlantic killifish; *Fundulus heteroclitus*) to relate the SPME accumulation to accumulation in biota. Preliminary results and their implications for the toxicity of oil photo-products will be presented.

Can Photo-Oxidized Oil Be Biodegraded by Marine Microbes?

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It has been found that crude oil can be biodegraded by marine microbes, and this naturally occurring process has been utilized as a method for oil spill remediation. Research done after the 2010 Deepwater Horizon Oil Spill revealed that over 50% of the oil that forms slicks undergoes photo-oxidation. This fraction of oil has been largely unaccounted for when looking into the ecological effects and the clean-up of oil spills. This study focused on whether the oxidized hydrocarbon photo-products can also be biodegraded by marine microbes. Weathered oil was fractionated on silica gel into hydrocarbon and oxidized hydrocarbon fractions. Oil samples were taken from both the unfractionated weathered oil and the fractions of this oil. Microcosms were created containing marine bacteria and an oil sample in artificial seawater. These samples were incubated for 0, 7, and 14 days. Oxygen sensing was done to determine the relative rate of cellular respiration within the different samples. Flow cytometry was done to determine the relative bacterial growth. Carboxylic acid and PAH analysis was done on the GC/MS to determine the change in abundance of specific carboxylic acids within the samples. The results showed preliminary evidence that the oxidized hydrocarbons can be biodegraded by marine microbes. This has implications for the potential toxicity of the oxidized oil, as well as oil spill clean-up. Future research should be done to investigate to what extent the oxidized hydrocarbons can be biodegraded and what bacteria populations are biodegraded the oil.

*Student Presenter

The Self-Assembly of Dispersants at the Oil-Water Interface Probed Through Small Angle Neutron Scattering and Cryogenic Electron Microscopy

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The search for effective and benign dispersant systems has led to the development of a formulation of a mixture of a food grade phospholipid (Lecithin (L) and a nonionic sugar based amphiphile (Tween 80) dissolved in a benign solvent such as propylene glycol. To understand the molecular behavior of this system, a mixture of Lecithin (L), a phospholipid extracted from soybeans, and Tween 80 (T), a nonionic surfactant used in foods have shown significant potential as an environmentally safe dispersant. We show that this mixture of food grade amphiphile self-assembles upon transfer from organic solvents to water. Through small angle neutron scattering (SANS) and cryogenic transmission electron microscopy (Cryo TEM), a nanoscale understanding of the phase behavior of these structures is presented. We observe a vesicle-to-micelle transition with an intermediate bicelle phase as the concentration of tween 80 increases. These structural transitions can be attributed to the solubilization of tween 80 into PC lipid bilayer structures which eventually leads to a system composed of mixed micelle aggregates. These mixtures show the capability of reducing the oil-water interfacial tension to 10^{-3} mN/m. Moreover, a stable and effective oil dispersions is observed through the baffle flask test. We observed the generation of biofilm at the oil-water interface upon exposure to alkane-degrading bacterium *Alcanivorax borkumensis* in systems where these food grade amphiphiles are used as dispersant. We used cryogenic scanning electron microscopy to obtain a nanoscale visualization of biofilm formation.

Molecular Composition of Photo Oxidation Products Derived from Sulfur Containing Compounds Isolated from Petroleum Samples

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Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS) has revealed the detailed molecular composition of oxygenated transformation products present in saltmarsh sediments that were contaminated after the Deepwater Horizon oil spill. The results suggest that species with low oxygen content, i.e. hydrocarbons, O_1 and O_2, disproportionally contribute to the photo-reactivity of petroleum, being transformed into highly polar species (O_x, where x>3) that dominate the chemistry of the weathered samples.[1] In general, the research efforts for understanding the photo-chemistry involved in DWH oil weathering are focused on highly polar oxygenated species. However, it is important to consider that the production of heavy, sulfur enriched oils has dramatically increased in recent years due to the depletion of low viscosity (light), sweet crudes. Thus, understanding the photo-oxidation behavior of sulfur-containing species is critical for predicting the potential environmental impact of heavy oils in future spills. In this work, we perform separation of high sulfur content crude oils and distillation cuts into fractions enriched with aromatic (thiophenic) and non-aromatic (sulfidic) sulfur species.[2] These fractions are subjected to microcosm photo-oxidation, and the oil- and water-soluble species are characterized by FT-ICR MS. The work proposed here is critical for understanding the contribution of specific compound families to the ultra-complex mixture of oxidized transformation

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products that have been reported in field samples. **References** 1. Huan Chen, Aixin Hou, Yuri E. Corilo, Qianxin Lin, Jie Lu, Irving A. Mendelssohn, Rui Zhang, Ryan P. Rodgers, and Amy M. McKenna. *Environ. Sci. Technol*. 2016, 50, 9061−9069. 2. Vladislav V. Lobodin, Winston K. Robbins, Jie Lu, and Ryan P. Rodgers. *Energy Fuels* 29, 10, 6177-6186.

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Novel Fractionation Techniques Applied to Field Samples with Subsequent Characterization by FT-ICR Mass Spectrometry Reveals the Complexity of Ox Transformation Products

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Deepwater Horizon (DWH) oil spill on April 20, 2010, released ~3,190,000 barrels of light, sweet crude oil into the Gulf of Mexico. Once released into the environment, the oil underwent physical and chemical processes that transformed a fraction of the oil into a recalcitrant, poly-functional, oxygen-rich species. A small fraction of these oxidized transformation products behaves like surfactants (interfacial material). These soap-like species accumulate at the oil/water interface to form emulsions, which reduce the effectiveness of remediation strategies. Interfacial material from weathered oil residues collected up to seven years post-spill were isolated, characterized at the molecular level, and acidic compounds further fractionated by hydrophobicity based on a modified aminopropyl silica (MAPS) separation method. Subsequent characterization by ultrahigh resolution FT-ICR mass spectrometry reveals tens of thousands of oxygen-rich interfacially active species in weathered field samples, whereas the inactive and unaltered whole oil species are composed of abundant hydrocarbon, nitrogen, and sulfur-containing species. In the current work, interfacially-active species isolated from field and laboratory-generated photo-irradiated MC 252 oil were further separated by hydrophobicity by (MAPS). The separation reveals both singly and doubly charged O_x, O_xS_y, and O_xN_y interfacially-active species, indicative of diacids. This research project has been conducted as part of a research experience for an undergraduate at Tallahassee Community College performed at the National High Magnetic Field Laboratory, which is supported by the NSF Division of Chemistry through DMR 16-144779 and the State of Florida.

The Structural Dependence of Photo Generated Transformation Products for Aromatic Hydrocarbons Isolated from Petroleum

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Following the Deepwater Horizon (DWH) oil spill in 2010, the weathering of oil species in the environment has been extensively studied. Although the dominance of photo-oxidation in the production of O_x transformation products has been established, the exact chemical processes and any potential structural dependence of those processes are still poorly understood. In the past, direct photo-oxidation reactions involving the absorption of photons by a chromophore (e.g., an aromatic ring attached to a hydrocarbon), have been thought to dominate, however recent research suggests that secondary reactions are also important. Furthermore, we hypothesize that the number of aromatic rings in a given petroleum compound may influence the abundance and type of transformation products formed through photo-oxidation. In this study, we employ a solar simulator in the lab to mimic photo-oxidation of oil in the environment. We chose an Arabian heavy petroleum sample due to its high structural and chemical complexity. The oil was subjected to high performance liquid chromatography (HPLC-3) fractionation to separate compounds by their aromaticity (aromatic ring number).[1] Fractions containing differing numbers of aromatic rings (1-5+ ring) are irradiated in the solar simulator and analyzed to reveal the ring number dependence of the photo-oxidation products. We compare the results to the products from the whole oil (unfractionated) and field samples collected after the DWH spill. After photo-irradiation, Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS) reveals the molecular-level changes to the irradiated ring fractions. It uniquely provides the resolution and accurate mass measurement required for subsequent assignment of molecular formulas to the photo-transformation products. **References**: 1. Jonathan C. Putman, Steven M. Rowland, David C. Podgorski, Winston K. Robbins, and Ryan P. Rodgers. *Energy & Fuels* 2017, 31 (11), 12064-12071. Acknowledgments: This research was made possible by a grant from The Gulf of Mexico Research Initiative. Work was also supported by NSF DMR-1157490 and DMR-1644779.

Photodegradation of High-Molecular Weight Polycyclic Aromatic Hydrocarbons Exposed to Ultraviolet and Visible Light

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Polycyclic aromatic hydrocarbons (PAHs) are a class of hydrocarbon compounds consisting of two or more fused benzene rings and are a significant component of oil. Considerable efforts have been made to determine the fate of PAHs when released into the environment. The United States Environmental Protection Agency (US EPA) list 16 PAHs as priority pollutants, however, of particular interest are high-molecular weight PAHs (HMW-PAHs), PAHs with molecular weight greater than or equal to 302 g/mol. Dibenzo[*a,l*]pyrene, is a HMW-PAH not listed by the US EPA, but is significantly more toxic than benzo[*a*]pyrene, the most carcinogenic priority pollutant PAH listed by the US EPA. One potential pathway significant to the fate of HMW-PAHs is photodegradation due to exposure to the sun. While HMW-PAHs exhibit relatively low water solubility on their own, photodegradation processes oxidize the PAH to products that may exhibit increased water solubility, and hence, greater bioavailability in the environment. The aim of this study is to investigate the photodegradation kinetics of HMW-PAHs when exposed to ultraviolet and visible light. Photodegradation kinetics is monitored using room-temperature excitation-emission matrices (RTF-EEMs), which allow for observing the total fluorescence of the sample, while liquid chromatography-mass spectrometry will be utilized in the separation and elucidation of the photodegradation products.

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The Analysis of Physical Parameters from the Stone Moorings in the Gulf of Mexico

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The Shell Stones Mooring observatory is being run as a partnership between Shell, Fugro, University of Southern Mississippi and Texas A&M University at College Station. This study is aimed at understanding the upper ocean circulation of the Gulf of Mexico at the Shell Stones buoy from data collected over the period from October 2016 to April 2018. Satellite images, met-ocean data from the surface buoy and subsurface data from a thermistor string, CTD and ADCP are combined to show variations in the upper 400 m in the Gulf of Mexico and relate them to winds, tides and the mesoscale eddy field.

Converting Halloysite Clay Pickering Microdroplets into Liquid Marbles for Synergistic Oil Spill Remediation with Delivery of Encapsulated Bacteria

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Halloysite clay is a natural, abundantly available raw material which has been shown to act as a solid stabilizer at the crude oil-water microdroplet interface[1]. The interface of the emulsion thus formed covered with the clay nanotubes is shown to be conducive to growth of hydrocarbonoclastic bacteria[2]. Progressing growth of the bacteria produces an exopolymer biofilm that helps to encapsulate the oil droplets and aid the degradation. We consider the bacteria, *Alcanivorax borkumensis* and the biofilm it produces in the presence of halloysite clay tubes to self-instrumentation for bacterial encapsulation. In the approach reversed to a classical oil Pickering emulsion, for a liquid marble, - highly hydrophobized halloysites surround and stabilize bacteria droplets covered with halloysite. The internal water /oil media feeds bacterial and produces structural biofilm supporting the reversed architecture of the liquid marble. Such liquid marble was then additionally modified through biocompatible polymers to strengthen the structure, slow down evaporation and retain the growth of bacteria for a duration of weeks. The bacteria encapsulated inside the engineered liquid marbles offer not only a strategy to deliver both halloysite as emulsifier and the bacteria as degrader to an oil spill site; but can also be developed as a general solution to room temperature storage of bacteria. **References**: (1) Nyankson, E.; Olasehinde, O.; John, V. T.; Gupta, R. B. *Ind. Eng. Chem. Res*. **2015**, *54* (38), 9328-9341. (2) Panchal, A.; Swientoniewski, L. T.; Omarova, M.; Yu, T.; Zhang, D.; Blake, D. A.; John, V.; Lvov, Y. M. *Colloids Surfaces B Biointerfaces* **2018**, *164*, 27-33.

How Does Oil Photo-Oxidation Influence the Toxicity of Oil? Computationally Predicting the Toxicity of Oil Photo-Products

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*Student Presenter

Eight years after the Deepwater Horizon Oil Spill of 2010, highly weathered and oxygenated oil remains across the U.S. Gulf Coast. To assess the toxicity of the weathered oil and its transformation products, we used ab initio software (COSMOtherm and COSMOmic) and analytical methods (Microtox bioassays and solid phase microextraction SPME) to predict the baseline toxicity (EC50) of possible photo-products in marine environments. Computational chemical calculations by COSMOmic and COSMOtherm for aliphatic oxygenated compounds and n-alkanes (up to carbon number 30) showed that there is a logarithmic increase in toxicity and logarithmic decrease in solubility with increasing carbon number. Alkanes were computed to have the highest toxicity yet lowest solubility values. Furthermore, COSMOmic calculations showed that oxygenated compounds with adjacent functional groups (e.g. 2-hydroxy carboxylic acids) are more toxic than compounds with functional groups bonded to opposite ends of the carbon chain (e.g. omega hydroxy acids). Microtox measurements showed similar trends for toxicity levels as compared to the toxicity levels calculated by COSMOmic. Additionally, preliminary SPME results showed increased accumulation on SPME fibers for compounds that had a higher Microtox or COSMOmic-calculated toxicity.

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

Oil Absorbent Boom

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The size and scope of the 2010 oil release in the Gulf of Mexico revealed serious shortcomings in the standard approach to oil spill control. The Algaentis HazMat Soft Boom Oil Recovery and Containment System is based on the use of floating booms constructed from open-cell urethane foam, floating in front of and attached to Hard Boom, which channels the oil sheen into the soft hydrophobic/oleophilic Boom. The Soft Boom employs a special polymer that exhibits a surface that rejects water [hydrophobic] and attracts oil [oleophilic], with open-cell [spongiform] structure in cylinders 6” to 24” in diameter and 6’ to 10’ in length. In water, these booms naturally float high and retain their buoyancy as they adsorb the hydrocarbons, which are generally less dense than water. U.S. Coast Guard and BP Strike Team observed that the 12” Soft foam booms would adsorb up to nine liters of light to medium gravity crude per cubic meter of foam, and maintain containment, while tethered to Hard Boom, in moderate to rough off-shore wave conditions. The Gulf Oil Spill was characterized by surface floating oil sheen and submerged emulsified oil and “tar balls”, dispersed below the surface water, rather than appearing on the surface as an oil film or “slick”. The emulsified oil and tar ball collection " Curtain Net" we deployed contained hydrophobic/oleophilic "open cell " foam blanket material, in the form of a flat foam sheet, approximately 1” - 2” in thickness, sandwiched between a closed sleeve of polypropylene mesh netting, in various void sizes down to a ½” void. This open Curtain Net sleeve, containing the hydrophobic/oleophilic blanket, was attached to the bottom of the hard boom, floating behind the soft boom, to control and suspend the Curtain Net, suspended below the Hard Boom, on a horizontal steel cable. We designed a floating system that will pick up the oil-loaded boom, & physically squeeze the oil out of the boom. Recovered oil then passes through on-board separation equipment, to remove traces of water, and captured oil will be stored in the vessel & transported to port for refining. The cleaned boom can then be continuously returned directly to water duty, to continue its work in spill

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remediation, or clean the boom, and return the Haz Mat Soft hydrophobic/oleophilic Boom to storage, for use in future incidents control.

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 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.

Gran Tarajal Oil Spill Accident

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The Oil Spill accident occurred in Gran Tarajal Harbor could change the Response Decision Making for the rest of similar accidents over the world. In this accident we used three new developments that reduced to almost zero, the environmental impact and the odour disturbances to the population. The three new technologies are: reusable sponges absorbents with very high Hydrophobic and Oleophilic properties, Granulates with same capacities, and bacteria inoculums with very high and quickly capacity to degrade the different hydrocarbons. The Gran Tarajal harbor is located in Fuerteventura Island, in the Archipelago of Canary Islands. The tropical storm EMMA, sunken several pontoons producing an important Oil Spill taking account the small dimension of the harbor, around 100 tons of different oils were spilled. Using the foam reusable absorbent, we have recovered 42 tons of hydrocarbon with around the 5% of water in two days, and in those 6 months we have recovered from water surface around 80 tons of Oil. The foam has a simple design/use with hand squeezed system, with very high Hydrophobic and Oleophilic capacities, 1 kg removes up to 30 kg of oil in every use and with more than 200 uses without losing these properties, 1kg of sponge can remove more than 5 tons of oil. The second development was the bacteria, *Pseudomona putida*, which degrades the oil very easy and quickly. Specially the light hydrocarbon like Diesel, but as well as the light fuel. The bacteria reduces the hydrocarbon viscosity and surface tension that means a reduction of the adherence to sand, rocks, concrete, and others surfaces. This property allows to increase the lixiviation process from

*Student Presenter

the sand, gravel, and mud to surface (Intertidal areas), and a constant degradation of the Oil attached to surfaces (Cleaning the harbour). The bacteria residues finally dissolved in water or sinking as organic matter. The third technology is a granulate with a great hydrophobic and oleophilic capacities, that allows to clean all the surfaces, tools, globes, boots, floor, and avoid the spills from the harbour again to the water when the machinery plenty of oil were recover. We also filtered the oiled water before spill back to the sea.

Response Driven Fundamental Science Questions: Coast Langmuir Circulations, Deep Transport Pathways and a Coral Mortality Event

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Three examples of response driven fundamental science questions will be presented, along with a general discussion of improved communication between the scientific and response communities.

1: How do turbulent mixing process in the upper ocean change as we enter the coastal zone? Large-eddy simulation (LES) of the ocean-mixed layer (OML) in coastal zones is being performed, where salient forcing conditions - winds, waves, coastal pressure gradient forcing, and the relative angle between these forces - are being systematically changed. “Coastal zones” implies the presence of lower bed (bathymetric) stress, thereby guaranteeing key physical departures from open ocean conditions, where OML fluctuations are damped by density (stable stratification). LES provides an opportunity to assess the influence of key parameters in a highly controlled environment. Targeted cases replicating natural conditions - informed by collaboration with co-investigators performing complementary field measurements - will provide yet more insights since LES provides space-time information on the column.

2: What is the fate of oil dispersed into the water column near the coastal zone? Or Is out of sight, out of mind? Classic potential vorticity conservation arguments lead to the result of flow along and not across isobaths. However, these arguments breakdown in the surface and bottom boundary layers. Bottom current observations from the Texas shelf will be presented which suggest two deep transport pathways between the coastal and open ocean: an advective mixing pathway and shoaling internal wave pathway.

3: How susceptible are the Flower Garden Banks coral reefs to hydrocarbon pollution? Open response questions, identified during an oil spill response workshop, led to a bottom current observational program on the Flower Garden Banks. To date, this program has generated 2 years of bottom current data over the Banks, which have provided insight into the 2016 localized mortality event.

Oil Spill Risk Assessment and Vulnerability Analysis of Shoreline and Offshore Habitats of the Gulf of Mexico and the Caribbean Sea

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The Gulf of Mexico region (GoM) is one of the largest oil producers in the world and this raises a growing concern on the preparedness and response to potentially devastating consequences due to chronic discharges, accidents during the transportation of petroleum, and large-scale oil spills. Given the possibility of oil exploration in deep waters of the southern GoM region in the short term; an oil risk and vulnerability assessment are presented herein to support contingency and emergency action planning. We developed a detailed region-specific vulnerability model for the southern Gulf of Mexico and the Caribbean Sea based on types, characteristics, and oil effects on the shoreline and offshore habitats. We evaluate the vulnerability using several data sources, including geographic information system analyses, scoring process, and the environmental sensitivity index of NOAA. We constructed an overall oil spill risk model and determined the regions with highest relative risk, combining the vulnerability results with a simulated oil spill scenario at a potential future oil exploration point provided by the Secretary of Energy (SENER) and the Mexican oil industry (PEMEX). We evaluated the shoreline and offshore vulnerability and elaborated an oil spill-risk map at 11 geographic regions inside the GoM and the Caribbean Sea. The Caribbean coast of Yucatan, the neritic area of Tabasco, Campeche and Yucatan, and the estuarine Laguna Madre lagoon are the most vulnerable regions to possible oil spills. The higher risk to the provided specific oil spill scenario was found in the coastal and marine areas in front of Tamaulipas. These results can enhance the emergency response operations by official agents and decision makers; and can have a significant impact on coastal planning, including emergency response priorities and resources allocation.

A Review of Potential *In-Situ* Decanting Methods for Oil Spill Response

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The skimming process is one of the most commonly applied response approaches in a marine oil spill incident. During the process, a large amount of decanted water (10%~70% in total) can be recovered. This type of wastewater is with toxicity and negative ecological impacts, which must be shore disposed. It therefore requires intensive storage space and transport equipment and leads to significantly reduction in oil recovery efficiency and dramatic increase in response time and cost. In-situ discharge can be a potential management strategy which can save 200%~300% of space and time. However, most of current practice is passively settling which is not able to efficiently remove oil and petroleum-related hazardous materials (i.e. PAHs, phenols and naphthenic acid). The presence of oil water emulsion could further extend the separation time for days or months. More advanced and effective technologies are hence much desired for in-situ decanting. This review is to evaluate the feasibility of in-situ discharge of decanted water by comprehensively summarizing the technologies with potential on the in-situ decanting of recovered fluid in the literature and practice. It includes the adaptable technologies for oil recovery enhancement during oil production (i.e. demulsification, gas flotation, cyclone, and coalescence) and the potential technologies with a higher organic removal rate (i.e. sorption, AOPs and membrane filtration). The pros and cons of these technologies are compared and discussed based on the separation efficacy, capacity and energy consumption. Furthermore, the holistic impact of potential disposal of treated water are summarized. The information is valuable to address challenges in terms of in-situ discharge of decanted water treated by various technologies. The recommendations on the improvement of decanting methods are given to help develop more promising and clean decanting technologies thus improve public confidence of the alternative response capability.

*Student Presenter

Airborne and Satellite Remote Sensing Approaches and Platforms: Bridge the Gap Between Available Technologies and Practices to Improve Community and Ecosystem Resilience

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Large oil spills (like Deepwater Horizon) leave long-term economic and ecological effects, as do chronic small scale spills. Airborne and satellite remote sensing capabilities now allow it to play pivotal roles in many aspects of the oil spill disaster cycle for small to large spills; however, implementation and integration into the spill response remains largely informal with most of its vast potential untapped. One group addressing these gaps is the NASA/NOAA-led FOSTERRS (Federal Oil Spill Team for Emergency Response Remote Sensing) working group, which provides a clearinghouse of available sensors and their capabilities. Uncertainty cannot be understated - all remote sensing approaches have distinct strengths and weaknesses. In this presentation we evaluate different remote sensing approaches and platforms in general and then make it real by applying the evaluation to a hypothetical 3000 bbl oil spill from a tanker offshore Corpus Christi. Spill scenarios are a useful disaster planning approach by carefully considering the compilations that can arise in a disaster response. The Gulf of Mexico is among the most exposed areas in the world to pollution with more than a billion barrels of oil transported or produced every year, with frequent spills identified in current NOAA survey products. Moreover, there is a clear spatial correlation between slicks and shipping lanes in a recent academic study. We evaluate different airborne and satellite remote sensing approaches and instruments to all phases of the disaster cycle - from detection to remediation, including integration into decision making processes of the Incident Command and the full spectrum of other key stakeholders. The spill scenario occurs within the environment of typical operational spills, and proposed efforts to mitigate against small spills. The talk focuses on critical needs to bridge the gap between available technologies and practices to improve community and ecosystem resilience.

Cause Factor Analysis for Occurrence of Offshore Oil Spill Accidents

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A major offshore oil spill can cause catastrophic environmental, economic and social impacts. This study reviewed the past 82 records from 1970 to 2010 and disclosed that about 44% of offshore oil spills were linked to the human errors (e.g., insufficient training/experience, fatigue, misinterpretation, etc.). Totally 119 cause factors, associated with human errors, mechanical failures, and natural disasters, were analyzed through the fault tree qualitative analysis technique. These factors were identified based on their contributions to the accidents with the four major sources (e.g., offshore oil & gas platforms, pipeline, oil tankers, and coastal refinery tanks). Monte Carlo simulation and fuzzy analysis were also incorporated for quantifying the uncertainties and evaluating the occurrence probabilities of cause factors to help examine the impact of data ambiguity and imprecision. To gain better understanding of the importance of human errors in causing offshore oil spills, the cause factors originated from human errors were further investigated for their individual and combined effects on

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the occurrence probability by the integration of human reliability and sensitivity analysis methods.
Keywords: cause factors, human errors; marine oil spills; occurrence; uncertainties

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

Racial and Economic Segregation, Disaster Exposure, and Self-Rated Health in the U.S. Gulf Coast

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Community resilience is recognized to be a dynamic property of populations and places generated through interactions at multiple conceptual, spatial and temporal levels. We explore differences in health between U.S. Gulf Coast residents in order develop new theory and hypotheses about these interactions. We consider the distributional aspects of community resilience, focusing on the social, economic, and political dimensions of the built and social environment. We also consider the possibility that (lack of) resilience reflects an accumulation of (mal)adaptive responses to ecological disaster over time. We descriptively explore the interrelationships between community resilience, exposure to material loss from a specific technological disaster (the Deepwater Horizon Spill, DWH), and individuals' health assessments. Survey data come from the 2016 Study of Trauma, Resilience, and Opportunity among Neighborhoods in the Gulf, for adults age 45 and older residing in counties/parishes bordering the Gulf of Mexico at the time of DWH. Using respondents' place of residence, we append measures of county-level economic inequality and sub-county residential segregation by race and economic status. We observe an unexpected positive relationship between economic inequality and better health that is exclusively observed among non-Hispanic white residents. This is associated with concentrated wealth in these communities, and it is not experienced by non-Hispanic black Gulf Coast residents. We also find that disaster-related property loss is uniquely detrimental to the health of adults exposed to racialized economic segregation. These findings suggest that inter-relationships between racial segregation, economic inequality, and ecological disaster, which are exemplified along the Gulf of Mexico, may address inconsistencies found in the broader scientific literature. Future analyses to improve causal inferences will be important to testing these hypotheses and guiding policy.

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

Mercury Levels in Louisiana Marsh Birds and Small Mammals after the Deepwater Horizon Oil Spill, on the Two Sides of the Mississippi River

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The reducing conditions created by the large input of organic matter from the Deepwater Horizon (DWH) oil spill potentially increased mercury (Hg) methylation and its bioavailability in aquatic and terrestrial food webs. The unknown effect of the oil spill on Hg levels compounds a general lack of understanding of Hg origin and transport in the Gulf of Mexico. We tested whether Hg levels in two species of vertebrates living in Louisiana marshes - the Seaside Sparrow (*Ammospiza maritima*) and the Marsh Rice Rat (*Oryzomys palustris*) - differed between DWH oiled and unoiled marshes. We quantified total Hg levels (THg) in blood samples collected during 2014-2016 from 119 marsh rice rats and 286 seaside sparrows in southeastern Louisiana, from west (Barataria Bay) and east (Breton Sound) of the Mississippi River Plume (MRP). Irrespective of the location, THg levels were higher in seaside sparrows than in marsh rice rats. In seaside sparrows, but not in marsh rice rats, THg levels were higher in unoiled compared to oiled locations. In addition, in both species THg levels were higher east than west of the MRP. THg concentrations were also higher in adult seaside sparrows compared to juveniles. The present results show novel fine-scale geographic differences in THg concentrations for marsh resident species, and document an association between THg levels and oiling history. The documented geographic variation is consistent with known hydrological differences, yet the precise mechanisms driving variation in THg between species and across sites remain to be clarified.

Microphytobenthos as Indicators of Oiling and Food Web Dynamics

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We hypothesized that phytoplankton accessory pigments would be altered in the sediment surface, along with the microphytobenthos (MPB) community, in response to hydrocarbon concentrations and especially in the summer when hydrocarbons may be volatilizing due to higher air temperatures. A total of 13 sites in Terrebonne Bay, West Barataria Bay (near Grand Isle) and East Barataria Bay (near Point Sulphur) were chosen, encompassing oiled and unoiled locations. We collected MPB samples in spring, summer and fall in 2015 through 2017 to test this hypothesis. HPLC analysis was paired with microscopic counts to determine the community composition. Initial results show a preponderance of diatoms, but also green algae and cyanobacteria (some of which may be toxin producers). Chlorophyll *a* (Chl *a*) concentrations were greater than 25 ug g^{-1} dry sediment in many samples. Few sites show statistically significant interannual or seasonal differences in Chl *a*. Variability in Chl *a* concentrations toward the end of four years post-spill (Fleeger *et al*. 2015 MEPS) was high as were values from our study, which covered 2015 to 2017. Our study did not sample from any "highly" oiled sites, however preliminary results suggest that total pigment concentrations were lower at oiled sites compared to unoiled sites. Other variables of importance are water level on the day of sampling and for several days before, incident radiation, salinity, sediment grain size and hydrocarbon concentrations. We also analyzed a series of sediment cores ranging from ~40 to 70 cm in length at some of the same sites. From these, we predicted that sediment microphytobenthos as identified by phytoplankton accessary pigments would correspond to phytoplankton counts, hydrocarbon components, and other sediment characteristics. Many of the phytoplankton pigments in these cores degraded rapidly with depth limiting their use for historic analyses.

*Student Presenter

Establishing Inventories of Invertebrates in Areas with Different Salinity Levels in Tidal Marshes of Coastal Louisiana using Different Trapping Methods

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Louisiana's coastal marshes provide numerous ecosystem services such as attenuating storm surges and erosion as well as acting as a refuge for immature shrimp and crabs among other important commercial species. However, subsidence, sea-level rise, salt water intrusion, oil spills and other stressors put this habitat and its associated services at risk. Freshwater and sediment diversions are being implemented to build marshland in opposition of these stressors. To assess the impact that future stressors and management practices have on marsh communities, baseline data are needed. Here we created an inventory of insects for intermediate (ca 3.5 ppt), brackish (ca 8 ppt), and salt marsh (ca 16 ppt) communities. Different collecting techniques were used in attempts to adequately assess the diversity of insects present in the different marsh habitats. Canopy traps, baited with dry ice, were used to target tabanids (horse flies and deer flies). Coastal horseflies were targeted as they have been shown as bioindicators of Louisiana marsh health. Sweep net collections were performed to assess predatory arthropods as well as the insect herbivores of the underlying plant communities. Various light traps were used to collect crepuscular and nocturnal insects as well as ground-dwelling insects; the use of pitfall traps was not found to be practical. The breadth of insect diversity collected using these methods will be presented. Future applications for these inventories include facilitating future marsh research and habitat management.

A Large-Scale Salt Marsh Mesocosm Facility to Test the Effects of Disturbances on Wetland Ecosystem Processes

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Coastal wetlands straddle the land/ocean interface, providing myriad ecosystem services yet are also especially vulnerable to disturbances across a range of time and space scales, including sea level rise and pollution. Most disturbance studies rely on either large-scale comparisons between disturbed and undisturbed sites that may have other uncontrolled, underlying differences or on small-scale manipulations of individual processes in isolation from other relevant processes. Here we report on the design and construction of a salt marsh mesocosm facility that is capable of testing the impact of disturbances on intertwined ecosystem-scale processes against a backdrop of controlled and uniform environmental conditions. The facility consists of 12, hydrologically independent *Spartina alterniflora* marsh mesocosms (2.7m diameter) each with its own paired tidal surge tank capable of generating tidal cycles with ranges up to 50cm via an automated water control system of blowers and airlifts. Water level, temperature and conductivity (from troughs surrounding each marsh) and soil temperature and redox potential (at 2, 10, 25 and 40cm in each marsh) are logged continuously. Each mesocosm also has porewater samplers permanently installed at 2, 10, 25, and 40cm. Other regular baseline measurements include: 1) soil physical and chemical properties; 2) soil biogeochemical process rates; 3) plant dynamics (biomass, production, stoichiometry, photosynthetic yield, spectral analysis, disease incidence, benthic microalgae, belowground CT scans, root ingrowth rates); 4) light and dark carbon dioxide and methane fluxes; 5) meiofauna and macrofauna abundances; 6) predator-prey interactions; and 7) oil and DOM concentrations and composition. Baseline measurements began

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in 2018 ahead of an experiment aimed at simulating a coastal wetland oiling event similar to what occurred after the 2010 Deepwater Horizon spill. Three marsh tanks were assigned to each of four treatments: control plus light, moderate and heavy oiling levels scaled broadly to the SCAT categories observed following the DWH spill. We are actively seeking collaborators who can perform non-destructive or minimally-destructive sampling or measurements within these mesocosms to test specific hypotheses related to the experimental design.

Spatial Patterns in Soil Biogeochemical Process Rates along a Wetland Salinity Gradient

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Louisiana has the highest rate of coastal wetland loss in the United States. These wetlands are subjected to numerous environmental stressors including increased salinity from sea level rise, decreased salinity from the construction of river diversions, and climate-related changes in vegetation patterns such as the expansion of black mangroves (*Avicennia germinans*) into salt marshes. We examined how rates of biogeochemical processes vary between wetlands with different dominant plant communities along an estuarine salinity gradient in Barataria Bay, Louisiana. Specifically, we measured in situ net soil greenhouse gas fluxes and quantified soil greenhouse gas production, denitrification, nitrification, iron reduction, and phosphorus sorption rates. These processes were targeted for their importance in regulating carbon balance and the cycling, retention, and removal of nutrients in the wetland ecosystem. Samples were collected from surface (0-5cm) and subsurface (10-15cm) depths in 3 plots from each of 4 sites along a salinity gradient. These sites included a freshwater marsh (0 ppt), a brackish marsh (7 ppt), a salt marsh (17 ppt), and an *A. germinans* stand (17 ppt; adjacent to salt marsh). For most processes measured, rates were higher at low salinity than high salinity sites. In situ net CO_2 and CH_4 fluxes also decreased with increasing salinity, supporting the spatial pattern observed in soil process rates. Soil water content, organic matter content, and extractable nutrient concentrations decreased with increasing salinity, correlating strongly with process rates. Rates at the two high salinity sites were similar to one another regardless of whether mangroves or salt marsh grasses were the dominant plants. These spatial patterns suggest that carbon and nutrient cycling in coastal wetlands is likely to change significantly in response to any environmental perturbation that alters the salinity regime. Salinity-driven changes in wetland biogeochemical processes should be considered when designing and managing future wetland restoration projects and river diversions.

Effects of River Diversions, Restoration, and Salinity on Nekton Community Structure in Southeast Louisiana Marshes

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Salt marshes are productive ecosystems that provide a variety of benefits, including protection from storms, carbon sequestration, nutrient removal, and food and refuge for the juveniles of many recreationally and commercially important species. Despite these benefits, Louisiana is losing marshes at an unprecedented rate of over 40 km^2 per year, in part due to a lack of sediment supply from freshwater inflow. Several solutions have been proposed to rebuild marshes, including reestablishing the natural hydrology of the Mississippi River and targeted placement of sediments in heavily eroded areas. However, the successional trajectory of fish and invertebrate community structure as it relates to restoration practices and changing salinity patterns due to riverine input, as well as the interactive effects, remains unclear. Here, we present preliminary fish and invertebrate data from marshes near the West Pointe a la Hache siphon. In year 1 of this project, we conducted trawls and suction sampling to quantify the abundance, diversity, and community structure of organisms in a range of natural and previously restored marshes. In years 2 and 3, we anticipate that the siphon will be operational and hypothesize detectable shifts in nekton community structure along both restoration and salinity gradients. These data will provide valuable information for environmental managers to determine best practices for operating diversion structures and marsh restoration methods to maximize fisheries production and will increase our knowledge of anthropogenic impacts, and mitigation efforts, in a rapidly changing ecosystem.

The Effect of *Avicennia germinans* Expansion on Salt Marsh Nitrogen Cycling

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Plant species expansion poses risks to ecosystem services through alterations to plant-microbiome interactions associated with changes to key microbial drivers such as organic carbon (C) substrates, nitrogen (N) availability, and rhizosphere-associated microbial communities. In the northern Gulf of Mexico (GOM), warming winter temperatures associated with climate change have promoted *Avicennia germinans* (black mangrove) expansion into salt marshes. We conducted a two-year field-based study to 1) Determine the impact of mangrove expansion on salt marsh N-removal and recycling via denitrification and dissimilatory nitrate reduction to ammonium (DNRA), respectively, with the goal of quantifying losses or gains in ecosystem services; and 2) identify the mechanisms driving changes in ecosystem services to improve predictions about the impacts of mangrove expansion on salt marsh functional resiliency. We found that N-removal rates and denitrifier gene abundances were generally comparable between vegetation types. However, denitrification rates in *A. germinans* were correlated with sediment chlorophyll *a* inventories and porewater ammonium concentrations, suggesting that changes in substrate quality associated with expansion may have enhanced C and N limitation of heterotrophic denitrifiers. In contrast, DNRA rates were significantly higher in *Spartina alterniflora* than in *A. germinans*, possibly due to changes in sediment redox conditions associated with changes in root structure. Additional results of the study will relate process rate measurements to sediment physiochemical characteristics and microbial community to identify drivers of long-term change in ecosystems services associated with black mangrove expansion.

*Student Presenter

What Causes Marsh Loss and Erosion within Northern Barataria Bay Louisiana: A Comparison of Measured and Modeled Erosion

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Our study of the structure, function, resilience and sustainability of coastal wetlands following the Deepwater Horizon oil spill resulted in observations of erosion caused by varying degrees of oiling in the marshes of Louisiana, USA. Our sampling sites span Barataria Bay from Wilkinson Bay to Bay Jimmy and represent areas of marsh shoreline classified as reference (no observed oil impact), moderately-oiled (some oiling identified), and heavily-oiled (significant oiling identified) as determined by soil total petroleum hydrocarbon concentrations and field observations. Available aerial images of the region were obtained over a time series to examine time periods representing a period prior to Hurricane Katrina (1998-2004), during Katrina (2004-2005), after Katrina but before the oil spill (2005-2010), and after the oil spill (2010-2013). Erosion was measured for each of the time periods. A semi-empirical wind wave model was used to calculate the expected marsh edge erosion based on measured fetch, wind direction, wind magnitude, and a water-level dependent erodibility coefficient. The modeled edge erosion did not significantly change between the time periods showing a slightly elevated level at the heavily oiled sites after the oil spill. The reference stations before Katrina reflected background erosion rate of approximately 1 m yr^{-1} as found in other studies. The measured erosion was significantly higher than the modeled data for all treatments during the Katrina period indicating that other factors not reflected in the model, such as storm surge and shearing of vegetation, influenced erosion during that period. A higher measured erosion rate continued through the period after Katrina and prior to the spill. Post-spill measured erosion rates were statistically similar to pre-spill/post-Katrina rates. These elevated rates after Katrina are similar to the modeled rates indicating that only marsh edge erosion via wind-waves adequately predicted erosion during these periods.

Diel Variation in Carbon Fluxes and Photosynthetic Efficiency in Salt Marsh Ecosystems

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Wetlands are globally important sites for carbon sequestration accounting for 44 million metric tons of carbon per year and can also be large sources of methane (CH_4) to the atmosphere. Sequestration occurs via a net flux of carbon dioxide (CO_2) into the soil as a result of photosynthesis exceeding respiration and through direct deposition of organic carbon onto marsh platforms. Much of our current knowledge of marsh carbon fluxes is based on sampling during windows of anticipated maximal photosynthesis limiting our understanding of diel variation in these important fluxes. In this study, we took advantage of a new *Spartina alterniflora* marsh mesocosm (2.7m diameter) facility in which we were able to maintain constant water levels in 4 marshes over a diel cycle, allowing us to decouple variation due to diel patterns from flooding regime seen in natural marshes. We measured CO_2 and CH_4 fluxes in 3 types of static chambers (light and dark plant chambers and a dark soil chamber located between stems) in each of 4 marshes at 7 time points over a diel cycle. Simultaneously, we measured photosynthetic yield on a leaf from five stems in each gas flux plot at the same frequency. There was essentially no net CO_2 emission in early morning and late afternoon (despite the sun being up), high net influxes into the soil during the midday and net emission to the atmosphere at night. In term of

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photosynthetic parameters, the slope of the response in electron transport rate (ETR) with increasing light (alpha) was higher during day than night but didn't vary throughout the illuminated period. In contrast, maximum electron transport rate (ETR_{max}) followed a very similar pattern to that observed for CO_2 fluxes. These results have important implications for scaling discrete measures of gas fluxes into wetland carbon cycling and sequestration models.

Characterizing Energy Sources to the Saltmarsh Food Web along the Salinity Gradient

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Investigating the Influence of Gulf Ribbed Mussel Density on *Spartina alterniflora* Primary Production and Soil Nitrogen Cycling

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Louisiana's coast is rapidly eroding due to multiple natural and anthropogenic stressors. To slow land loss, restoration efforts such as living shorelines need to be optimized. In Louisiana salt marshes, *Spartina alterniflora* and the gulf ribbed mussel, *Geukensia granosissima*, are coexisting ecosystem engineers that form a mutualistic relationship that may enhance marsh stability and living shoreline restoration efforts by physically stabilizing marsh soil. We hypothesized that gulf ribbed mussels will increase the total nitrogen pool in the soil allowing *S. alterniflora* to be more productive. In this experiment we investigate the effect of *G. granosissima* presence and density on *S. alterniflora* primary production and productivity. We planted three *S. alterniflora* shoots in each of 20, 10cm diameter tubes that allow lateral water exchange. The plants were assigned evenly between five treatments (0, 125, 250, 500, and 1000 mussels per square meter) and the tubes were installed in situ adjacent to and at the same height as the marsh platform for natural tidal exposure. We measured live and dead stem heights and density, number of leaves and flowers, and PAM fluorometry over four months. At the end of the study we measured aboveground and belowground primary production, as well as CO2 and CH4 fluxes. Additionally, we measured soil properties, nitrogen pools and nitrogen cycling rates. Preliminary data suggests the highest stem density is correlated to the highest mussel treatment. Our results will provide insight into the direct effect of the mussels on plant biomass and nutrient availability, and if these effects are density dependent. Understanding the dynamic relationship between *G. granosissima* and *S. alterniflora* is a critical precursor to the use of ribbed mussels for shoreline restoration.

Invertebrate Community Composition and Organic Matter Decomposition in Created and Natural Brackish Marshes in Coastal Louisiana

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Coastal land loss is a major issue in Louisiana. One method employed to combat this problem is marsh creation projects that rebuild degraded or lost coastal wetlands. However, to determine the success of

these efforts, it is important to compare the ecological structure and function of these newly created mashes to existing natural marshes. This study focuses on the Lake Hermitage Marsh Creation Project in Plaquemines Parish, Louisiana, which created over 1,000 acres of marsh over a three-year period from 2012 to 2014. To examine marsh community composition and organic matter decomposition rates, leaf litter bags were placed along three 100 meter transects at two created and four natural marshes in the project area during the summer of 2018. After two months, these litter bags were recovered and the associated insects and other invertebrates were then separated, identified, and enumerated. Leaf litter was dried, weighed, and compared to its initial mass to estimate average decomposition during this time period. Data analysis is ongoing and will be presented to test for any differences in community composition or decomposition rates between sites.

Fungal Pathogen Presence and Diversity of Four Salt Marsh Plants in Louisiana

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Salt marshes are important coastal environments that provide several ecosystem services throughout their range. Despite their productivity, salt marshes routinely experience both biotic and abiotic stressors often simultaneously. Biotic stressors such as plant disease have received relatively little attention, especially for plants other than *Spartina alterniflora*. Here, we explored the presence of plant disease in Gulf coast marshes. Specifically, we researched patterns of plant disease in *S. alterniflora*, S. patens, *Juncus roemarianus* and *Distichilis spicata* and documented which fungal pathogens are potentially infecting these marsh plants. We conducted surveys on disease presence at three long-term marsh study sites predominantly composed of *S. alterniflora*, but with all other species in patches throughout the marsh landscape. We collected leaf tissue samples from plants showing signs of disease, mostly fungal lesions, for each species at all sites for fungal isolation. We used both morphology and DNA sequencing to identify fungal species. Our results suggest variation in disease presence between plant species with *S. alterniflora* having greatest disease presence followed by *D. spicata*. Additionally, we found differences in fungal species richness between plant species with *S. alterniflora* and *J. roemarianus* having the highest fungal species richness and *D. spicata* and *S. patens* having lowest fungal species richness. Our results suggest marsh plants are subject to different fungal pathogen communities and vary in vulnerability of disease infection following stressors. This research is some of the first to document disease and fungal pathogen communities on *S. alterniflora* and other marsh plant species. Ultimately, this will improve our understanding of the diverse stressors salt marshes regularly experience.

Mercury Biomagnification in Coastal Louisiana Food Webs Immediately Following the 2010 Deepwater Horizon Oil Spill

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Understanding the trophodynamics of biocontaminants in the coastal Louisiana ecosystem is a critical in addressing management and conservation concerns. The sub-tropical climate and strong riverine influence in coastal Louisiana facilitates the methylation of mercury (Hg), which enters the food web and accumulates in consumers. Stable isotope analysis is commonly used to estimate consumer trophic

position and as such can provide insights in the source and magnification of Hg in coastal food webs. Using samples collected from coastal Louisiana from June to December 2010 by Deep Water Horizon (DWH) Natural Resource Damage Assessment (NRDA) we examined relationships between Hg burden, trophic position, and habitat use across species ranging from primary consumers (oysters) to top predators (seabirds). Results indicate a high correlation between trophic position and total Hg concentration across consumers in 2010. However, Hg values in oysters 2010 immediately following the DWH oil spill not differ from Hg values in oysters collected prior to the spill as part of NOAA's Mussel Watch Program. Using Hg concentrations and trophic position we calculated a trophic magnification factor (TMF) for the coastal Louisiana following the DWH spill. The TMF value will be compared to values derived from other coastal Gulf of Mexico food webs to provide further insight into the extent of biomagnification of Hg in this region.

Trophic Niche of Seaside Sparrows (*Ammodramus maritimus*) and Marsh Rice Rat (*Oryzomys palustris*) in Louisiana Saltmarshes Affected by the 2010 Deepwater Horizon Oil Spill

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Previous studies of Seaside sparrows (*Ammospiza maritima*) and marsh rice rat (*Oryzomys palustris*) have highlighted their utility as indicators species in estuarine ecosystems. In coastal Louisiana salt marshes, these two species are two of the most highly abundant terrestrial vertebrates, and as such have been the focus of research and monitoring efforts following the 2010 Deepwater Horizon oil spill. However, the use of these species as biomonitors requires a solid understanding of the degree of interannual, interspecific, and intraspecific variation in foraging behaviors which act to mediate their exposure to the direct and indirect effects of oil and/or other environmental stressors. Stable isotope analysis has become a common tool to estimate species' foraging niche as consumers "are what and where they eat" with isotopic abundance of consumer tissues reflecting these same biomarkers in their diet and surrounding habitats. As such the goal of this research was to defining the trophic niches of Seaside sparrows and marsh rice rat in coastal Louisiana salt marshes affected by the Deepwater Horizon oil spill by examining stable carbon and nitrogen isotope values in whole blood across three years (2015, 2016, and 2017). Stable isotope values differed between years, across species, and exhibited a significant interaction between these two factors. While there was some overlap in the isotopic foraging niches of species, nitrogen stable isotope values indicate a higher trophic level in sparrows relative to rats. In addition, carbon stable isotope values indicate a relatively higher use of aquatic resources in rats relative to sparrows. Moreover, both species exhibited a high degree of intraspecific variation, though a preliminary analysis does not suggest that a site's oiling history influences this variation. Regardless, this research provides insights into the foraging niche of each species which can be used to refine their use as biomonitors and interpret their responses to environmental stressors.

*Student Presenter

Using Functional Marker Genes to Characterize Denitrifying Microbial Populations in Oil-Impacted Barrier Islands

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Disturbances to coastal ecosystems drastically alter ecosystem services. Erosion and loss of sediment accretion, nutrient loading, invasive species, and oil spills are examples, which affect the physical and biological components of these vital systems. In this century, these ecosystems are further threatened with chronic stresses and pulse disturbances (i.e. oil spills, flooding, super storms). The Chandeleur Islands, located forty miles south of Gulfport, MS, are an important coastal defense and ecological habitat. The purpose of this study was to assess the denitrifying microbial populations using nitrogen (N) cycle biomarker genes. We hypothesized that oiling events would further increase the vulnerability of this barrier island chain thereby reducing its resiliency to future stresses. The primary objective of this study was to assess denitrification capacity in saltmarsh cordgrass and black mangrove marsh study sites on the Chandeleur Islands. We applied quantitative polymerase chain reaction (qPCR) to key functional genes in the microbial denitrification pathway. We measured gene products that catalyze the first, second, and third enzymatic steps in the denitrification pathway from (nitrite to dinitrogen; NO^{2-} to N_2). Three N-cycle microbial biomarker genes were investigated; (1) *nirS*, encoding the nitrite reductase gene; (2) *norB*, encoding the nitric oxide reductase gene; and (3) *nosZ*, encoding the nitrous oxide reductase. A comparison of the relative abundances of *nirS* and *nosZ* recovered from cordgrass and black mangrove areas indicated significant changes in denitrifying population abundances as a function of time and predominant vegetation type. Site 2 had a higher relative abundance of *nirS* denitrifying populations in marsh sediments predominated by black mangroves as compared to those predominated by marsh cordgrass. As denitrification in coastal and estuarine habitats are responsible for as much as 50% removal of nitrogen released to the ocean, such changes in microbial N-cycling populations may impact the microbial N transformation processes. Thus, N cycling alterations may further decrease water quality as denitrifers contribute to reduction N loading to estuarine/coastal systems.

Evaluating Fish Abundance and Composition in Restored vs. Natural Salt Marshes

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Investigation of Intertidal Eukaryote Biodiversity within Previously Oiled Sheared and Unsheared Coastal Island Margins in Barataria Bay

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This project investigates invertebrate biodiversity to determine if margin shearing in Louisiana marshes impacted marsh health. While the immediate acute toxicity of the oil from the DHOS has passed, there are still long term effects in play. In the marshes of coastal Louisiana, one major effect of the oil was the weakening of shorelines due to plant death and weakening. Wave action associated with storms

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has since sheared away portions of the already weakened marsh, advancing coastal land loss. Significantly sheared sites on southeast facing shorelines in Bay Jimmy have been previously recorded via satellite analysis. Many marsh soil meiofauna have short range dispersal, are largely sedentary, and spend their entire lives in the marsh. Since these invertebrates are tightly bound to the marsh, their biodiversity should be heavily impacted by changes in the marsh. This means that biodiversity of this group can be used to compare sheared and unsheared marshes. Soil cores were taken from paired sheared and intact sites along a transect leading away from the marsh edge. Total DNA was extracted from 3 aliquots from each of the core and the 18S small ribosomal subunit portion of the DNA was sequenced on the Illumina Hiseq platform using Earth Microbiome Project primers. Eukaryote biodiversity was then analyzed via a metabarcoding approach using the SILVA database in QIIME 2. A wide diversity of Eukaryote OTUs were discovered and a detailed summary will be provided.

Microbial Community Structure and Diversity of *Avicennia germinans* and *Spartina alterniflora* Associated Sediments in Northern Gulf of Mexico Salt Marsh Habitats

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Salt marshes are coastal wetlands that support critical services (e.g., water quality, mitigation of shoreline erosion). As coastal wetlands undergo more frequent and intense threats in this century arising from chronic and pulse disturbances, communities are faced with daunting economic losses. The 2010 Gulf of Mexico oil spill, coupled with significant population changes in human land use, act as add-on catalysts to further accelerate deterioration and loss of barrier islands, particularly those at low-elevation such as the Chandeleur Island chain. The Chandeleur island chain's native vegetation is primarly *Spartina alterniflora*. However, *A. germinans*, an expanding species is also present. During the 2010 spill, oil impacted the barrier island chain to varying degrees; therefore, it was important to investigate the microbally-driven ecosystem service, denitrification, a nitrogen (N) removal pathway. Objectives of the study were to i) characterize microbial community composition in *S. alterniflora* and *A. germinans* dominated sediments, ii) temporally assess impacts of expanding black mangrove on microbial diversity, and iii) characterize denitrifying microbes and diversity indices along sampling gradients (Sites 1 and 2). Proteobacteria, Firmicutes, and Bacteroidetes were most abundant temporally and spatially for cordgrass and black mangrove sediments. When fold differences between black mangrove and cordgrass sample sites were compared, black mangrove exhibited lower abundances at Site 1 for *Beta-*, *Gamma-*, Epsilonproteobacteria, Bacilli (July), and Clostridia. At Site 2, black mangrove lower abundances were observed for *Alpha-*, *Beta-*, Epsilonproteobacteria, and Bacilli when compared to cordgrass Site 2 data. Principal component analysis (class level) highlighted clustering according to vegetation and sample site. Last, no significant differences were observed in alpha diversity. On average, however, alpha diversity was higher at Site 1 for both plant types compared to Site 2.

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Long-Term Response and Recovery of Coastal Salt Marshes following the Deepwater Horizon Oil Spill

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The Deepwater Horizon (DWH) oil spill detrimentally affected coastal shoreline salt marshes in various degrees. We have conducted a long-term field study to investigate oil impacts to coastal salt marshes and their recovery for eight years. We established 21 field stations that received heavy, moderate and no oiling as reference in salt marshes along northern Barataria Bay, one of the most heavily oiled areas during the DWH oil spill. Concentrations of the surface soil total petroleum hydrocarbons were approximately 70 mg g^{-1} and 500 mg g^{-1} 9 months after the spill in moderately and heavily oiled marshes, respectively, and about 100 mg g^{-1} eight years after the spill in heavily oiled marshes. In moderately oiled marshes, dominant plant species, *Spartina alterniflora* and *Juncus roemerianus*, recovered within 1-3 years after the spill. In contrast, heavy oiling resulted in almost complete mortality of plants initially. Recovery of total live aboveground biomass of heavily oiled marshes was <50% eight years after the spill although live *Spartina* aboveground biomass recovered within 2-3 years; however, *Juncus* has not recovered since the spill. As a result, heavy oiling changed vegetation structure from a mixed *Spartina-Juncus* community to predominantly *Spartina*. In addition, live belowground biomass in heavily oiled marshes was significantly lower than that of the reference marshes. Impacts of heavy oiling on marsh plants resulted in weaker soil shear strength compared to reference marshes, thus potentially affecting marsh stability and sustainability.

Impacts of Deepwater Horizon Oil Spill Exposure on Soil Carbon in Louisiana Salt Marshes

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Previously documented impacts of Deepwater Horizon (DWH) oiling on salt marsh plant growth have potentially important implications for ecosystem stability by reducing the rate of soil carbon accumulation, which directly influences the capacity to keep pace with sea level rise. Here, we assess the long-term effects of DWH oiling on soil carbon content in the salt marshes of Barataria Bay, Louisiana, exposed to moderate and heavy oiling. Results spanning a 7-yr timeframe from 2011 to 2017 show that oiled marshes had significantly lower soil carbon content (mg C g^{-1} soil) compared to reference marshes that received no apparent oiling. Reduced soil carbon caused by oiling also corresponded with increased soil bulk density (g soil cm^{-3}), likely due to reduced belowground biomass contributions to soil volume. However, when soil carbon was converted to a volume-basis (taking into account soil bulk density), the main effect of oil exposure on oiling category was masked and instead revealed the initial intensity of the DWH spill at heavily oiled marshes. These results indicate that DWH oil exposure compromised salt marsh stability over the long-term, and recovery of ecosystem function is not yet complete.

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Compositional Changes of the Deepwater Horizon Oil Residues in Coastal Louisiana Marshes from 2010 to 2017

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The composition of DWH oil residues that reached the shoreline was substantially changes from its initial makeup at the discharge point by weathering factors dominated by dissolution during assent, and surface evaporation and photo-oxidation of floating slicks. The oily residue then washed ashore on beaches and marshes and was subjected to biodegradation. Interestingly, isomer patterns of most PAH compounds that case ashore showed PAH weathering even in residues with little evidence of n-alkane biodegradation. We have followed the chemical composition of oil residues collected just offshore before landfall in June 2010, and then after landfall onto coastal Louisiana marshes for seven years. These stranded oily residues were subjected to mostly aerobic weathering with some of the oil sequestered below the surface in borrows undergoing anaerobic weathering. Presumably, photo-degradation was only a minor component of onshore weathering. Weathering and dispersion by weather events (storms) dramatically reduced the quantity of oily resides in coastal marshes during the first three years, and the composition was also significantly altered from that which came ashore. The PAH composition changes from being dominated by the lower molecular weight 2-3 ringed parent and alkyl aromatics to being dominated by the 4 and 5 ringed compounds. Extensive weathering seemed to leave oily residues predominantly composed of the chrysene family. Since 2014, the PAH composition in surface marsh sediments became dominated by PAH compounds with a signature of pyrogenic sources. The petroleum biomarker compounds also underwent biodegradation changing showing significant compositional changes to the sterane biomarkers with lesser degradation of the terpanes. Sequestered oily residues underwent only minor anaerobic weathering compositional changes.

P-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?

Pelagic Connectivity: The Flux and Composition of Sinking Material in the Oligotrophic GOM

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The oligotrophic Gulf of Mexico (GOM) is characterized by extremely low surface nutrient concentrations and deep light penetration depths (1% light levels often in excess of 100m), but little is known about the region's biogeochemistry. Two cruises (May 2017 and 2018) sought to elucidate ecosystem dynamics and the biogeochemistry of these waters to develop hypotheses regarding the spawning behavior of Atlantic Bluefin Tuna, an endangered tuna species, which spawn in oligotrophic waters of the GOM and the Mediterranean. In this study we analyze mixed layer-deep chlorophyll max-mesopelagic connectivity based on material captured by surface-tethered sediment traps, bulk inventories, and biological rate measurements.

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Sinking POM was sampled below the base of the mixed layer (50 m), near the bottom of the euphotic zone (120 m) and at the top of the mesopelagic (200 m). By measuring gravitationally settling particles within the euphotic zone we can assess the level of connectivity between the surface mixed layer and the underlying water column. Preliminary results indicate flux attenuation within the deeper euphotic zone was highly variable ranging between 0% and 62%, while total export ratios (*e*-ratio = sediment trap export / NPP) of the euphotic zone ranged from 0.10 to 0.29, on the high end of previous studies of *e*-ratios in oligotrophic waters. Furthermore, flux at the base of the surface mixed layer was always comparable to or greater than flux out of the euphotic zone suggesting that the deep euphotic zone is a net sink for organic matter. Phytoplankton pigments, isotopes, and U:^{234}Th disequilibrium will be used to further elucidate these mechanisms.

On the Age and Growth of Deep-Pelagic Fishes of the Gulf of Mexico

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Mesopelagic and bathypelagic fishes provide important ecological services. They play a key role in carbon sequestration via the biological pump and are a food source for economically important species such as billfishes and tuna, and federally protected cetaceans and seabirds. These attributes are becoming increasingly recognized, while at the same time mesopelagic fisheries are becoming of interest as coastal fisheries have become overexploited. Additionally, climate change, ocean acidification, and seabed mining threaten deep-sea fishes. With increasing interest in deep-sea fisheries and anthropogenic threats, age and growth information on these fishes is a necessity for management. A major stumbling block for deep-pelagic research, conservation, and management is that very few age estimations have been validated. Additionally, the vast majority of age and growth studies have been performed on the family Myctophidae (lanternfishes) due to their presumed importance in food chains via vertical migration; most other taxa remain relatively uninvestigated. Further, age and growth studies are extremely rare for bathypelagic fishes. It is currently unknown what an otolith increment (the standard ageing technique for teleosts) represents time-wise for these deep-dwelling fishes. In order to address these information gaps, we will present a survey and synthesis on the available age and growth information for deep-pelagic fishes. This synthesis will precede a follow-on analysis of the age and growth of fishes collected during the GOMRI-supported Deep Pelagic Nekton Dynamics of the Gulf of Mexico (DEEPEND) Consortium.

Roll Call: Community Composition of Zooplankton in the Gulf of Mexico

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Zooplankton are an important, yet often underappreciated, component of marine food webs. They provide a critical link between primary producers and upper-level trophic consumers. Zooplankton are able to consume and transfer energy from primary producers to higher trophic levels that would otherwise be unable to access that energy due to the inability to capture prey of such small size. Understanding the distribution and community composition of zooplankton in the deep Gulf of Mexico will aid in the development of food web models and in the creation of much needed baseline data for the Gulf. We characterized the Gulf of Mexico's bathypelagic to epipelagic zooplankton community

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composition in the context of environmental factors such as chlorophyll, salinity, depth, and temperature. Taxa densities were determined from ZooScan images taken from MOCNESS samples collected on NOAA National Resource Damage Assessment cruises performed in response to the Deepwater Horizon Oil Spill in Fall 2010 and Spring 2011. Sampled zooplankton from paired day and night tows were identified and sorted into 58 categories. Epipelagic depths (0-200m) had the most zooplankton overall. Copepods were the most abundant by two orders of magnitude, and represented four taxonomic orders: Calanoida, Cyclopoida, Harpacticoida, and Poecilostomatoida. Additionally, copepod density in spring tows was an order of magnitude greater than in the fall. Diel migratory behavior was observed in multiple taxa of interest including copepods, heteropods, annelids, amphipods, mysids, and salps. The results of this analysis will be utilized in a food web model that will encompass epipelagic, mesopelagic, and bathypelagic zones of the Gulf of Mexico.

Biliary Polycyclic Aromatic Hydrocarbons (PAHs) in Pelagic Species in the Gulf of Mexico

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Fisheries populations and their ecosystems are negatively impacted by stochastic inputs of pollutants, including oil spills such as the Deepwater Horizon blowout. Prior to the Deepwater Horizon (DWH) blowout in July 2010, little was known about polycyclic aromatic hydrocarbon (PAH) exposure and uptake in pelagic fish species in the Gulf of Mexico (GoM). The Center for Integrated Modeling and Analysis of Gulf Ecosystems (C-IMAGE) has conducted comprehensive fish surveys in the GoM between 2011 and 2018. These surveys have allowed extensive studies of PAH concentrations in sediment, water, and demersal species. However, transfer of PAHs to pelagic prey and large epipelagic predators is poorly understood. As part of the pelagic portion of these surveys, this study aims to investigate PAH burdens in pelagic species. Twenty-two pelagic species including Yellowfin Tuna (*Thunnus albacares*), Blackfin Tuna (*Thunnus atlanticus*), Escolar (*Lepidocybium flavobrunneum*), Lancetfish (*Alepisaurus* sp.) and Swordfish (*Xiphias gladius*) were sampled throughout the GoM during the C-IMAGE demersal longline surveys (2011-2017) and pelagic longline survey (2018). Biliary PAH equivalents were quantified in the 22 pelagic species using high performance liquid chromatography coupled with a fluorescence detector (HPLC-FLD). Average concentrations of total biliary PAHs (naphthalene, phenanthrene, and benzo[a]pyrene) ranged from 80,000 nanograms per gram in the Southwest GoM to 110,000 nanograms per gram in the North Central GoM. This work is part of a larger study quantifying tissue (liver, muscle, and gonad) concentrations of PAHs in both pelagic, mesopelagic and demersal species in order to investigate the vertical transfer of contaminants through predator-prey interactions. Analyses from this study will help improve our understanding of PAH uptake and trophic transfer in the pelagic ecosystem and improve our collective understanding of impacts of oil spills on economically-important fisheries.

Deep-Pelagic Ichthyoplankton in the Northern Gulf of Mexico: Vertical Distribution Patterns of Dominant Mesopelagic Families

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Deep-pelagic fishes are often characterized by their extensive diel vertical migrations and contributions to the biological carbon pump, but little is known about the vertical distributions of the early life stages

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of deep-pelagic fishes beyond the epipelagic region (< 200 m depth). The deep-pelagic plankton cruises conducted during the Deepwater Horizon Natural Resource Damage Assessment (NRDA) provide an unprecedented opportunity to investigate mesopelagic ichthyoplankton dynamics in the northern Gulf of Mexico (nGOM), improving our understanding of baseline conditions in the deep-pelagic environment, which will be invaluable for anticipating the effects of future environmental perturbations. Here, we describe the vertical distribution patterns of the dominant mesopelagic ichthyoplankton families in the nGOM, sampled during day and night depth-discrete net tows to 1,000 m depth. We examined potential environmental drivers (e.g., diel periodicity, water column stratification) and spatial patterns of depth distribution in four mesopelagic families: Myctophidae (lanternfishes), Gonostomatidae (bristlemouths), Sternoptychidae (hatchetfishes), and Phosichthyidae (lightfishes), representing 73% of the total fish larvae. At the family level, myctophid and phosichthyid larvae were largely constrained to epipelagic regions, while gonostomatid and sternoptychid larvae were found at broader depth distributions in both the epipelagic and mesopelagic. Because the mesopelagic fish larvae were most abundant in the epipelagic zone, we conducted further depth analyses at a finer scale, examining vertical distribution patterns within the upper water column using depth-discrete net tows to 160 m depth. The early life history stages of deep-pelagic fishes are a major component of the open ocean plankton community, and understanding their distribution within the water column will be critical for understanding their role in ocean carbon and nutrient cycling.

Deep-Pelagic Ichthyoplankton in the Northern Gulf of Mexico: Analysis of Community Assemblage Structure

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The early life stages of deep-pelagic fishes play a critical role in pelagic food webs and oceanic carbon cycling, yet little is known about the taxonomic composition and distributions of larval fishes in the northern Gulf of Mexico (nGOM). The deep-pelagic plankton cruises conducted during the Deepwater Horizon Natural Resource Damage Assessment (NRDA) provide an unprecedented opportunity to investigate mesopelagic ichthyoplankton dynamics in the nGOM, improving our understanding of baseline conditions in the deep-pelagic environment, which will be invaluable for anticipating the effects of future environmental perturbations. Here, we describe the community assemblage structure of mesopelagic ichthyoplankton in the nGOM from six deep-pelagic plankton cruises, sampling 48 stations with depth-discrete net tows to 1,000 m depth, and occasionally sampling to 1,500 m and below. These stations yielded 149 families, and at least 267 genera and 277 species of larval fishes (including taxa exclusive to epipelagic waters, < 200 m). Myctophidae (at least 19 genera, 42% of total fish larvae) and Gonostomatidae (at least 6 genera, 20%) dominated the catch at nearly all stations. In addition to standard metrics of taxonomic diversity and richness, analysis of similarities will be used to test for differences in ichthyoplankton assemblages among stations and sampling periods, and similarity percentages analyses will be applied to determine the taxa driving these differences. Similarity profile tests and non-metric multidimensional scaling analyses will be conducted to identify and visualize significant groupings among samples and identify spatial and environmental patterns in larval fish community composition at differing depths. These analyses aim to fill key gaps in knowledge about the distributions of deep-pelagic larval fish in the nGOM and the biophysical drivers that structure them.

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A Synthesis of Lanternfish Ecology in the Gulf of Mexico

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Lanternfishes (Myctophidae) are a highly diverse and globally-important family of fishes, which form a ubiquitous part of the deep-pelagic micronekton. The majority of lanternfish species conduct diel vertical migrations (DVMs) from the mesopelagic (200 - 1000 m) to the epipelagic (0 - 200 m) where they feed at night. As voracious zooplanktivores and an important food source for commercially-important fishes, seabirds, and deep-living predators, myctophids play a key role in the biological pump and are an important intermediate trophic group, linking coastal, upper-ocean and deep-ocean ecosystems. Nonetheless, relatively little is known about the variability of myctophid biodiversity, assemblage structure and species distribution patterns, or of their DVM behaviours over spatial and temporal scales. In this study, we present a synthesis of recent research findings examining vertical and horizontal distribution patterns in a high-diversity myctophid assemblage in the Gulf of Mexico, and their variability both through time and in relation to mesoscale oceanic processes. The analyses were conducted using depth-stratified data (spanning 0 - 1500 m), collected between 2011 and 2017 across a 200 x 700 km survey area. Analyses indicate that the lanternfish assemblage in the Gulf of Mexico is weakly structured, and shows limited coherence at the measured scales. However, individual species show stronger responses to mesoscale environmental conditions, which are evidenced primarily by changes in their vertical migratory behaviours. These findings suggest that the overall assemblage is comprised of a highly-dispersed, well-mixed suite of individual populations and life-stages, which respond independently to environmental cues. We discuss the implications of these findings for ecosystem structuring and carbon transfer between the surface and deep oceans.

Analysis of Microbial Communities Reflects Diel Vertical Migration in the Gulf of Mexico

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Oceanic diel vertical migration (DVM) constitutes the movement of various mesopelagic organisms migrating vertically daily from depth to feed shallow and return to deeper water during the day. In spite of decades of research on DVM, many questions still abound. Accurate classification of taxa that participate in DVM remains non-trivial, and there can be discrepancies between acoustic and trawl-based estimates of organismal density. DEEPEND consortium (www.deependconsortium.org) scientists have been characterizing the diversity and trophic structure of pelagic communities in the Northern Gulf of Mexico (GOM) for the past three years (2015-2017). Profiling has included bacterioplankton communities (also known as “microbiomes”) from the surface down to 1600 m depth. We hypothesize that high throughput (HT) sequence analyses would complement ongoing characterizations of DVM via acoustic and net sampling. During two DEEPEND cruises in the GOM, we examined the fine-scale acoustic responses of a vertically migrating layer using an autonomous multifrequency echosoundera at about 320 m. We then placed CTDs to collect water samples before and during the upward DVM of organisms. Multiple amplicon libraries (n=40) of 16S rRNA (for prokaryotes) and 18S rRNA (for eukaryotes) were derived and sequenced from 19 pre-, 18 during and 3 post DVM samples. Comparisons of acoustic and microbiome data types would test the limits of microbial forensics, inferring organismal identities and co-occurrences that could elucidate ecological patterns. Results to date show distinct prokaryotic taxa at different stages of the DVM, and combined with the results of

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18S rRNA sequencing, this study has the potential to reveal broad community shifts associated with DVM.

Barreleyes and Spookfishes (Teleostei: Opisthoproctidae) in the Deep Pelagic Waters of the Northern Gulf of Mexico

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Barreleyes and spookfishes (Teleostei: Opisthoproctidae) are a little-studied family of deep pelagic fishes. Prior to the BP oil spill, three species were known from the entire Gulf of Mexico. The ONSAP and DEEPEND investigations following the spill have discovered at least another three species residing in the northern Gulf of Mexico, with *Bathylychnops brachyrhynchus* as the most abundantly sampled species. These new specimens have also allowed for an increased understanding of their vertical ecology, size range, diet, and reproduction in deep pelagic waters.

Comparison and Potential of Gap-Filling Algorithms for Satellite Data in the Gulf of Mexico

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Ocean color remote sensing has revolutionized our ability to monitor surface waters at broad spatial scales. However, many marine phenomena occur over short time-scales. While satellite-borne instruments that are commonly used for regional-scale marine applications have revisit times of few days, most satellite images have large data gaps because of cloud cover. For example, in 2017, any given location in the Gulf of Mexico was on average visible in about 20% of daily MODIS Aqua images, 40% of 3-day composites, and 60% of 8-day composites. Consequently, our ability to monitor marine phenomena with high temporal variability from space is severely limited by data gaps. Furthermore, because some areas have more frequent cloud cover than others, data gaps related to clouds can bias estimates of regional averages and their trends. To overcome these problems, we compared the performance of several previously published and newly developed gap-filling algorithms for ocean color data, including geostatistical interpolation methods, machine learning methods and hybrid approaches. Using chlorophyll *a* concentrations as an example, we found that gap-filling algorithms can considerably reduce errors caused by clouds in estimates of regional mean chlorophyll concentrations, and that spatio-temporal interpolation algorithms performed best overall. We conclude by discussing the potential of gap-filling algorithms to improve environmental monitoring and research in the Gulf of Mexico.

Can Evolution in the Prey to Develop Toxicant Resistance Help Save Its Predator?

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The Deepwater Horizon oil spill is considered to be the largest marine oil spill in the history of the Gulf of Mexico (GoM). Given the size of this spill, we may expect the resulting toxicity to impact species, and consequently species interactions, for an extended period of time. These impacts may change over

time as the effects of the spill go away but they may also change as a result of species responding to the toxicity. In particular, long-term exposure to a toxicant may result in rapid evolution of toxicant resistance in relatively short-lived species. In this study, we use mathematical modeling to investigate the possible effect of such an evolution on predator-prey dynamics when only the prey population evolves to develop resistance to the toxicant. This kind of scenario may happen when, for example, the lifespan of the prey population is considerably shorter than the predator population, such as sperm whales and their main food source giant squid. We show that the evolution of toxicant resistance of prey population may allow both the predator and prey population to survive when, without the evolution, both may go extinct. [This research was made possible by a grant from The Gulf of Mexico Research Initiative.]

Looking into Atlantic Bluefin Tuna Connectivity in the Gulf of Mexico Through Genetic Characterization of Early Life Stages

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Atlantic bluefin tuna (ABFT) *Thunnus thynnus* (Linnaeus, 1758) is a highly migratory species that spawns in oligotrophic open waters with a well-established spawning area in the Gulf of Mexico (GoM). Western and Eastern ABFT stocks are segregated for fisheries management purposes. The study of early life in this heavily exploited species has been prompted by ecosystem-based fisheries management and the incorporation of larval indices into stock assessment. Systematic collection of early life stages that allow correct origin assignment of specimens to a certain spawning ground is critical to understand connectivity of highly migratory species. In May 2014 ABFT larvae were collected using plankton nets from hydrographically differentiated areas in western and eastern GoM. A subset of larvae was genetically characterized to assess genetic connectivity within the GoM. Genomic DNA was extracted from over 50 individuals to genotype 8 neutral microsatellite loci; Ttho-1, Ttho-4, Ttho-7 (Takagi *et al.*, 1999), Tth-34 (McDowell *et al*., 2002), Tth16-2, Tth 1-31, Tth 157, and Tth 208 (Clark *et al*., 2004). Genetic diversity estimators and analysis of molecular variance in the 2014 larvae indicate absence of ABFT population structuring within the GOM. Future monitoring of ABFT population diversity within western spawning grounds is essential for the conservation of this highly valuable pelagic species and to predict resilience of the GoM pelagic ecosystem.

This study was financed by NASA grant NNX11AP76G “Management and conservation of Atlantic Bluefin tuna (*Thunnus thynnus*) and other highly migratory fish in the Gulf of Mexico under IPCC climate change scenarios” and ECOLATUN PROJECT CTM2015-68473-R (MINECO/FEDER) funded by the Spanish Ministry of Economy and Competitiveness.

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Genetic Discovery of a New Species of the Anglerfish Genus *Ceratias* (Lophiiformes: Ceratiidae) from the Gulf of Mexico

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A key objective of the DEEPEND (Deep-Pelagic Nekton Dynamics) Consortium is discovery and documentation of the biodiversity of meso- and bathypelagic fishes of the Gulf of Mexico (GOM). Here, we use a combined molecular and morphological character approach to document a new species of anglerfish in the family Ceratiidae. Up to now, the anglerfish genus *Ceratias* comprised three species, distinguished primarily on the basis of morphological characters associated with the esca, the light-emitting organ characteristic of female anglerfishes. These species include two circumglobally distributed taxa, *Ceratias holboelli* Krøyer, 1985, and *C. uranoscopus* Murray, 1877, and a single species endemic to the Southern Ocean, *C. tentatulatus* Norman, 1930. Based on the accepted taxonomy of the genus (simple esca with no filaments), our focal species was identified as *C. uranoscopus*. However, subsequent analyses of molecular sequence data (two concatenated mitochondrial genes and four concatenated nuclear genes) placed our sampled species as a reciprocally monophyletic sister group to a clade comprising the three recognized *Ceratias* species. Additionally, mitochondrial (COI and 16S) sequence data for the new species (*Ceratias* sp.) showed clear divergence from the three recognized species (8.5 - 9.6% [uncorrected] and 5.4 - 5.8% [model corrected]). Nuclear gene genetic distances of the new species were higher than or fell within the range of distances separating the three known species. Finally, a fully darkened escal bulb distinguished the new species from its morphologically most-similar congener, *C. uranoscopus*. Upon formal description, our findings will add a fourth species to the anglerfish genus *Ceratias*, and suggest that specimens identified as *C. uranoscopus* collected from the Western Central Atlantic (at least) may need reexamination.

Atlantic Bluefin Tuna Larvae (*Thunnus thynnus*) Trophic Pathways Interannual Variability Based on Isotopic Signature Analyses in the Gulf of Mexico

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Atlantic bluefin tuna (ABFT, *Thunnus thynnus* Linnaeus, 1758), is a migrating large predator and its western stock spawns in oligotrophic open waters of The Gulf of Mexico (GOM) during late spring and early summer months (May & June). The trophic ecology of ABFT larvae from the GOM was examined by nitrogen and carbon stable isotopes analyses (SIA). ABFT postflexion larvae were collected in the eastern Gulf of Mexico during the spawning season in two hydrologically different years, 2014 and 2017. These years were differentiated by their temperature regime and relative productivity, with the 2017 being significantly warmer and less productive than 2014. A total of 61 larvae were used for this study within the same size range of 5-9 mm standard length (SL). Significant higher $\delta^{15}N$ values were observed for ABFT larvae in 2014 together with lower $\delta^{13}C$, whereas higher trophic positions (TP) were estimated in larvae from 2017. Significant linear increase of $\delta^{13}C$ with SL observed in both years may be explained by changes of the relative carbon isotopic sources. A significant positive relationship between $\delta^{15}N$ and SL was observed in 2014, suggesting piscivory behavior. Larval ABFT isotopic trophic

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widths were also estimated using SIBER package (Stable isotope Bayesian ellipses in R) of SIAR (Stable Isotope Analysis in R) in both years in order to discuss their interannual variability and trophic behavior. These results provide insight for a trophic pathways interannual variability in the main western spawning grounds for ABFT larvae in the GOM. This study has been financed by ECOLATUN CTM2015-68473-R (MINECO/FEDER) to IEO and funded by NOAA RESTORE to NOAA-SFSC.

Diet Composition and Feeding Success of Atlantic Bluefin Tuna (*Thunnus thynnus*) Larvae of Varying Early Life History Stages in the Gulf of Mexico

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Effective management of western Atlantic bluefin tuna (ABT) depends on understanding larval survival rates and the stock-recruitment relationship (SRR) in their spawning grounds in the Gulf of Mexico (GoM). Larval feeding success in the GoM increases rapidly with size, with smaller larvae more likely to be nutritionally challenged by spatiotemporal variability in prey concentration. We collected ABT larvae in May 2017 and May 2018, categorized each by flexion stage and dissected each for prey identification. Gut content analyses were performed on 117 larvae (8 pre-flexion, 81 flexion, 28 post-flexion) and 1217 prey were identified. Maximum prey size at growth stage (pre-flexion, flexion, post-flexion) increased with size (0.474mm, 0.789mm, 1.387mm, respectively). Prey item per gut increased from pre-flexion to flexion but declined for post-flexion, indicating older larvae were eating fewer, larger prey than the younger counterpart. These results are part of a broader effort to determine the specific environmental factors favoring preferred prey of ABT larvae and mechanistically link the success of ABT larvae to prey dynamics and plankton primary and secondary production. Such information is crucial to advancing our understanding of pelagic ecosystems and improving existing stock assessment tools for resource managers.

Estimates of Food Limitation Experienced by Coastal-Pelagic Fish Larvae in the Gulf of Mexico

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Since the 2010 Deepwater Horizon oil spill, advances in the development of three-dimensional hydrodynamic ocean models have significantly improved our ability to predict Gulf of Mexico circulation. However, these models have only begun to be applied to understanding lower trophic level ecology. Of particular importance is our ability to estimate zooplankton abundance and variability. In addition to strongly impacting the global carbon cycle, zooplankton function as an important energy pathway between the base of the food chain and higher trophic levels. During the vulnerable larval

stage of marine fish, zooplankton serve as the primary food source for many economically valuable species. In the ocean, mortality is known to largely dictate the fate of larval fish. Starvation is a dominant contributor to mortality primarily during the period where larvae switch to exogenous feeding. To evaluate larval fish susceptibility to starvation, we configured a coupled physical-biogeochemical ocean model in the Gulf of Mexico and developed a methodology to estimate food limitation based on model-estimated zooplankton concentrations and larval metabolic requirements. Model estimates of zooplankton concentrations are validated against, and agree well with, a multi-decadal zooplankton database (SEAMAP). Based on model zooplankton fields, we find both periods and regions in the Gulf of Mexico where food deplete and replete conditions exist. Coupling to an individual-based Lagrangian fish model enables investigation of starvation-driven mortality throughout the pelagic larval duration. Further integrative modeling studies that examine zooplankton are needed to predict impacts of future perturbations on the Gulf of Mexico ecosystem and to support informed decision making for the region.

Spatial and Temporal Variability in *Sargassum*-Associated Juvenile Fish Assemblages in the Northern Gulf of Mexico

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To support an Ecosystem-Based Fisheries Management (EBFM) approach, an emphasis has been placed on incorporating habitat science, with the goal of better understanding the role of habitat interactions on fisheries production. *Sargassum*, a genus of brown macroalgae, is an important holopelagic habitat in the Gulf of Mexico. The habitat provides many juvenile fish species with refuge and foraging opportunities that presumably promote growth and survival in early life stages. Two species of *Sargassum* (*S. natans* and *S. fluitans*) aggregate to form these complexes that support rich diversity of invertebrates and juvenile fishes, including many recreationally and commercially important species (e.g., Grey Triggerfish, Greater Amberjack).In this study (funded by the NOAA RESTORE Science Act Program), *Sargassum*-associated fishes were collected using a 505 µm mesh neuston net and hook-and-line fishing across 22 different sites in July 2017, May-June 2018, and July 2018 in order to quantify the variability in juvenile fish assemblages in the northern Gulf of Mexico. Here we present abundance estimates, diversity indices, community assemblage comparisons, and length-frequency distributions for dominant taxa. Results of this study will provide evidence of the spatial distribution of juvenile fishes associated with *Sargassum*, and the environmental conditions that contribute to the observed variability between and within years and seasons. Further, these results contribute to the overall project goal of developing *Sargassum* habit indices for inclusion in stock assessments and EBFM applications.

A Vertically-Resolved End-to-End Ecosystem Model to Study the Role of Vertical Exchange Processes within the Oceanic Gulf of Mexico Food Web: GoMex-ECOTRAN

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Understanding of Gulf of Mexico ocean ecosystem dynamics is hampered by our lack of understanding of the connectivity between the epipelagic, mesopelagic, and bathypelagic depth zones. Our lack of

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understanding was brought into sharp relief during the Deepwater Horizon oil spill where a large proportion of the released oil remained at depth. The consequences of this and other perturbations is difficult to quantify given our lack of knowledge of the baseline dynamics of Gulf of Mexico deep-water ecosystems. In our current GoMRI project, we aim to quantify connectivity within and between the epipelagic, mesopelagic, and bathypelagic depth zones of the Gulf of Mexico ecosystem. We are concerned with exchange via trophic linkages, as mediated by vertical migration, and exchange via physical the processes of particle sinking and vertical mixing. We are applying a vertically resolved end-to-end ecosystem model to the oceanic Gulf of Mexico. ECOTRAN was originally developed as a generalized model platform for comparing the dynamics of shelf ecosystems that exist within diverse physical settings. ECTORAN has been used to show how physical exchange between the shelf and ocean affects transfer efficiencies through the food web and can lead to an apparent decoupling of lower and upper trophic level production - reducing upper trophic production relative to plankton production (upwelling) or enhancing upper trophic level and benthos production (downwelling). Here we ask: How important are vertical exchanges of individuals, nutrients, and detritus between depth zones to the Gulf of Mexico ocean ecosystem? How do perturbations to exchange processes or to the food web within any depth zone affect the others? To define trophic relationships within each depth zone, our model incorporates knowledge of deep-pelagic nekton and micronekton community gained by the GoMRI DEEPEND consortium and from stomach content and stable isotope analyses conducted as part of our own GoMRI project.

Diet Composition of Atlantic Bumper Relative to Dissolved Oxygen Concentration and Fish Size

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One of the largest human-caused coastal hypoxic zones is located in the northern Gulf of Mexico (NGOMEX). Our understanding of the impacts of hypoxia on trophic interactions in pelagic and bentho-pelagic food webs is limited. We explored the impacts of dissolved oxygen concentration and ontogeny on diet composition of and mass-specific consumption by Atlantic bumper *Chloroscombrus chrysurus*, a numerically dominant planktivorous fish in the northern Gulf of Mexico. There was no significant difference in Atlantic bumper catch per unit effort (CPUE) between hypoxic and normoxic areas. Small Atlantic bumper in hypoxic areas had greater mean mass-specific consumption than fish in normoxic areas. Shrimp larvae were the most common prey type for both large and small Atlantic bumper. Large quantities of fish larvae were consumed by adult Atlantic bumper in hypoxic regions. Atlantic bumper are a very common forage fish in the NGOMEX, and our findings provide important basic knowledge that will be useful for several ecosystem models used to simulate energy flow and food web dynamics in the region.

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The Population Genetic Dynamics of Three Deep-Sea Lanternfish Species (Family: Myctophidae) following the Deepwater Horizon Oil Spill

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Assessing the impacts of the Deepwater Horizon oil spill (DWHOS) on the deep-sea fish communities of the Gulf of Mexico (GOM) has been hindered by an absence of baseline (pre-spill) data concerning the biology and ecology of the meso- (200-1000 m) and bathypelagic (>1000m) waters of the GOM. In fact, despite their vital roles in deep-sea ecosystems, very little is known about the population genetic dynamics of fishes occupying the deep waters of the GOM. The lanternfishes (Myctophidae) are a speciose, yet understudied, taxonomic group, that comprise a significant portion of the global deep-sea biomass, making them integral members of meso- and bathy-pelagic food webs. In addition, myctophids possess relatively short generation times (approximately one year), making them ideal candidate species to study the multi-generational impacts of the DWHOS on the genetic diversity and population integrity of deep-sea taxa. Herein, we used a genomic approach (double digest restriction-site associated DNA sequencing) to investigate the temporal genetic dynamics of three species of lanternfishes within the GOM in the region of the oil spill [*Ceratoscopelus warmingii* (n = 85), *Diaphus dumerilii* (n = 43), *and Lepidophanes guentheri* (n = 44)]. Fishes were sampled in 2011 immediately following the DWHOS, and then again in 2015, and 2016, and genotyped using SNP markers. Overall, all three species were characterized by low levels of genetic diversity, high inbreeding coefficients, and subtle indications of shifts in population-level allele frequencies across the temporally-spaced samples. In fact, two of the three species (*D. dumerilii* and *L. guentheri*) demonstrated a reduction in genetic diversity (the number of private alleles) between the generations following the DWHOS, suggesting the potential for long term impacts by the DWHOS to the population persistence and resilience of this functionally important group of deep-sea fishes.

Food Web Structure of Deep-Pelagic Micronekton Assemblages in the Gulf of Mexico

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A major goal of ecological research is to attain the ability to model food web dynamics so that predictions regarding changes in food web and ecosystem structure can be made. Before accurate food web models can be constructed, information regarding trophic relationships among major functional groups, including estimates of trophic structure using both stomach content analysis (SCA) and stable isotope analysis (SIA) must be completed. Currently, several data sets utilizing SCA to describe trophic structure of micronketon (2-10 cm) in the deep-pelagic Gulf of Mexico (GoM) exist but studies utilizing SIA are less common. Through the use of a taxonomically comprehensive data set, we describe the structure of deep-pelagic micronekton assemblages in the GoM using SIA of $\delta^{13}C$ and $\delta^{15}N$. Vertically migrating taxa (25 species), and non-migrating taxa (23 species), representing a range of feeding strategies, depth distributions, and putative trophic levels were selected in order to describe the full breadth of trophic variability within deep-pelagic assemblages. Additionally, surface samples of *Sargassum* spp. and particulate organic matter (POM) samples taken within the epi-, meso-, and bathypelagic zones were used to delineate carbon source isotopic signatures. Isotopic signatures of POM samples were significantly different across depth zones and displayed a pattern of enrichment in ^{15}N with increasing depth. The $\delta^{13}C$ values of micronekton varied among species, ranging from -22.73‰ to -16.35‰ suggesting consumers utilize POM throughout the water column. Micronekton $\delta^{15}N$ values

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ranged from 1.85‰ to 10.97‰ encompassing ~3 trophic levels. Elevated $\delta^{15}N$ values in some non-migratory taxa suggest an increased reliance on deep-suspended POM when compared to migratory taxa who receive the bulk of their carbon from epipelagic sources. This project provides data that can be used to inform ecosystem models and will provide insight into the structure of the northern GoM deep-pelagic ecosystem.

DEEPEND: Molecular Evidence for Environmental Change in the Deep-Pelagic of the Gulf of Mexico

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Historic fluctuations in population size often reveal the effects of major ecological events on the genetic diversity of a population or a species. These fluctuations can be inferred through the use of molecular data. Numerous studies have uncovered strong evidence of recent genetic bottlenecks in coastal marine fishes attributed to these changes in the marine environment. However, it was long believed that little environmental change occurred in the deep-sea. This idea has been challenged as long-term monitoring efforts have uncovered evidence of rapid alterations in deep-sea temperatures. Furthermore, recent studies have suggested that benthic deep-sea communities are currently being altered as a result of climatic changes. In this study we sought to investigate whether thirteen different deep pelagic fish species have undergone recent population size changes. To answer this question, we employed several different methods of analysis utilizing DNA sequence data; frequency-based and tests that make use of the topology and branch lengths of genes trees to infer changes in population size over time. Using these approached we inferred population size increases in seven of the thirteen study species. The onset of this inferred change varied by species. The most recent population expansion began 70,000 years ago while the oldest began approximately 300,000 years ago. The great difference between species regarding the timing of their population increases does not point to a single event being responsible for the demographic changes we recovered. Instead, it points to an environment that may regularly undergo change.

Phytoplankton Nutrient Uptake and Growth Dynamics in the Spawning Region of Atlantic Bluefin Tuna in the Oligotrophic Gulf of Mexico

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Western Atlantic Bluefin Tuna (ABT) are an important commercial fishery in the Northern Atlantic. Although ABT migrate throughout the Atlantic to forage, the western stock spawns almost exclusively in extremely oligotrophic regions of the Gulf of Mexico (GoM). The nitrogen sources supporting plankton communities in these regions remain unknown, with possibilities including nitrogen fixation, nitrate upwelled at the edges of mesoscale eddies, or horizontal advection of nutrients from the Mississippi River Plume. Here we use in situ and deckboard incubations to investigate primary productivity, nitrate uptake, and ammonium uptake as a function of phytoplankton biomass, nutrient concentrations, and light availability. Preliminary results suggest a community supported primarily by recycled production, with new production dependent on upwelled nitrate. As future oceans may become more oligotrophic, leading to reduced productivity and food availability at multiple trophic

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levels throughout the ecosystem, next generation stock assessment models should incorporate predicted changes in upwelling into future recruitment scenarios.

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

A Modeling Study of Tidal- and Wind-Driven Estuary-Shelf Exchange through a Narrow Tidal Inlet: The Barataria Pass, Louisiana

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The circulation and particle transport through the 800-meter wide Barataria Pass and onto the shallow Louisiana continental shelf are numerically examined using the three-dimensional baroclinic Finite Volume Coastal Ocean Model (FVCOM). The numerical model domain extends longitudinally from Mobile Bay, Alabama to west of Galveston Bay, Texas and offshore to about 27°N. Inside the Barataria Basin all major water bodies and intertidal wetlands are covered, including the existing Davis Pond freshwater diversion and proposed mid-Barataria sediment diversion. Near Barataria Pass the model resolutions are ~ 40 m horizontally and ~ 0.1 m over the shoal and ~ 1 m at the thalweg vertically. The model is driven by winds at the surface, tidal and subtidal sea level variations at the open boundary, and freshwater inflows from various Mississippi River and Atchafalaya River passes, and the Davis Pond Diversion. Strong ebb flows resulting from this combined forcing transport estuarine water seaward through the inlet to form a radially spreading buoyant surface plume over the shelf. Ambient shelf circulation is primarily wind driven and westward flowing Louisiana Coastal Current can be turned to eastward during westerly wind events. Wind-driven currents greatly influence the appearance of the inlet plume. Cross-shore wind determines the landward retardation or seaward spreading of the plume, while along-shore wind leads to asymmetric spreading of the plume relative to the inlet axis. Internal waves are also identified on the plume interface. Under landward winds, surface passive particles released at maximum flood tides can move ~ 12 km landward of the inlet, and stay inside the estuary during the next ebb period. On the contrast, most of surface particles released at maximum flood tides under offshore winds are expelled offshore during next ebb tides. Particles released at mid-depth are easier to enter the inlet compared with those that are released at surface and near bottom. This result has clear implication for shelf-to-estuary transport of pollutants (such as oil slicks) and estuarine ingress of larval recruitment.

System Architecture of an Oysters' Gape Measurement Apparatus

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In this work we describe the hardware and software used in developing a bivalve gape measurement system. This system employs the Hall Effect phenomenon to accurately measure and report the gape of a bivalve. The system uses a Hall Effect sensor (Symmetry Electronics H2425) and a small magnet that

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are glued to the outside of the shells of a bivalve. The Hall Effect sensor reports the magnet distance, and hence the gape opening, at a rate controlled by the user, to a microcontroller that records and transmits that data to ground station. This system has been designed to operate in the field as well as in a laboratory environment. In a laboratory setting, this system uses WiFi or Bluetooth to transmit its data. In the field, however, and due to the lack of availability of power, two setups have been developed. The first one does not transmit data, but saves it in an SD card inside the system's enclosure. This setup is fully submersible. The battery, microcontroller and SD card reader are all submerged with the bivalve. This system can work for as long as 29 days with single battery charge. Therefore, each month, the battery of this system will have to be replaced if data collection is to continue. The second field system is one that uses the cellular network to communicate its data. This is a viable solution since most reefs exist close enough to the shore where cellular signal is available. The system uses a solar collector panel to charge a battery during the day that will keep the system transmitting at night. The laboratory systems as well as the underwater field system are fully operational and have been producing gape data for several months. The cellular system is currently being tested. Data from all these systems will be made available under the MBRACE project data repository.

Wind and Tide Effects on the Choctawhatchee Bay Plume at Destin Inlet, Florida

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Ebb-phase estuarine plumes, which are common in the Northern Gulf of Mexico, can directly impact the near-shore transport of surface material such as oil and chemical pollutants, fish larvae and other biological material. In December 2013, a series of experiments (Surfzone Coastal Oil Pathways Experiment) were performed near the Choctawhatchee Bay and Destin Inlet, situated along the Florida Panhandle, to study mechanisms that influence near-shore surface transport. During low tide, SCOPE satellite imagery showed a visible brackish surface outflow at Destin. The goal of the present study is to quantify variability in the plume signature at Destin, during November - December 2013, due to changes in wind and tidal forcing.

Density driven flows at Destin Inlet are modeled using three dimensional, baroclinic capabilities of ADCIRC (Advanced CIRCulation). The Choctawhatchee Bay and River System is represented by a high-resolution, unstructured, estuarine- and shelf-scale finite element mesh. The plume behavior in successive tidal cycles can differ due to the rotary winds associated with winter cold fronts. Modeled tides, salinities and plume signature are validated against in-situ observations and satellite imagery and then applied to analyze plume response in two scenarios. In the first case, model plume behavior is analyzed on successive days of near-constant tidal amplitudes and changing wind directions due to passing cold fronts. In the second case, plume response is investigated during consecutive days of neap-spring variability in the tides and near-constant wind speeds. Model results reveal a larger plume during spring tides and periods of weak wind forcing. Offshore winds enhance the north-south expansion of the plume, whereas onshore winds restrict the plume to the coastline. Research findings lead to a better understanding of estuarine plume behavior in the inner shelf and provide insights that will be useful for oil response operations and fisheries management.

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Plankton Thin Layer Mechanism of Formation and Cascading Ecological Impacts in the Northern Gulf of Mexico

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Thin layers are dense aggregations of phytoplankton or zooplankton that span less than 3 m in the vertical dimension and have been described in many coastal oceans with strong density stratification. Although thin layers serve as trophic "hot spots" and can dramatically influence exposure rates of plankton to spilled oil, little is known about their frequency of occurrence or mechanisms of formation in the northern Gulf of Mexico (nGOM). We resolved the extent of a thin layer on the nGOM shelf on July 24, 2016 with an *in-situ* plankton imaging system, along with a suite of oceanographic properties. The *Odontella* spp. diatom-dominated thin layer was ~0.5 m thick, had a peak chlorophyll *a* of 23.9 mg m^{-3} (> 4x background concentration), and a distinct arc shape ranging from 8 m depth in the north and 5 m in the south. Estimates of phytoplankton apparent growth (0.69 d^{-1}) and microzooplankton grazing (0.61 d^{-1}) rates suggested that grazing balanced phytoplankton growth. Copepods and doliolids were the most abundant macro-grazers around the layer and had starkly differing distributions. Copepods concentrated near the surface, south of the layer, reaching concentrations of over 400,000 ind. m^{-3}. In this same area, there was an abundance peak in chaetognaths, shrimp, and marine snow aggregates. Doliolid abundance peaked at the north and south ends of the thin layer, near chlorophyll *a* fluorescence maxima, and doliolid local abundance maxima followed the trajectory of the thin layer. Hydromedusae were most abundant in deeper waters north of the thin layer. The high-resolution physical oceanographic model indicated that a surface convergence, which propagate northward frequently in this area, drove the formation of the layer. The differences among zooplankton groups suggest that even under strong physical forcing, behavioral differences among groups play an important role in structuring their distributions.

Fine-Scale Distributional Patterns of Gelatinous Zooplankton are Driven by Seasonal Environmental Changes in the Northern Gulf of Mexico Shelf

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Knowledge of environmental effects on distribution of zooplankton during different seasons is crucial for estimating organism vulnerability to oil and other pollutants. The gelatinous zooplankton community represents an important component of the northern Gulf of Mexico ecosystem. However, the environmental drivers determining their distributions are poorly understood. This is due to biases associated with net samplers, which integrate abundances across large spatial scales and damage their fragile gelatinous bodies. We used a plankton imaging system (ISIIS) equipped with a CTD, dissolved oxygen sensor, and chlorophyll-*a* fluorometer, to obtain fine-scale spatial distributions of 23 gelatinous zooplankton taxa in relation to their environment. Daytime "tow-yo" transects (~54 km) from surface to ~4 m from the bottom off Perdido Bay, FL were performed during Spring, Summer and Fall (2015-2016). Although conditions were well-mixed during Fall, the ISIIS measured increasingly stratified waters between Spring and Summer. Taxon-specific distributional patterns were observed within and among seasons, driven by environmental conditions. Multivariate analyses grouped all taxa into four

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summer and three spring clusters (ANOSIM) that differed significantly in temperature, salinity, chl-*a* and dissolved oxygen concentration. In other words, each cluster represented a distinct water mass occupied by different taxa. SIMPER analysis revealed that temperature and oxygen contributed most to among-cluster differences during summer, while oxygen and salinity contributed most to differences during spring. Spatial overlap was higher among taxa within clusters than among taxa from different clusters, indicating that taxa found in similar environmental conditions were more likely to co-occur in space. Our findings highlight the highly structured distributions of plankton in stratified coastal waters and the need for high-resolution sampling during spills in order to better forecast and model exposure and ecosystem consequences.

Defining the Mississippi River Plume with Numerical Drifters

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A river plume is the mixing region between seawater and fresh water. Many properties change within and outside a river plume that researchers want to study; for example, the baroclinic instabilities due to freshwater discharge, and the salt gradient. These different properties will impact oil dispersion patterns and decay rates, so a good understanding of the difference in the distribution of such properties inside and outside the river plume would provide some guide information for responding to oil spill events. However, how to quantitatively define the boundary of a river plume is still a problem. Here, we propose using statistical metrics for numerical drifters to quantitatively define the river plume boundary. The velocity fields used to drive numerical drifters are taken from Texas-Louisiana continental shelf ROMS model hourly output. The algorithm of the Lagrangian trajectory model is from TRACMASS, which has been wrapped in Python, now called TracPy. For the setup, the initial distance between drifters is set to 1000m, located uniformly across all the domain. The simulation was run hourly, starting every day in June and July for 30 days, between 1994 and 2017. The Mississippi river plume is typically filled with baroclinic instabilities during summer. Due to these eddies, drifters inside the river plume have complex, smaller-scale dispersive motion whereas drifters outside the river plume move more uniformly and with larger length scales. We utilize the summer results to separately calculate the mean squared separation distance of the drifters that remain always inside a particular isohaline, and those always outside of the particular isohaline. We propose the isohaline that maximizes the difference between patterns of these two divided regions as a quantitatively defined river plume boundary.

Mercury Concentrations and Fluxes in Sediment Cores from the Southern Gulf of Mexico

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Mercury is an element of global concern, characterized by its capacity to spread widely, persistence in the environment, high potential to bioaccumulate and biomagnify through the trophic web and significantly impair human health. Due to the enforcement of the Minamata Convention in 2017, the assessment of mercury concentrations and their impact on human health and the environment is

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extremely relevant. In this study, we present preliminary results of an ongoing assessment on the spatial and temporal variability of mercury concentrations in the Southern Gulf of Mexico, by using ^{210}Pb-dated sediment cores, collected during the 2015 and 2016 C-IMAGE sampling expeditions, and within the Términos Lagoon between 2016 and 2017. Mercury concentrations were analyzed by cold vapor atomic absorption spectrometry, and mercury enrichment was evaluated through a normalized enrichment factor (EF) by using Al as a reference element (analyzed by X-ray fluorescence spectrometry). Mercury concentrations in open sea cores were comparable (11.2 - 69.2 ng g^{-1}) and intermediate between those observed in the cores collected close to the eastern (6.0 - 34.4 ng g^{-1}) and the western (34.9 - 137.7 ng g^{-1}) inlets of Términos Lagoon. The EF in most open sea cores indicated minimal contamination (EF <2); however, in the coastal and lagoon cores, the EF evidenced steady increasing mercury enrichment, most likely associated to hydrodynamic and sedimentary processes (e.g. sea level rise, soil erosion from the catchment) than direct discharges.

Influence of the Deepwater Horizon Oil Spill on Primary Productivity in the Northern Gulf of Mexico

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Primary production by phytoplankton, which forms the base of marine food chains, occurs in the euphotic zone of the ocean. Eight years after the Deepwater Horizon (DwH) oil spill, how primary productivity responded to the spill is still to be addressed. Here, we use the normalized Fluorescence Line Height (nFLH) from the Moderate Resolution Imaging Spectroradiometer (MODIS) as an indicator of chlorophyll a concentration (Chl a) to investigate the potential effects of the DwH accident on primary productivity and the timeline of recovery. First, the spatiotemporal variations of nFLH are analyzed from 2001 to 2017. Then, a stepwise multiple regression model is conducted to examine the correlations between nFLH and various environmental factors such as river discharge (Q), total nitrogen load (TN), total phosphorus load (TP), photosynthetically available radiation (PAR), sea surface temperature (SST), and wind speed (WS). Results show that TN, SST, WS, and Q are the primary factors that regulate nFLH in the DwH area. By comparing the time series of MODIS nFLH with the estimated nFLH from the regression model, it is found that a reduction of nFLH after the DwH oil spill for a relatively long period (from 2011 to 2014)—but nFLH recovered to the pre-spill level in 2015. Although this study may not be conclusive due to lack of long-term field observations, it provides information for assessing the potential impacts of the DwH oil spill on local primary productivity, which may be serve as a reference for impact assessments of other spills.

Seasonal Three-Dimensional Connectivity Pattern of the Deep-Water Coral *Callogorgia delta* in the Northern Gulf of Mexico

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Deepwater corals (deeper than 50 m) are crucially important to marine ecosystems as they create habitats for numerous other species. The dispersion of coral larvae controls the exchange of gene

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information across coral communities and contributes to the probability of speciation and genetic diversity. It is therefore necessary to investigate the connectivity and dispersion pattern among coral populations and factors controlling coral larvae transport for the preservation and restoration of deep-water corals. In this work, a regional model system at 1km horizontal resolution and with 50 vertical layers is employed to study both the horizontal and vertical connectivity patterns of *Callogorgia delta*, which commonly occurs in the northern Gulf of Mexico. More than 20000 Lagrangian tracers are released from 6 sampling sites in different months (i.e., February, May, August and November). The combined analysis of our model simulations and genetic data focuses on the depth-differentiation hypothesis. Specifically, the genetic analysis revealed a pattern of isolation by depth; we test the role that physical dispersion plays in such pattern. Results also suggest that connectivity between sites is not only controlled by the bathymetry of the continental shelf, but varies also seasonally, affected by seasonally varying submesoscale circulations. In the end, the role of diapycnal dispersion is also discussed.

Short-Term and Seasonal Forecast of Harmful Algal Blooms on the Eastern Gulf of Mexico Coast

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Both short-term and seasonal forecast tools are developed to help federal, state, and local end users monitor and manage harmful algal blooms on the west coast of Florida. The short-term forecast products are based on (1) the West Florida Coastal Ocean Model (WFCOM) that downscales from the deep ocean, across the continental shelf and into the estuaries and covers the coastal ocean of the eastern GOM from the Florida Bay, Charlotte Harbor, Tampa Bay, the Florida Big Bend to the Panhandle regions, and (2) the Tampa Bay Coastal Ocean Model (TBCOM) that has a higher resolution for the region that covers the Tampa Bay, Sarasota Bay and the inter-coastal water ways and all of the inlets connecting these with the adjacent GOM. Observed *Karenia brevis* cell count data are uploaded daily into the WFCOM to generate 3.5 day forecasts of the bloom trajectories on the shelf and in the estuaries. The tracking tool displays modeled bloom trajectories at the surface and near-bottom with five categories of cell concentrations (that each approximately represent an order of magnitude). The seasonal forecast is based on a hypothesis that interactions by the Gulf of Mexico Loop Current with the shelf slope under certain conditions can reset the West Florida Shelf (WFS) nutrient structure in ways that may obviate bloom development. The Self-Organizing Map (SOM), an unsupervised neural network technique, is used to identify such Loop Current patterns and their cumulative duration of occurrences from more than two decades of satellite altimetry data. This serves as an indicator of offshore forcing of anomalous upwelling. Given its consistency in hindcasting the occurrence of (or lack of) severe WFS coastal blooms in 20 of 25 years for which joint altimetry and cell count data exist, the offshore forcing index may serve as a seasonal predictor for major *K. brevis* blooms on the WFS.

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Gulf of Mexico Hypoxic Zone 'Omics Data Elucidate Active, Non-Canonical Methanotrophs That Have the Potential to Impact Hydrocarbon Fate in the Coastal Zone

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Microbially mediated hydrocarbon oxidation is of particular interest in the northern Gulf of Mexico (nGOM) basin due to the chronic natural and anthropogenic inputs of hydrocarbons. Methane, a potent greenhouse gas and the primary component of natural gas, was the most abundant hydrocarbon released during the Deepwater Horizon spill. Additionally, supersaturated concentrations of methane are produced by microbes in anoxic sediments and advected to the upper water column. Given the high methane concentrations in the nGOM hypoxic zone, the second largest human-caused coastal dead zone in the world, 16S rRNA gene, metagenome and metatranscriptome sequencing (Illumina) was carried out on five samples collected from the 2013 hypoxic zone. Analysis of the 16s rRNA gene amplicon data revealed very low abundances of canonical methanotrophs. Yet, particulate methane monooxygenase (*pmoA*) was one of the most highly expressed transcripts observed in the unassembled metatranscriptomic data, similar to observations made in the Deepwater Horizon oil spill deep-sea plume. Metagenome-assembled genomes (MAGs) were obtained and annotated, revealing six MAGs with at least one *pmoA*gene copy. These bins are classified as *Planctomycetaceae* (bins 22, 32, 56), *Verrucomicrobiales* (bins 11, 34), and one unclassified Bacteria (bin 50), putatively identified as PAUC34f/SAUL or *Latescibacteria*/WS3. Currently, these microorganisms are not recognized as marine methanotrophs, which suggests that previously unrecognized methanotrophs may be acting as a biofilter by mitigating methane flux to the atmosphere. This new information will be used to inform ongoing efforts of the Gulf of Mexico Research Initiative (GoMRI) Consortium for Simulation of Oil-Microbial Interactions in the Ocean (CSOMIO), particularly as it relates to microbial oil and gas disposition in a dynamic coastal zone that experiences annual hypoxia and is impacted by anthropogenic inputs of hydrocarbons.

Shelf Bottom Dissolved Oxygen Conditions and Their Impacts on Adjacent Estuarine Systems in a Region of Fresh Water Influence, Mississippi Bight

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The generation and/or amplification of shelf hypoxia due to the respiration of hydrocarbons remains difficult to assess, in part due to limited historical baseline data in many regions. Observations of multi-year (2010-2016) summer time satellite-derived sea surface salinity (SSS), in conjunction with in-situ data from a collection of sampling programs on the shelf and in Mobile Bay are used to investigate the dissolved oxygen (DO) conditions in the region of freshwater influence (ROFI) east of the Mississippi River Delta during the summer of 2016. Time series of SSS data indicate that the shelf region is impacted by a seasonal eastward expansion of freshwater that can drive strong stratification. The ROFI

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is expected to be influenced by local freshwater sources which, while individually small, make a notable contribution in aggregate to the region but are significantly lower in nutrients than Mississippi River discharge. The subsequent DO conditions under this freshwater cap were spatially and temporally variable and persisted throughout the peak summer season at several sites on the shelf. Furthermore, coastal Ekman circulation (i.e. upwelling and downwelling) was observed to be an important process by which these shelf conditions impacted the DO concentrations in Mobile Bay, an adjacent estuarine system. Hydrographic data revealed that upwelling events are linked to the advection of low DO bottom waters into the Bay. Understanding the shelf conditions as well as this offshore delivery of DO highlight the importance subsurface transport pathways that need to be considered when assessing potential impacts of oil spills.

Mississippi River Influence on the Chemistry and Biology of the Northern Gulf of Mexico

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The Mississippi River and its watershed represent one of the world's largest rivers. As with any major river, its influence on the adjacent continental shelf is evident in its geographic interface with the coastal ocean (especially coastal currents and sedimentary characteristics), the physical, chemical and biological parameters of the continental shelf, and ecosystem productivity and food webs. Mississippi River-influenced features are more evident west of the bird foot delta than to the east, and in decreasing prominence from its major distributary, the Atchafalaya River. The salinity signature can reach far to the west into south Texas nearshore waters and as far to the east as the west Florida shelf, out the Florida Straits and onto the southeast U.S. coast. More normally, the effect is from Galveston TX to Mobile Bay AL. Biological responses are more restrained, e.g., long-term chlorophyll biomass data demonstrate a diminishing concentration from the bird foot delta to 96° W and from the delta to 93° W. With distance from the Mississippi River, however, additional rivers begin to mix and influence the east-west signature of the river discharge, especially to the east. The combined flows of the Mississippi and Atchafalaya rivers account for 96% of the annual freshwater discharge and 98.5% of the total nitrogen load for the area between Galveston Bay (Texas) and the delta. The watershed and human-influence upon it and human modifications to the Mississippi River itself have altered constituent flux to the adjacent continental shelf, with resulting ecosystem responses. These alterations will continue and will be aggravated by complications of a warming climate. Knowing the historical and predicted changes of this linked watershed-coastal ocean ecosystem should enhance understanding of this interface between the land and the open Gulf of Mexico to which increasing oil and gas production will shift.

Exchange Properties of the Louisiana Bight

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The Louisiana Bight is an ecologically (and economically) important region of the northern Gulf of Mexico shelf. Relatively shallow and enclosed by land on two sides, its exchange with the rest of the Gulf of Mexico is a function of the complex interplay between mesoscale flow features in the deeper Gulf and local forces, especially the Mississippi River outflow and winds. Its connectivity with

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surrounding waters is critical to understanding its vulnerability to future oil spills and releases of other pollutants. Here we report on the exchange properties of this area in spring 2017 as observed in the large drifter deployments of SPLASH (the Submesoscale Processes and Lagrangian Analysis on the Shelf field campaign). Ancillary measurements and a concurrently run regional ocean model are used to identify the mechanisms that control whether the flow is primarily recirculating within the Bight or freely exchanging waters with the rest of the shelf and/or the deeper Gulf. The resulting insights can inform future response strategies to protect the resources in this region.

The Effects of Tidal and Inertial Motions on Sediment Resuspension

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This study discusses the effect of tidal and inertial motions on the resuspension of sediments on the continental shelf in the Mississippi Bight in depths shallower than 60 meters. Hydrocarbon molecules from natural seeps and man-made oil spills can adsorb to both suspended sediment in the water column and to already deposited sediment on the continental shelf. High frequency motions then resuspend these oiled sediments back into the water column, where they can be dispersed by currents. Our objective is to discover what processes cause the sediment resuspension. We will present the analysis of existing data from the SEED project and recent ADCP and CTD data collected in 22 meters of water offshore of Dauphin Island. Our primary goal is to document the characteristics and energy of the tidal and inertial motions, as recorded in our data sets. Moreover, we will also estimate shear stresses from wave and current data and correlate these with ADCP-derived acoustic backscatter data and CTD measurements.

Constraining the Factors that Regulate Methane Oxidation in the Northern Gulf of Mexico Hypoxic Zone

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Hypoxic conditions in the northern Gulf of Mexico (nGOM) bottom waters generate an extreme and dynamic habitat characterized by unique patterns of microbial biogeochemical cycling. Significant research effort has attempted to understand the implications of nitrogen on the nGOM system. However, very little data has been published on the importance of carbon cycling in this area, especially with regards to methane oxidation. We sought to understand the relevance of methane as a substrate for microbial carbon cycling and explored the relevant geochemical parameters that regulate methane cycling. We combined *in-situ* geochemical analyses with tracer rate measurements to constrain microbial methane oxidation and characterize the microbial community mediating methane dynamics. We hypothesized that specific factors beyond oxygen concentration may control methane oxidation in the nGOM hypoxic zone, and addressed this question by making instantaneous additions of methane, ammonium, and trace metals to rate incubations. We observed methane oxidation in surface and bottom waters of multiple recurrent hypoxic sites and show that these waters serve as methane sinks, with methane oxidation rates exceeding 100 nanomoles liter^{-1} day^{-1}. Rate incubations with chemical additions revealed that nutrient and trace metals play multiple roles in methane oxidation, suggesting an unexplored relationship between carbon and nitrogen cycling. Additionally, the metabolism of other carbon species, such as methanol, could be important in hypoxia-impacted

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environments. Coupled with molecular genomic information, these data offer significant advances for the microbial ecology and cycling of nitrogen and carbon of the northern Gulf of Mexico shelf ecosystem undergoing chronic stress due to high nitrogen loading and low oxygen conditions.

Drogued and Undrogued Drifter Observations Help Improve Our Understanding of Oil Slick Transport across the Shelf in the Northern Gulf of Mexico

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The Deepwater Horizon event posed a visible challenge to ocean prediction models and evidenced the need for observational programs that would provide adequate datasets, not only for fundamental quantification of ocean transport processes, but also for direct model evaluation and enhanced model development. Since then, GOMRI has enabled the deployment of over 2000 drifters to study the pathways and dispersion processes that can drive oil, and other surface tracers of interest, from the deep ocean up to the coasts of the GOM. This presentation will focus on the largest of these deployments, consisting of dense targeted releases of over 1000 near-surface drifters (0.60 m draft) in the area of the DWH spill in winter 2016. The numerous winter storms of that year left about half of the drifters undrogued (0.05 m draft), serendipitously creating a unique dataset of concurrent measurements very close to the surface (where oil slicks are). We will compare trajectories and statistics of the two drifter types, with special attention to the multiple pathways across the shelves of FL, AL, LA, and TX, and to the processes affecting the landing of surface material. The drifting characteristics of both types of drifters have been thoroughly studied in the laboratory and in the field. The motion of undrogued drifters in particular have been shown to be driven, like thick oil slicks, by wave-induced Stokes drift, much more so than drogued drifters, which could explain the striking similarity in landing locations of both the DWH oil and the undrogued drifters.

Simulating Pathway Changes under a Barrier Island Removal Simulation

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The Mississippi-Alabama barrier islands restrict water exchange between the Mississippi Sound and the Mississippi Bight. The limited surface and subsurface pathways preserve the coastal lagoon that is the Mississippi Sound, and these pathways play a critical role in how oil might arrive at the northern Gulf of Mexico coast in the event of future spills. However, the barrier chain is translating westwards, and extensive documentation shows a net subaerial land loss to each island that can be linked to storm impacts, wave action, anthropogenic activities, and relative sea level rise. Consequently, modeling how transport pathways change under extreme geologic shifts can help focus restoration efforts. The Consortium for Coastal River Dominated Ecosystems (CONCORDE) Synthesis Model is being used to simulate the removal of Petit Bois Island and the western half of Dauphin Island. Three forcing scenarios are being run to compare how circulation changes between simulations with the island complex intact and with it removed. Modeled drifters will be released in Mobile Bay, Petit Bois Pass, the Pass aux Herons, and the central Mississippi Bight for each simulation, and drifter paths will be compared between the scenarios. Changes in hydrological parameters are also examined. The extreme simulations aim to ascertain the importance of the Petit Bois Dauphin Island complex in moderating

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flow to and from the Mississippi Sound and to establish how pathways might evolve if the island were to disappear.

Variability of Submesoscale Frontal Eddies on the Texas-Louisiana Shelf

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Frontal eddies play a role in ocean circulation patterns on the shelf and consequently spilled oil transport. In this study, the decadal simulation of submesoscale frontal eddies over the Texas-Louisiana (TXLA) shelf is evaluated based on non-assimilative ocean modeling. The variability of frontal eddies is analyzed using the 23-year hindcast outputs after the model was validated against densely sampled CTD casts. At the seasonal scale, the monthly mean rms (root-mean-squared) of eddy kinetic energy (EKE) and salinity gradients is positively correlated with streamflow and negatively correlated with seasonal wind stress. It is thought that wind stress, the strongest in winter and weakest in summer, contributes to the suppression of baroclinic instability during non-summer seasons. Whereas, streamflow, usually the highest in spring, creates sharp density fronts, a necessary condition for the development of baroclinic instability and resultant eddies, which may result in strong EKE on the shelf in summer. At the inter-annual scale, there is an increase in the trend of streamflow between 1994 and 2016, which is in line with the trend in salinity gradients and EKE. The rms EKE increases by 8 percent for the 23-year period; while, the volume of freshwater increases by three percent. Whereas, wind stress decreases slightly (0.13 percent for the period). Although the result is in line with the seasonal variability, the two mechanisms are different. The known links between streamflow and climate indicators (e.g. ENSO, AMO) imply a potential link between frontal eddies and climate variability.

Wind-Driven Mixing of the Mobile Bay Plume in the Northern Gulf of Mexico Shelf

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The complex coastal hydrodynamics of the northern Gulf of Mexico (GoM) shelf are poorly understood and inadequately modeled because of the challenges posed by substantial fresh water input onto a saline GoM shelf. The GoM has a vigorous mesoscale eddy field that can influence the shelf. Intermixed influences of river discharge, including strong horizontal and vertical salinity gradients, with tides, atmospheric forcing, bathymetry and mesoscale processes create multi-scale modeling requirements. The CONsortium for oil spill exposure pathways in COastal River-Dominated Ecosystems (CONCORDE) conducted a field campaign offshore of the Mobile Bay inlet from March 30 through April 20, 2016 to assess the mixing processes of the freshwater plume. The rivers flowing into Mobile Bay have an annual average discharge of 1730 $m^3 s^{-1}$, maximum in the spring with a plume thickness between 0-3 m on the shelf. Turbulence parameters such as turbulent kinetic energy (TKE), TKE production and dissipation were estimated using six bottom moorings instrumented with acoustic Doppler current profilers located offshore of Mobile Bay inlet, using the structure function and variance methods. Ocean-color remote sensing and drifters released at the inlet at different times provided background

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information on the changing plume locations. During the deployment period, winds were highly variable: a cold front with strong southward winds (>10 m s^{-1} on April 2-3), highly variable winds after the cold front (<10 m s^{-1} on April 4-9), a strong burst of northwestward winds (>10 m s^{-1} on April 10-11), and relatively steady westward winds (~10 m s^{-1} on April 15-20). Two main TKE patterns occurred, with the strongest dissipation values (10^{-4} m^2 s^{-3}) found during northward and westward winds. Dissipation estimates ranged from 10^{-7} to 10^{-4} m^2 s^{-3}. The higher dissipation rate would lead to a vertical salt flux of ~20 g m^{-2} s^{-1} and completely mix a Mobile Bay plume of 3 m thickness in about an hour.

Modeling Pre-Settlement Condition of Oyster Larvae Sourced from Non-Indigenous Mississippi Reefs

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Oyster landings from Mississippi reefs have declined to only 10% of historic commercial yields from only a decade ago. In response to this dramatic decline in oyster productivity, the Mississippi-based RESTORE Act Center of Excellence (MBRACE) prioritized efforts for the restoration of legacy reefs in coastal MS waters, and in part to explore the efficacy of oyster larvae recruitment from indigenous, non-harvestable MS reefs and from non-indigenous oyster reefs in neighboring Alabama and Louisiana waters. To this end, a COAWST-based (Coupled Ocean Atmosphere Wave Sediment Transport Modeling System) regional ocean model was used to simulate the hydrographic and circulation properties in the Mississippi Sound and Bight. Drifter releases were included as part of the numerical experiments that were performed in order to capture along-track environmental conditions throughout the duration of oyster larvae transport. A Habitat suitability index (HSI) model was then used to analyze the combined effect of temperature and salinity to quantify along-track condition of oyster larvae from spawning to settlement. Model results indicate that oyster larvae supplies to Mississippi reef areas are positively influenced by contributions from indigenous, non-harvestable MS reefs as well as from Louisiana and Alabama sources.

Connectivity of the Gulf of Mexico to the Mississippi Sound

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A study of the connectivity of the Gulf of Mexico to the Mississippi Sound is being developed to give a probability of an offshore oil spill affecting the Mississippi. In this first iteration a seasonal index is developed based on surface current climatologies from CODAR HFR stations. The Mississippi Bight is divided into 9 regions and the connectivity of each region to the Mississippi Sound is estimated using virtual drifters released in each region. Preliminary results and plans for extending this to intra-seasonal variability, and the entire water column using the operational Gulf of Mexico models and the CONCORDE Synthesis Model are discussed.

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Laboratory Facility for Oil-Particle Interaction in Deep Langmuir Retention Zones

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In strong wind-wave conditions, full depth circulation associated with Langmuir supercells (LSCs) has been shown to entrain sediment throughout the water column in offshore regions deeper (10-30m) than the surf zone. In the presence of an oil slick, this entrainment of sediment particles could coincide with the trapping of oil droplets into subsurface Stommel retention zones associated with the downwelling component of Langmuir circulation, facilitating an interaction between the two species and producing oil-particle aggregates (OPAs) that can settle out of the water column. This constitutes an alternative pathway for the fate of spilled oil that has only recently been identified.

A facility is being developed to observe the dynamics of suspended material within deep Stommel retention zones of the type observed in Langmuir supercells. This 1m × 0.2m × 0.5m volume is mechanically forced by conveyor belts imposing upward or downward shear stress at the side wall boundaries. One side wall is movable, permitting the creation of vortex pairs of varying aspect ratio. When the shear is in the same direction, the downwelling or upwelling regions of a counterrotating vortex pair are created through convergence or divergence near the top and bottom boundaries. This mimics the essential 2D aspects of deep Langmuir circulation. Using particle image velocimetry (PIV), image segmentation, and particle tracking, we will be able to characterize the spatiotemporal distribution of particles and oil in relation to external parameters such as the orientation of the vortices, the strength of forcing, and turbulent characteristics of the background flow. High magnification imaging will be used to observe aggregation efficiency in relation to the types and initial size distribution of oil droplets and particles. These observations will form an important validation for modeling parameterizations of suspended oil and sediment in Langmuir supercells.

Suspended Sediment Transport in Mississippi Bight During Two Cold Front Events in Spring 2016

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The high frequency (3-7 days) of cold front events in the northern Gulf of Mexico from mid-October to April causes coastal erosion and the transport of suspended sediments to the continental shelf. The interactions between suspended sediments and oil play a key role in the dispersion and degradation of spilled oil, so it is important to understand the sediment transport pathways in this region during cold fronts. Two 600 kHz Acoustic Doppler Current Profilers (ADCPs) were deployed along the CONsortium for oil spill exposure pathways in Coastal River-Dominated Ecosystems (CONCORDE) middle corridor in Mississippi Bight during the Spring 2016 field campaign. A suspended sediment concentration time series was generated from the ADCP's echo intensity using in situ suspended sediment concentration, temperature, salinity and particle size data. A cold front affected the study area on 1 April and resulted in westerly alongshore and southerly across shore surface currents, and opposite flows in the bottom

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water at both sites. Suspended sediment concentration of 20 mg/L was present within the water column. A second cold front event on 10 April caused variable alongshore and across shore currents at the surface and at depth, and higher suspended sediment concentration compared to the first cold front. CONCORDE synthesis model's temperature and salinity, in situ wind and currents suggest the southwesterly Ekman transport of fresh water from Mobile Bay during the post cold front phase was the main cause of the increased suspended sediment concentration observed within the water column.

Biogeography of Phytoplankton Community Structure in the Northern Gulf of Mexico

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The northern Gulf of Mexico is a dynamic and diverse ecosystem that is driven by a complex circulation pattern. The Mississippi River plume is rich in nutrients delivers 90% of total nitrogen load and 87% of total Phosphorus load to the basin. The plume flows mostly close to the coast over the continental shelf although during years of high discharge, it has been observed flowing south past the Florida Keys and even as far as off the coast of Georgia. The loop current on the other hand is depauperate in nutrients and can shed large mesoscale eddies with attendant smaller scale features. In addition, we have also shown that natural oil seeps in this region can enhance phytoplankton abundance. These large and small scale forcing result in high spatial and temporal variability in the phytoplankton community structure. We used spectrofluorometric, and HPLC measurements of phytoplankton pigment composition as well flowcytometry to investigate the spatial and temporal variability in phytoplankton community structure in the northern Gulf of Mexico. We will present the results of this study and discuss the biogeography of phytoplankton in the northern Gulf of Mexico.

Microplankton Trophic Dynamics in the Northern Gulf of Mexico

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Improved understanding of microplankton (20-200 µm) community dynamics and trophic connectivity between primary producers and heterotrophic protists is central to plankton ecological studies. Despite their ecological significance in structuring aquatic ecosystems, there is limited knowledge on phytoplankton-microzooplankton trophic interactions in the northern Gulf of Mexico (nGOM). Here we describe the microplankton community structure using a morphological based functional group approach to classify microplankton images obtained from imaging in-flow technology (FlowCAM), rates of primary production (photosynthesis-irradiance curves, P-E), and phytoplankton apparent growth and mortality (dilution experiments) within inner shelf surface waters of the nGOM during two seasons (fall, spring). Phytoplankton biomass was dominated by diatoms in both seasons, with average chlorophyll *a* (3.8 mg m^{-3}) more than twice that of fall (1.7 mg m^{-3}). Needle-like (*Pseudo-nitzschia* sp.) and cells with setae (*Chaetoceros* sp.) were the predominant diatoms, whereas small (< 20 µm) *Heterocapsa* sp. and larger Gymnodinoid-type dinoflagellates comprised more than 80% of the flagellate community in both seasons. Aloricate choreotrichid ciliates (*Strombidium* sp., *Strombilidium* sp.) were the primary microzooplankton grazers, although >50% of the ciliates were the autotrophic *Myrionecta rubrum*. Phytoplankton production (0.01 - 0.38 gC $m^{-3}d^{-1}$) and growth (0.01 - 2.53 d^{-1}) were

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greater in spring, despite fall having highest maximum photosynthetic rate (P^B_{max} = 34.07 g C g Chl^{-1} h^{-1}). Microzooplankton consumed on average ~ 40% and > 65% of the phytoplankton biomass and daily primary production, respectively. The ratio of microzooplankton grazing to phytoplankton growth (m:μ) averaged 1.14, suggesting that microzooplankton grazing is an important top-down control on phytoplankton production in this system.

The Impact of Diurnal Winds on Exchange through Barrier Island Passes into the Mississippi Sound

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In coastal regions, including the northern Gulf of Mexico, there is often a significant diurnal variability in the winds due to differential heating of the land and ocean (land/sea breeze). While this process can even be observed at the global scale, atmospheric forcing for ocean circulation models often under-represents this variability due to temporal and spatial resolution issues. As part of the CONsortium for oil exposure pathways in COastal River-Dominated Ecosystems (CONCORDE) project, an hourly 0.01 degree gridded CONCORDE Meteorological Analysis (CMA), partially based on Real-Time Mesoscale Analysis winds (RTMA), was created which well resolves the land/sea breeze. The CMA is used to force a 400 m horizontal resolution Regional Ocean Modeling System ocean circulation model.

A major focus of the CONCORDE project is to examine transport through the barrier island passes between the Mississippi Sound and Mississippi Bight. Here, we ran simulations using the base CMA forcing, as well as forcing with the diurnal variability of the winds filtered out. Preliminary results show that at every pass examined there were significant differences in the short-term transport variability through the pass. This has implications for predictive modeling of material transport into Mississippi Sound and connectivity between shelf and estuarine waters.

Impact of Wave Forcing on Sediment Resuspension and Transport in the Mississippi Sound and Bight

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Sediment resuspension events and subsequent transport alters the sediment distribution and also influences light attenuation in the shallow waters of Mississippi Sound and shelf of Mississippi Bight. The sediment resuspension increases light attenuation, which thereby impacts ecosystem dynamics on the shelf by limiting primary production and other planktonic interactions. The sediment transport is also important for the filter feeders such as oysters in the estuarine waters of Mississippi Sound because high sediment loads can cause reduced fitness leading to decreasing populations. Therefore, it is important to understand the impact of forcing agents causing sediment resuspension in the water column. This study aims to investigate the impact of wave forcing on sediment transport, with a primary focus on sediment distribution and sediment re-suspension events. The Coupled Ocean Atmosphere Wave Sediment Transport (COAWST) model is used to study the dynamics in the Mississippi Bight as part of the Consortium for oil spill exposure pathways in Coastal River Dominated Ecosystems (CONCORDE). Field data collected during multiple cruises during CONCORDE indicate

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sediment resuspension events on Western Mississippi Bight during the spring season. Model simulations are initialized for those time periods to analyze wave-driven sediment transport and also to explore the balance between wave- and current-driven sediment transport in Mississippi Sound and Bight.

Temporal and Spatial Abundance and Distribution of Epibenthic Macroinvertebrates in *Spartina alterniflora* Salt Marshes

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There have been relatively few studies focusing on the distribution of epifaunal communities in Spartina salt marshes of coastal Gulf of Mexico. Previous studies have determined the importance of infauna in the salt marsh food web, but there have been fewer studies focused on evaluating the importance of epifaunal invertebrates. The focus of this research is to determine the spatial distribution, areal abundance, and diversity of marsh macrobenthic epifauna and examine how these patterns vary seasonally. Seasonal patterns were evaluated during four seasons (October-November, January-February, April-May, July-August) over a single year (2017-2018). Litter bags were staked onto the marsh surface at placed at each of 5 distances from the marsh edge (1, 10, 20, 30 and 50 m) at three longterm marsh monitoring sites in Cocodrie, LA, and were recovered after one month. Organisms were then Identified to the lowest taxonomic level possible. Preliminary results suggest spatial patterns in abundances with marsh position but that these patterns might vary with season. For example, epibenthic invertebrate abundance significantly increased with distance from the marsh edge (r^2=0.84) during fall 2017 but did not show a pattern in winter (r^2=0.28). Interestingly, the total abundance of all invertebrates observed at the three marshes remained similar across seasons, but the organisms dominating the community shifted significantly with most individual taxonomic groups displaying significant changes in abundance (i.e. > 80%) between seasons. This presentation will discuss the relationships between these epifaunal communities and their distance from the marsh edge along with the possible influences seasonality and hydroperiod may exert on the communities.

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

Comparison of Exopolymeric Substances (EPS), Transparent Exopolymeric Particles (TEP) and Microgels in Mesocosms and Batch Experiments with Macondo Oil Water Accommodated Fraction

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Exopolymeric substances (EPS), produced by microorganisms, are ubiquitous and abundant in the ocean, greatly influencing the fate of oil. Transparent Exopolymeric Particles (TEP) are operationally

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defined as particles (>0.4 µm) that can be stained with Alcian blue, while EPS, are measured chemically as the sum of the main components: polysaccharides and proteins. Marine microgels in the filter-passing fraction are reversibly formed from EPS, and can be determined by DLS and flow cytometry. Mesocosm experiments provided the opportunity to compare the 3 different methods for EPS determination in a water-accommodated fraction of oil and a control with only seawater. Our results revealed a significant correlation (p< 0.001, r=0.70, n=28) between concentrations of TEP and EPS extracted from SPM. EPS electrostatically held on particle surfaces extractable by EDTA accounted for < 1% of TEP. However, the acid hydrolysis of whole sinking marine snow increased the measurable total carbohydrates by 3-37 fold, in contrast to that determined with EDTA extractable EPS from the same particles. In addition, in a bottle experiment incubated with natural bacterial consortia from the Gulf of Mexico, the whole particle analysis increased the EPS to TEP percentage to 31%, in contrast to 6%, as determined with the EDTA extractable fraction. This indicates that most EPS is not electrostatically bound to particles, and thus, not extractable by EDTA, yet could be released via acid hydrolysis. Furthermore, Alcian blue might stain acidic polysaccharides in particles more indiscriminately. Microgel concentration measured by flow cytometry is very close to total EPS concentration. While there is some discrepancy between NMR-quantified EPS and the total EPS determined by spectrophotometric methods, this likely results from the fact that spectrophotometric methods have limitations in identifying refractory carbohydrates. This study is the first time that TEP, EPS and microgels were compared in the same samples.

Assessment of the Change of Crude Oil Microdroplets Exposed to Different Bacteria Species and Consortia under Different Flow Velocities

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Among different oil cleanup methods, bioremediation using oil-degrading bacteria is an effective and environmentally friendly green cleanup method. Hydrocarbon consuming bacteria inhabiting marine environments consume oil hydrocarbons as a preferential source of carbon. A profound understanding of the oil consumption ability of different bacteria species in addition to bacteria consortia, as well as the effect of hydrodynamics on oil degradation is critical. In our previous work, we reported the effectiveness of the size of the oil microdroplets on the bacteria-oil interaction and biodegradation. Further experiments, under the non-flow condition, were conducted to explore the interaction of different bacteria species on stationary oil microdroplets versus microbial interaction of oil-degrading consortia. Additional experiments were conducted reiterating previous experiments under flow conditions. To achieve the results, we developed a micro-bioassay containing an enclosed chamber with bottom substrate printed with stationary oil microdroplets and a digital holographic interferometer (DHI). The experiments of consortia and various flow shears on biodegradation will be reported in the details.

Variation of Sedimentary Biogenic Silica Deposition in the Southern Gulf of Mexico before and after the IXTOC-I Oil Spill (1979-80)

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The IXTOC-I oil spill (1979-1980) was one of the largest oil spills in history and it is likely that Marine Oil Snow Sedimentation and Flocculent Accumulation (MOSSFA) occurred as a direct result. MOSSFA occurred during and following the Deepwater Horizon Oil Spill (DWH, 2010). In an effort to constrain the occurrence of MOSSFA after IXTOC-I and compare DWH - associated MOSSFA, sedimentary biogenic silica (BSi) content was measured in cores collected from the Bay of Campeche in the southern Gulf of Mexico (IXTOC-I) and from the northern Gulf of Mexico (DWH) that were dated using short-lived radioisotope (i.e. $^{210}Pb_{xs}$) age models. BSi provides an independent record of the surface derived portion of MOSSFA inputs. Sedimentary BSi can also be used as a proxy of surface water primary productivity (e.g. diatom blooms). Sedimentary BSi was elevated in sedimentary intervals influenced by the DWH spill. However, only one core (of three from oil spilled area utilized in this study), collected 81 km from the IXTOC-I wellhead, had elevated levels of BSi content in the sedimentary interval associated with IXTOC-I. Also, the down-core profiles of BSi from the other cores collected in the southern Gulf of Mexico are consistent with the history of dam construction (1949 to 1989) on the Grijalva and Papaloapan river systems. These two river systems are the dominant freshwater and nutrient sources for primary production in the Bay of Campeche region and therefore the dominant control on diatom productivity and sedimentary BSi distribution. Consequently, distribution of annual fresh water outflow and nutrient supply has transitioned from seasonal and highly variable (before 1940's) to stable (after 1980's). Overall, sedimentary BSi provides an independent record of surface derived MOSSFA inputs and serves as a proxy for other anthropogenic influences related to surface primary productivity variability.

Identifying MOSSFA Sensitive Areas to Guide Future Oil Spill Response Strategies

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The MOSSFA (Marine Oiled Snow Sedimentation and Flocculation) event was the reason that substantial amounts of the spilled oil reached the seafloor during the Deepwater Horizon Spill. The presence with superfluous amounts or organic matter from the marine snow reduced the biodegradation of the oil and increased the ecological impact on the benthic community. A MOSSFA event thus extends the impact of the oil spill and should be prevented/avoided to happen in future oil spills were possible. Based on insight in the factors that can initiate a MOSSFA event, MOSSFA sensitive areas were identified in off-shore oil production areas. Field research already confirmed that MOSSFA actually occurred before in such a sensitive area. Global maps of oil/gas platforms and particular organic carbon concentrations, both derived from satellite measurements, along with several other environmental variables, are used to infer the probability of MOSSFA events should an oil spill occur in the ocean. Insight in MOSSFA sensitive areas can help to develop the best response strategy in case of future spills in these areas during phytoplankton blooms.

A Nanoscale Understanding of MOSSFA Events at the Oil-Water Interface

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Microbial communities are considered one of the primary biologically-derived contributors to the MOSSFA phenomena, since the bacterial biofilm they produce have adhesive properties. Marine bacteria form biofilm both on solid surfaces and at the oil-water interfaces to protect themselves from the environment and facilitate hydrocarbon degradation. A model hydrocarbon degrading marine bacterium *Alcanivorax borkumensis* is used in this work to simulate biofilm formation at the crude oil-water interfaces and oil-water interfaces sterically stabilized by natural and modified clay particles. The colonization of oil droplets and the growth of biofilm are clearly visualized through high-resolution cryo-scanning electron microscopy. The results indicate ubiquitous colonization of the organism on the surface and between clay platelets of the stabilized droplet with extensive biofilm formation bridging these particle stabilized droplets.[1] Excess clay particles embedded in biofilm sediment carry out small amounts of entrapped oil. We also simulate biofilm growth on the quiescent oil slick and characterize the dispersion properties of the *A. borkumensis* biofilm, which could disperse up to 40% of oil in the baffled flask test. Cryogenic scanning electron microscopy is one of the key techniques for furthering our understanding of the emulsion formation and its stability. Cryo-SEM gives insight onto bacterial attachment onto oil droplets, as well as provides clear evidence of the exopolymer presence on the surface of bacterial cells and the oil droplets. We additionally show that as biofilm matures and rigidifies at the oil-water interface, oil becomes less susceptible for effective and effortless dispersion by the chemical dispersant. **References**: Omarova, M, Swientoniewski, L, Mkam Tsengam, I, Panchal, A, Yu, T, Blake, D, Lvov, Y, Zhang, D, John, V. "Engineered Clays as Sustainable Oil Dispersants in the Presence of Model Hydrocarbon Degrading Bacteria: The Role of Bacterial Sequestration and Biofilm Formation". *ACS Sustainable Chem. Eng*., Article ASAP DOI: 10.1021/acssuschemeng.8b02744

Effect of High Hydrostatic Pressure on the Activity of Hydrocarbon-Degrading Bacteria

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Bioorthogonal noncanonical amino acid tagging (BONCAT) is a method that uses a methionine analog to fluorescently tag cells undergoing active protein synthesis. Here we use BONCAT to follow the activity of microbes under atmospheric and high pressure. Actively growing cells that take up these methionine analogs, homopropargylglycine (HPG), are subsequently fluorescently tagged using click chemistry, and assessed microscopically or by flow cytometry (FCM). Three strains isolated from the Gulf of Mexico following the Deepwater Horizon oil spill were included in this study: *Halomonas titanicae* (Bead 10BA), *Shewanella indicae* (Bead 36) and *Alcanivorax xenomutans* (Bead 18). Cells were cultivated in ONR7a Media with hexadecane up to mid-log phase at their optimal temperature. After HPG labeling, they would be transferred into sterile serum vials, with addition of HEPEs buffer and Nitrate as alternate electron acceptor under anaerobic conditions. Cells would be fixed as a function of time. After click chemistry, HPG-labeled cells can be assessed by flow cytometry. We also stained cells with DNA stain, Hoechst 33342 to count the total number of cells. Flow cytometry results were analyzed in FlowJo. Cells are determined as active, if their fluorescence intensity are higher than that of negative control (without HPG labeling). The number of active cells is divided by the total, and this is the fraction of active cells. The results indicated different responses to hydrostatic pressure among the strains. High hydrostatic pressure (25 MPa) inhibited the activity of *Shewanella indicae* Bead 36. However, after decompression, cells immediately recovered and displayed activity levels equivalent to cells that did not experience pressurization. These results indicate that pressures equivalent to 2.5 km depth can inhibit the activity of *Shewanella indicae* Bead 36, but these effects are reversible. In contrast, *Alcanivorax xenomutans* Bead 18 increased its BONCAT labeling at high pressure over an incubation period of 3 hours. We suppose this difference between different taxa is related to their

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original living environment. *Alcanivorax xenomutans* Bead 18 was isolated from 1509m, who is more adapted to high pressure environment, than *Shewanella indicae* Bead 36 isolated from 46m.

Effect of Flocculation on Suspended Cohesive Sediment in Langmuir Turbulence

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The concentration of suspended sediment in the coastal water is important to quantifying the natural ability of coastal water in sequestrating spilled oil through formation and settling of oil-mineral aggregates. One of the major uncertainties in suspended sediment modeling is the sediment size, which is modulated by flocculation processes including both aggregation and breakup. In this study, a suspended sediment concentration model including the effect of flocculation is embedded in a turbulence-resolving hydrodynamic model to investigate the effect of flocculation on the spatial distribution of suspended sediments in shallow-water wave-driven Langmuir turbulence. Flocculation processes modify the vertical profiles of mean floc concentration, and also increase the horizontal heterogeneity of floc mass.

Adhesion of *Marinobacter hydrocarbonoclasticus* to Surfactant-Decorated Dodecane Droplets

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During the Deepwater Horizon spill, hydrocarbon-degrading bacteria interacted with surfactant-laden oil-water interfaces created when dispersants were applied at the wellhead. Here, we characterize the effects of chemical surfactants on the ability of bacteria to move near and adhere to oil/water interfaces, as expected during the initial stages of biodegradation, using microfluidics and optical microscopy. Surfactant-decorated dodecane droplets of diameter 20 - 60 mm are generated using a co-flow microfluidic device, introduced into aqueous suspensions of *Marinobacter hydrocarbonoclasticus* bacteria (at varying salt concentrations), and imaged in 3-D over time. Using image analysis algorithms, we determine the number of bacteria adhering at oil/water interfaces over time in the presence of dioctyl sodium succinate (DOSS), a component of the Corexit dispersant used in oil-spill recovery. The adsorption of bacteria at the oil/water interface follows Langmuir first-order kinetics for all droplet sizes, with the greatest areal number density of bacteria adhered to the smallest droplets. We vary the surfactant type [DOSS, dicyclohexyl sodium sulfosuccinate (DCHSS), dibutyl sodium sulfosuccinate (DBSS), cetyltrimethylammonium bromide (CTAB), and Tween 20] and concentration and examine the effects on long-time adhesion of bacteria. For a fixed droplet size the areal density of bacteria at the interface decreases with increasing surfactant concentration, due to a reduction in oil-water interfacial tension that increases the free energy of adhesion of the bacterium. Information on how dispersants modify the ability of bacteria to accumulate at interfaces is expected to inform the development of models that predict the rate of degradation in an oil-spill scenario.

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

Analysis of the Macondo Blowout Using BP Gulf Science Data

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After the Deepwater Horizon oil platform explosion, an estimated 172.2 million gallons of gas-saturated oil was discharged uncontrollably into the Gulf of Mexico, causing the largest deep-sea blowout in history. In an attempt to entrap petroleum hydrocarbons compounds in the deep sea, chemical dispersants were deployed 1522 m deep at the gushing riser pipe of the Macondo prospect's wellhead. Here we use the comprehensive BP Gulf Science Data to quantify petroleum dynamics throughout the 87-day long blowout and present an analysis of the water column chemistry extensively sampled witching a 10-km radius of the blowout throughout the application period of sub-sea dispersant injection volume.

Wind LiDAR Measurements and Numerical Modeling to Investigate Transport of Aerosolized Oil Droplets in the Marine Atmospheric Boundary Layer

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This research aims to develop improved eddy-diffusivity models for accurate predictions of production of aerosolized oil droplets at the sea-air interface, their transport within the marine atmospheric boundary layer (ABL) and deposition over a coastal region. The scientific goals of the proposed project are to understand the role of ABL structure and wave motion on aerosol generation at the sea-air interface, and investigate effects of transitioning from the ocean to the coast on aerosol concentration and distribution. This project encompasses an experimental task consisting on LiDAR measurements of wind speed and aerosol distribution within the marine ABL, and a modeling task with large-eddy simulations (LES). The UTD mobile LiDAR stations has been deployed at the Galveston Island State Park, Texas, to perform simultaneous and co-located measurements of wind speed and aerosol distribution. Indeed, the backscatter on the laser beam emitted by the LiDAR in the atmosphere allows quantifying the line-of-sight wind speed through the Doppler shift on the laser wavelength, while the concentration of aerosol within each measurement volume is probed by the LiDAR backscattered coefficient. This dataset is analyzed with different statistical and spectral techniques in order to relate wind turbulence with the spatio-temporal distribution of aerosol. Modeling of aerosol transport is performed using an LES wind turbulence model, which utilizes a boundary-fitted grid system for capturing sea-surface wave effect and a hybrid pseudo-spectral/finite-difference scheme for simulating oil aerosol transport in marine ABL. The LES model will employ the upward flux of aerosol near the sea surface obtained from the LiDAR experiments as the source condition and simulate the subsequent vertical and downwind turbulent transport of aerosol concentration. The high-fidelity LES data will be used for both understanding the flow physics and developing the eddy-diffusivity models. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

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Improving Oil Fate and Transport Models with GCxGC Acquired Data: Enhanced Component Property Characterization over Time

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Proper oil characterization is important in modeling unintended releases of oil because the ultimate fate is dependent upon the oil's physical properties. Although oils are a mixture of thousands of compounds, most oil spill models, such as OSCAR, group the oil characteristics into "pseudo-components" that behave similarly in the environment over time. These "pseudo-component" subgroups can be implemented using a pre-set list of oil types or the mass fraction can be manually adjusted if sufficient data is known regarding the oil makeup. Additionally, the oil fate in the environment is also highly dependent on the oil weathering that occurs. Comprehensive two-dimensional gas chromatography (GCxGC) can be used to generate relevant model input data on oil composition. The enhanced mixture component separation capability allows for a more accurate hydrocarbon mass fraction measurement, which in turn provides more robust fate and transport estimations. Furthermore, the orthogonal chromatographic separation inherently provides chemical properties of the mixture that are vital to understanding the environmental fate in a release. These measurements can further help monitor weathering characteristics to ensure the model is constrained to the current scenario and free of significant deviations. In this work, an oil release scenario will be presented that illustrates how the output of GCxGC data can be incorporated into the oil spill model by either comparing lab data with the model predicted weather composition or using the lab data to update the oil composition of the model for continued spill modeling.

Oil Droplet Transport in Rivers: An Eulerian RANS Approach Combined with a Lagrangian Particle Dispersion Model

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We studied oil droplets transport in rivers by coupling computational fluid dynamics (CFD) with Lagrangian particle dispersion model. The Reynolds-averaged Navier Stokes (RANS) equations were solved within commercial CFD code Fluent to simulate river hydrodynamics. The volume of fluid (VOF) method was adopted to track the water-air interface of rivers, and standard wall function with a sand grain roughness height was used to describe riverbed roughness. In addition, RNG k-epsilon turbulence model was used in conjunction with RANS equations to model river turbulence. The obtained river hydrodynamics were compared with analytical solutions from open-channel hydraulic theory. The RANS results were then exported to the Lagrangian particle tracking code NEMO3D to predict the transport of inertial particles representing oil droplets, and the particle kinematics were simulated by solving the equation of motion accounting for major local forces. The randomness of droplets was modeled through random walk method, which fluctuation velocity components are evaluated through eddy viscosity and Gaussian noise. The effect of the gradient of eddy viscosity on particle transport was also incorporated into the model. The ensemble properties (i.e. centroid, variance and spreading coefficients) of plumes with different droplet sizes were studied to understand the transport. This

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investigation is significant since it has implications for oil spill response (releasing of dispersant), oil biodegradation and oil-particle aggregation (OPA) in rivers.

Oil Droplet Transport under a Deep-Water Plunging Breaker

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We describe a new approach of modeling oil droplets transport under breaking waves by coupling computational fluid dynamics (CFD) with Lagrangian particle tracking. The Reynolds-averaged Navier Stokes (RANS) equations were solved within the CFD code FLUENT to simulate the movement of breaking waves in the absence of wind stress and large-scale turbulence. A deep-water plunging breaker was reproduced using the approach proposed by Rapp and Melville (1990). The hydrodynamics of the generated breaker (i.e. intrusion depth, velocity, and vorticity) were compared with published experimental results. The RANS results were then exported to the Lagrangian particle tracking code NEMO3D to predict the transport of buoyant particles representing oil droplets, and the droplets kinematics were simulated by solving the equation of motion accounting for major local forces under breaking waves. The randomness of droplets was modeled through random walk method, which fluctuation velocity components are evaluated through eddy viscosity and Gaussian noise. The transport of plumes of different droplet sizes was simulated, and the intrusion depth of oil droplets was studied. The successful coupling of FLUENT and NEMO3D models for oil droplets transport under breaking waves unlocks many potential investigations such as prediction of oil concentration through the transport of oil droplets and subsurface droplets breakup and diffusion under breaking waves.

Predicting Oil Transport in Oceanic Flows: Are Artificial Neural Networks Up to the Task?

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Predicting the transport of spilled oil in a turbulent ocean is no easy task. Artificial neural networks (ANN), machine learning paradigms that use interconnected “neurons” to mimic how the human brain learns through experience, have demonstrated remarkable success at handling many challenging prediction problems. One then wonders: can ANNs be used for oil spill forecasting in an ocean laden with instabilities? The potential and limitations of a simple single-layer ANN for predicting particle trajectories are investigated using a hierarchy of simulated oceanic flow regimes ranging from uniform steady flow to more realistic cases involving turbulent coherent structures. Particles are released and tracked every half hour for seven days and ANNs are trained to predict a particle’s velocity at time t_m using its previous velocity at time t_{m-1}. ANN outputs are compared to persistence predictions, defined as the best prediction that can be made if only a single instantaneous velocity measurement is known. The ANNs easily learn most of the cases within minutes, providing significant improvement over persistence predictions and exceptional computational efficiency. Since ANNs learn by themselves during training, they also require much less software development than traditional theory-driven prediction methods. Particle trajectories computed from ANN-predicted velocities show impressive agreement with the real trajectories. Not surprisingly, predicting the complex interactions of turbulent coherent structures is notably more challenging. Nevertheless, the results are sufficiently promising to

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test these techniques on observational drifter data collected by the Consortium for Advanced Research on Transport of Hydrocarbon in the Environment. Our results suggest that ANNs may provide a new data-driven approach to modeling and forecasting the transport of spilled oil in the ocean.

Progress and Challenges for Process-Based Modeling of Oil Spills from Meters to Basins

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A diversity of ocean modeling techniques exist for studying processes one at a time that relate to oil spills: chemistry, waves, turbulence, submesoscales, mesoscales, and circulation. However, synthesizing all of these different processes into operational, data-assimilating, process-based models remains a challenge. I will address some of the processes that have been highlighted by observations collected by the CARTHE consortium and discuss the state of affairs for their inclusion into coastal modeling systems presently used in the Gulf of Mexico and elsewhere. Observed processes where parameterizations exist, but have not yet been implemented or vetted in operational models will be highlighted.

Coupling of Surface and Deep-Ocean Currents in the Gulf of Mexico

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Coupling of surface and deep-ocean currents exist under some circumstances such as mesoscale eddies encountering large bathymetric features. Detecting and understanding the coupling of surface and deep-ocean currents in the Gulf of Mexico (GoM) potentially provides a new way to infer deep-ocean information from satellite measurements and is useful for understanding the dispersal of materials, including gas and oil, in the deep layer of the GoM. Here, we use a combination of satellite and archived deep-ocean current measurements to examine the coupling of surface and deep-ocean currents in the GoM. Significant correlations between surface and deep-ocean (below 1200 m depth) currents within the period of 25-100 days are found at a number of the examined mooring sites, mostly in the northeastern GoM. The mooring sites with significant correlations are primarily in the area with a high ratio of Eddy Kinetic Energy (EKE) to Kinetic Energy (KE) variance, confirming mesoscale eddies play an essential role in the coupling of surface and deep-ocean currents. A few moorings showing significant surface and deep-ocean coupling are then examined individually. For those moorings, short-term events lasting tens of days in the deep ocean are revealed and closely related to the surface mesoscale features. Other factors that are potentially important for the surface and deep-ocean coupling in the GoM, such as bathymetry, mesoscale eddies trajectory, are also examined and discussed in this study.

Fate of Oil Spill Droplets in Texas A&M Oil Spill Calculator Exposed to Random Displacement and Turbulent Diffusion Solution for Wind

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The need for oil spill models that include variable environmental conditions is significant, especially with the increase of marine operations in the Arctic and the potential risk for an Arctic oil spill. The Texas A&M Oil spill Calculator (TAMOC) includes Lagrangian particle tracking for bubble or droplet time-average trajectory prediction through the water column that includes a combination of fate processes, including dissolution, heat transfer, and advection equations. We have adapted TAMOC to include a random displacement model and empirical relationships for vertical turbulent diffusivity as a function of density gradient and free-surface wind stress to better predict oil droplet fate in shallow water. The surface wind has proved to be a driving force in turbulent diffusivity, specifically in the mixed layer depth. We apply the adjusted TAMOC model to scenarios of oil blowouts and subsea spills in Alaska with varying winds and compare results with the General NOAA Operational Modeling Environment (GNOME) tool, which uses wind and random walk diffusion movers. The results of these Arctic oil spill scenarios using the random displacement TAMOC model, validated with other models, will improve the predicted oil path and have potential to improve oil spill response and forecast.

Invisible Oil Beyond the Deepwater Horizon Satellite Footprint

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Major oil spills are catastrophic events that immensely impact environment and society, yet determining their spatial extent is a highly complex task. During the Deepwater Horizon (DWH) blowout ~149,000 km^2 of the Gulf of Mexico were covered by oil slicks, according to which, areas were closed for fishing. Yet, satellite-footprint does not necessarily account for the entire oil-spill extent. Here, we use *in-situ* observations and oil-spill transport modeling to examine the full extent of the DWH spill, along with the effectiveness of the fishery closures in covering that extent. We show that the spill extended beyond the satellite footprint, and demonstrate that some ranges of oil concentrations are toxic and invisible to satellites. With a global increase in marine petroleum-related activities, a careful assessment of oil-spills' full extent is necessary to maximize environmental health and public safety.

Settling Dynamics of Oil-Mineral-Microbial Interaction: Calibrating a 0D Floc Model Using Jar Experiments

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Since the Deepwater Horizon (DwH) oil spill, considerable research resources have been spent in order to understand different aspects governing the fate of oil. However, it remains lacking in the role that microbes play in determining the eventual fate of oil and their impacts on the ecosystems. Therefore, it is a necessity to improve a more complete understanding of the interplay between physical and biochemical processes that act on petroleum in the ocean and their impact on the shelf ecosystem. As part of the Consortium for Simulation of Oil-Microbial Interactions in the Ocean (CSOMIO), lab

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experimental studies were conducted to help to calibrate the present floc modeling. Firstly, a series of flocculation experiments with sea-water, crude oil and cohesive sediment mixtures (clay and EPS) have been designed using a stir-jar system. To obtain high-quality floc population data (including floc size, settling velocity etc.), a novel high-resolution floc video instrument LabSFLOC-2 (Laboratory Spectral Flocculation Characteristics) has been adopted for the first time to study oil-mineral aggregates (OMAs) and marine oil snow (MOS). Meanwhile, a Nortek Vectrino II is adopted to measure flow turbulence statistics. Several experiments were conducted, which varied in terms of sediment concentration, sediment type (bentonite vs. kaolinite), and presence/absence of artificial Extracellular Polymeric Substances (EPS). The results reveal that the oil-mineral aggregates can easily form in any mixture of oil, cohesive sediment in seawater. However, in EPS or bentonite clay cases, the oil flocs tend to be much larger and with higher densities than those in kaolin clay cases, which could result in the significant variability of the flocs settling velocities. In terms of the MOS which commonly exists in natural water system after the DwH, it can form in the cases with bio-culture, oil, clay and filtered seawater in lab incubation. Toward the objective of developing coupled oil - sediment models within CSOMIO, a 0D floc model based on population balance equations is calibrated using data from these lab tests.

Physical Processes Influencing the Sedimentation and Lateral Transport of MOSSFA in the NE Gulf of Mexico

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Accurate predictions of the transport and fate of oil spilled in the marine environment are essential for response and mitigation efforts. The sedimentation of oil-associated marine snow (MOS) has been shown to be an important pathway by which Deepwater Horizon (DWH) oil was removed from the water column. Here, our goals are to (1) estimate the vertical and lateral transport of marine snow and MOS particles based on the physical environment in the NE GoM during and after the DWH oil spill, (2) characterize the impacts of interannual environmental variability on particle fluxes during summer 2010, 2011, and 2013, and (3) discuss major circulation features influencing the transport of marine oil snow particles. The physical environment was simulated using the Connectivity Modeling System (Paris *et al*. 2013). Field measurements of marine snow provided initial conditions for the simulations. High Mississippi River (MR) discharge during 2010 and 2013 resulted in strong eastward flowing fronts along the shelf break to the east of the MR and an anticyclonic eddy at the shelf break, which retained and aggregated particles and likely enhanced MOS sedimentation. 2011 did not show strong distinguishing circulation features. Back track simulations indicated that vertical advection was constrained by the depth of the mixed layer (<100 m). Particles originated from both the east and the west sides of the study area and advection occurred primarily along bathymetric lines or via smaller mesoscale eddies present in the NEGoM. Forward simulations suggested that particles with high sinking rates (200 m d^{-1} reached the seafloor within < 5 to 15 days, depending on the depth. Particles with high sinking rates also settled within 0 - 30 km of their origin, while particles with low sinking rates (30 m d^{-1}) were dispersed up to 110 km away from their origin. Suspended particles (no sedimentation rate) may be transported over 300 km or sediment when its water mass came into contact with the seafloor along the shelf slope. Future modeling efforts should combine a coagulation model that uses realistic particle characteristics and sinking rates to simulate MOS formation and flux, coupled with a mesoscale-resolving hydrographic model to better understand the vertical and lateral dispersion rates of sinking MOS.

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Modelling the Atmospheric Transport and Concentration of Evaporated Oil from Marine Oil Spills

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We have developed an atmospheric transport model that uses fluxes from evaporated surface oil in the OSCAR model to account for the fraction of volatile compounds that spread further into the atmosphere. Through inhalation, light hydrocarbon compounds may have a toxic effect on animals, including humans, that are located near evaporating oil. An atmospheric numerical transport model can be used to better understand the risk imposed by the evaporated oil fraction. The developed model uses a Lagrangian approach by solving stochastic differential equations corresponding to the advection diffusion equation in the limit of a large amount of particles. We present the structure of the atmospheric transport model: the micrometeorology parametrization of diffusivity for different atmospheric stability regimes and the numerical transport and integration schemes. The model is applied to the case of the DWH spill, focusing on the area right above the release site, where most surface oil evaporation took place. We show how subsea dispersant application can reduce the concentration of volatile compound in the atmospheric surface layer of surfacing oil near the release site. The presented model can be extended to include evaporation from shoreline oil, natural gas blowouts, and microdroplets produced by wind and breaking waves over surface slicks. We conclude that the inclusion of atmospheric transport of evaporated oil compounds allows the complete tracking of the fate and toxic effect of oil spills at sea. Oil spills of national significance, such as the Deepwater Horizon, can result in large quantities of petroleum oil dissolved in the ocean, stranded on shorelines, or adhered to seabed sediments, with potentially toxic effects to animal life in each of these compartments.

Seasonal Effects on Changes in the Physical Properties of Bitumen Blends and Conventional Crude Naturally Weathered on Water

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When an oil spill happens, the physical properties of the oil spilled (e.g. density and viscosity) and the season in which it occurs can limit the effectiveness of response options. With time, natural weathering may alter the oil's physical properties again changing possible response options. In these experiments, dilbit, dilsynbit, synbit and conventional crude were naturally weathered on seawater in the spring and summer (Atlantic Canada) to examine changes in their physical properties. The empirical data from each experiment was fitted to a hyperbolic function, with their coefficients of determination, R^2, ranging from 0.86 to 0.99. T-Tests showed that season had a significant ($p < 0.05$) effect on the changes in the physical properties of the oils weathered on seawater. Values for physical properties of the oils, that could limit response option choices, were taken from the literature and integrated with the data from this study. The findings suggest that, regardless of seasonal effect, dispersant might be an impractical choice to treat surface spills of weathered bitumen blends in aquatic areas. Oil containment and recovery, in situ burning, and natural attenuation were all applicable options, but only when feasible to do so and with limitations.

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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.

Observed versus Simulated Oil Film Thickness during Deepwater Horizon Oil Spill

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Surface oil thickness has been retrieved from NOAA satellite imagery for several dates during the 2010 DeepWater Horizon oil spill. We compare this to the oil film thickness distribution from the open source oil drift model OpenOil, which is implemented within the OpenDrift framework. Various algorithms for prognostic calculation of oil thickness is tested, including a statistical thickness probability distribution, as alternative to uniform thickness. Metocean forcing data are taken from the University of Miami 1/50 degree GoM-HYCOM ocean model for the Gulf of Mexico (GoM) with realistic river input and ECMWF global forecasts of wind and wave parameters with 0.125 degree resolution.

Application and Parameterization of a Sediment Flocculation Model for OMA Formation for a Gulf of Mexico Continental Shelf Site

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Observations from the Deepwater Horizon event in the Gulf of Mexico showed that oil droplets, marine snow, and mineral grains combined and formed aggregates having a wide range of transport characteristics, which modified dispersal and fate of the oil. Oil Mineral Aggregates (OMAs) refer to particles composed primarily of a mixture of oil and mineral sediment. Though the Gulf of Mexico has some very turbid waters, to date, few numerical models have accounted for the range of aggregation processes likely to form OMAs there. However, interactions between oil and mineral aggregates can be represented using recently developed sediment flocculation models. Towards this, CSOMIO (Consortium for Simulation of Oil Microbial Interactions in the Ocean) is using an existing flocculation model to examine the impact of oil droplets on the vertical transport of sediment, and settling of oil to the Gulf of Mexico seafloor. This presents results from a one-dimensional (vertical) water column model that includes sediment transport and oceanographic turbulence, implemented in the Coupled-Ocean-Atmospheric-Wave-Sediment Transport (COAWST) modeling system. The model represents a

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50-m deep water column, uses hydrodynamic forcing from the Gulf of Mexico, and incorporates OMA formation using a population dynamics flocculation model, FLOCMOD. The characteristics of the OMAs, and the aggregation parameterizations for FLOCMOD will be derived from laboratory experiments. The formation of OMAs changes the vertical transport of both the oil and the mineral grains; modifying sediment settling, while increasing deposition of oil to the bed. Parameterizations gained from the one-dimensional (vertical) model will be directly transferrable to a three-dimensional coupled oil - sediment - microbial model being developed by CSOMIO.

Modeling of Surface Oil Transport in the Modified COAWST

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In this study, we examined the surface oil transport in a modified coupled-ocean-atmosphere-wave-sediment transport modeling system (COAWST). The modifications to the COAWST have been considered owing to the presence of surface oil, which include (1) the changes to the surface roughness; (2) the changes to horizontal temperature gradients; (3) the changes to the ocean surface waves. The transports of surface oil are presumably different due to the presence of oil slick from those without considering the feedback of surface oil itself. The surface oil transports were compared with and without the multifold effects of oil slick. Some preliminary results were provided.

Development of the SOSim Model for Inferential Tracking of Sunken Oil

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Modern cracking techniques have increased the production of heavy oils that can be pumped, resulting in more spills of oil that sinks to the bottom. Moreover, sunken oil is difficult to locate due to limited visibility, limited availability of wide-range remote sensing technology, lack of information on bottom currents, and the effects of changes in temperature (oil density), salinity, weathering, and wave-induced sediment entrainment. To support response efforts in such cases, the SOSim (Subsurface Oil Simulator) model is currently being expanded as an alternative to existing oil spill models that track oil based on pre-existing flow-field data on water currents. The model uses predictive Bayesian statistical techniques and limited available field reconnaissance data on oil concentrations in space to assess the location of the entire oil mass and project its movement in time. A Lagrangian modeling technique is coupled with Bayesian inference to assess unconditional probabilities, equivalent to relative concentrations of oil on the bottom of a water body. In addition, a novel approach to incorporate bathymetry into the model as prior information has also been introduced, by which the bathymetric profile is treated as an inverse prior distribution and sampled to create a prior likelihood function. With this prior information, initial results using limited data from the DBL-152 oil spill are consistent with observations from NOAA scientists in that the oil moved in a southerly direction, perpendicular to bathymetric contour lines. Further demonstration using data from the Athos I oil spill is planned. In addition to accepting prior bathymetric information, the new model is being expanded to allow modeling of continuous oil releases. Given its parallel development for modeling submerged (water column) oil, and ability to integrate information from other models, it is expected that SOSim will become an effective compliment to existing emergency response tools.

*Student Presenter

Inferential Forecasting of Submerged Oil Trajectory: A Predictive Bayesian Multi-Modal Gaussian Model

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Submerged (water column) oil is difficult to locate and track because of present limitations in detection and modeling. In particular, during the Deepwater Horizon oil spill (DWH), autonomous underwater vehicles remained distant from the submerged oil, due to the fact that oil droplets would foul the dissolved oxygen sensor. Also, submerged oil tracking models were limited in their accuracy due to limitations in data on temperature and salinity below the main thermocline. To enhance forecasts, we develop a predictive Bayesian multimodal Lagrangian Gaussian model, SOSim, to track and forecast the distribution of submerged oil mass in time and space for an emergency response. This model accepts near real-time field reconnaissance data, including observed qualitative or quantitative concentrations in time and 3-D space, and parallel output from SINTEF's Oil Spill Contingency and Response (OSCAR) model, as inputs. A prior likelihood function is calculated by sampling from the OSCAR spatiotemporal concentration data. A posterior likelihood function is then calculated from the prior using the observed field data as it becomes available during emergency response. We then use the predictive Bayesian method to infer relative probability distributions for oil mass locations in time. These unconditional multi-modal Gaussian relative probabilities, and depths of the submerged isopycnal oil layers, are plotted on a map as outputs. SOSim is thus a 3-D model, and has the capability to model both continuous and instantaneous oil releases. The model has been initially validated versus synthetic multi-modal, multiple sampling campaign data. Further development will focus on model demonstrations for the DWH and IXTOC I oil spill cases. Thus, the final model will rigorously integrate available field data, together with the results of OSCAR and other current models, to support emergency response efforts in the search for submerged oil.

Mixing of Sediment Particles and Oil Droplets by Langmuir Supercells

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Interaction between the wind-driven shear and the wave-induced Stokes drift in the upper ocean leads to Langmuir cells consisting of wind-aligned counter-rotating vortices. In inner-shelf regions undergoing strong wind and wave forcing during storms, Langmuir cells can reach the bottom of the water column while increasing in intensity and coherency. These full-depth Langmuir cells have been denoted as Langmuir supercells or LSCs because they provide a dominant mechanism for sediment resuspension and subsequent lateral transport by the current. LSCs have been discovered through their resuspension of sediments along the upwelling limbs of the cells. In the presence of oil broken up into droplets at the surface of the sea, LSCs also serve to entrain the droplets along the downwelling limbs of the cells. Lagrangian particle tracking simulations will be presented demonstrating the sediment resuspension and oil droplet entrainment dynamics induced by LSCs. The methodology consists of a steady-state Reynolds averaged solution of the flow resolving the LSCs with particle tracking based on a discrete phase model using a random walk method to account for the turbulence. Accumulation zones of sediment particles and oil droplets induced by LSCs and dispersion across these zones will be investigated to assess the potential mixing between oil and sediments which can lead to the formation of oil-particle aggregates.

*Student Presenter

Mixing Characteristics in Four Aspirator Bottles with and without Vortex

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Four types of aspirator bottles (20 mL, 2 L, 4 L and 20 L) were adopted to evaluate the effects of rotation speed and bottle size on mixing characteristics in water accommodated fraction (WAF). The water in these bottles was mixed using magnetic stirrer bar with a diameter ranging from 1.5 cm to 6.3 cm. The research comparisons were conducted between no visual vortex and 22.5% height-of-water vortex. Particle image velocimetry (PIV) technique was used to measure the water velocity. Two-dimensional velocity fields were obtained along with nine points near the vortex. Turbulence properties were obtained from the near vortex zones. The water speed varied from ~1 cm/s (20 mL bottle without vortex) to >0.2 m/s (20 L bottle with 22.5% vortex). The maximum vorticity was obtained to be around ~0.01 s^{-1}. The spatial energy spectra obtained at these experiment conditions showed a region with "−5/3" slope, which confirmed the existence of the inertial subrange and the presence of turbulent flow in these bottles. The average energy dissipation rate varied from around ~0.01 watt/kg (wall region in 20 mL bottle without vortex) to >0.2 watt/kg (20 L bottle with 22.5% vortex). The energy dissipation rate in near vortex region of 20 L bottle with 22.5% vortex test was over 0.25 watt/kg. By comparing the effects of different magnetic stirrer bar and volume of aspirator bottles with and without vortex, mixing energy characteristics can be well understood when preparing water accommodate fraction experiments, together with similar tests in other research fields.

The Development of Offshore Environmental Sensitivity Indices Relevant to Deep Water Oil Well Blowouts in the Gulf of Mexico

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Oil spills and oil well blow outs can result in losses of biological and economic marine resources for variable periods of time. Much research has been done to identify sensitive areas of coastal areas and shorelines through methods including the use of Environmental Sensitivity Indices (ESI). USA and Mexico oil production has increasingly moved further off shore and focused on deep water sources in order to maintain production. As oil production drilling continues to move further off shore, pelagic and deep-water marine resources become increasingly susceptible to oil well blowouts. A methodology is proposed to spatially quantify these off shore marine resources and to assess their relative sensitivity in the Gulf of Mexico (GOM) using an ESI and illustrated by using a set of biological and economic data sets. A multi-attribute utility model is used to integrate biological resource sensitivity measures and economic measures of potential loss to define an overall spatial and temporal sensitivity. Four modeled hypothetical deep-water blowouts were analyzed and compared using these ESIs. These four modeled blowouts represent the Deepwater Horizon blowout, a Deepwater Horizon blowout occurring during the fall, a blowout occurring on the west Florida slope, and an oil well blowout occurring in the western GOM. The differences in the impacts on included off shore marine resources due to these four blowouts are discussed.

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Lagrangian Convergence along Fronts during the LASER Experiment

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The fate of the oil in the Northern Gulf of Mexico depends in part on the surface circulation above the continental shelf and slope, which is influenced by submesoscale processes, large salinity gradients due to river outflows, and effects of the wind and waves. In an oil recovery context, the above factors affecting surface oil transport are relevant in how they impact floating particles distributions by concentrating them along fronts, thereby making oil easier to target and remove. Using massive drifter arrays from the LASER experiment, we look at different methods/metrics to identify those fronts in a Lagrangian setting and attempt to monitor the convergence tendencies and properties along these fronts, particularly how submesoscale-based convergence is affected by wind events.

Estimation of the Removal Rate of Dispersed Oil via Scavenging by Phytoplankton Aggregates: An Operational Subroutine for Use in Oil Spill Models

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Incorporation of dispersed oil droplets into fast-sinking marine snow particles is considered to be an important mechanism whereby oil is removed from the water column and ultimately transported to the seafloor. This removal mechanism has not, to date, been integrated into existing operational oil spill models, even though during the Deepwater Horizon spill approximately 15% of the total oil released ended up on the seafloor because of it. Previous field observations, laboratory studies and modeling work have shown that phytoplankton aggregates (one particular type of marine snow) are capable of incorporating oil droplets and transporting them to depth. The work presented here adapts the results from a phytoplankton aggregation model based on coagulation theory to a simplified operational module that can be used in conjunction with oil spill transport and weathering models to estimate potential rates of oil removal via incorporation into aggregates. The primary inputs required for the subroutine are near real-time satellite chlorophyll-*a* data, which is accessed from ERDAPP using a simple Python code, and turbulent eddy diffusivity, which is normally specified or calculated within the transport/weathering model. In cases where oil removal by this mechanism is significant, and may result in large quantities of oil depositing on the seafloor, spill decision makers can tailor response strategies accordingly.

Reynolds-Averaged Simulation of Langmuir Supercells in the Coastal Ocean

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Langmuir turbulence in the upper ocean is driven by winds and waves and is characterized by Langmuir cells (LCs), parallel counter rotating vortices roughly aligned in the wind direction. In the coastal ocean during the passage of storms, the largest LCs can span the full depth of the water column becoming more coherent and persistent than LCs in the upper ocean mixed layer. These full-depth cells have been termed as Langmuir supercells. Traditionally, flows with LCs are computed via either (1) large-eddy simulation (LES) in which a range of the Langmuir turbulence (or cells) is resolved or (2) Reynolds

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averaging in which none of the Langmuir scales are resolved and the effect of the Langmuir turbulence is accounted for through the turbulence model. A new solution strategy based on Reynolds averaging is introduced, relying on the coherency and persistence of Langmuir supercells. Here these cells are treated as a secondary component to the wind and/or pressure gradient-driven primary flow. As such, the Reynolds-averaged governing flow equations and the mesh are designed to resolve both the primary flow and the Langmuir supercells with the turbulence model accounting for the smaller Langmuir scales. The resolved cells and associated statistics will be compared with their counterparts in LES. The new solution strategy will also be used to simulate Langmuir supercells in water column depths ranging between 10 and 20 meters over lateral distances spanning several kilometers. The goal is to understand the effect of water column depth on the intensity, coherency and aspect ratio of the cells (cell height-to-cell width).

Mutual Dependence and Joint Intensification Between Loop Current and Loop Current Frontal Eddies

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An improved understanding of strong ocean features such as the Loop Current system is crucial to improve forecast models and accurately predict oil transport in the Gulf of Mexico. During the Deepwater Horizon oil spill in 2010, an underestimate part of the oil was trapped in Loop Current Frontal Eddies (LCFE); cold-core eddies formed in the vicinity of the Loop Current (LC). These eddies, which are also known to play an important role in the Loop Current Eddy (LCE) shedding, are difficult to predict and their dynamic is still not fully understood. The Loop Current and its eddies were tracked using a sea surface height (SSH) dataset from AVISO for the 2009-2011 period. The results show that, after their formation, LCFE intensify on the periphery of the LC including exponential increases in kinetic energy while SSH decreases. Some cyclones experience an increase of up to ten times their kinetic energy, with a proportional decrease in SSH, and only a few lead to a LCE shedding. The area of the eddies also increases with kinetic energy which suggests that vortex stretching is not the mechanism driving the intensification. When the LCFE intensifies, a concomitant local intensification (increase in kinetic energy) of the LC is observed to occur at the interface with the cyclone. Maps of finite-size Lyapunov exponents (backward in time) show filaments converging to the interface between the LC and the LCFE. The two features seem to create a zone of attraction of particles where mass and energy is being extracted from the background flow and transferred to the LCFE-LC features, allowing them to grow. These results provide new insights into understanding the LC dynamics as the LCFE seem to interact not only during the shedding but in all stages of the LC. It also highlights the importance of assimilating in situ data into models to improve their ability to resolve transports throughout the water column.

Flume Experiments to Model Transport of Sunken Oil

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Oil spilled into water can float, be neutrally buoyant in the water column (submerged), or sink to the bottom (sunken) depending on the: density of water and oil, the extent of weathering, ambient mixing energy, and sediment/marine snow interaction. Currently, there are few trajectory models designed to

address sunken oil and its behavior, fate and transport. Estimating sunken oil transport is especially challenging due to visual constraints and limited field data. This mesoscale research focuses on predicting the movement of sunken No. 6 heavy fuel oil (HFO) with respect to water velocity (0.5, 1, and 2 knots), water temperature (12, 27, and 38 °C) and volume of spilled oil (10, 100, and 200 g). The experiments used two flumes operated by the Coastal Response Research Center (CRRC) at the University of New Hampshire (UNH) to identify conditions when the sunken oil would likely move along the bottom and/or remobilize into the water column. The measured results and calculated values were then used as input parameters to improve a sunken oil transport model developed by CRRC. The No. 6 HFO was mixed with kaolinite clay (28.6% clay/oil by weight) and placed on a fine-sand substrate. Over the 60-minute runs, the morphology and surface area of the oil were recorded using two GoPro cameras placed overhead and alongside the oil. Instantaneous water velocity measurements were taken by an Acoustic Doppler Velocimeter (ADV). Using the velocity measurements, the bed shear stress was calculated and compared with video to estimate the critical shear stress of the oil. In addition, temperature measurements were taken at the start and end of each trial to estimate the oil's viscosity. A temperature vs. viscosity relationship was measured using a rheometer. The model will allow responders to use readily available environmental parameters to rapidly estimate the sunken oil's movement.

Oil Spill Propagation in the Presence of Freshwater Lenses

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Freshwater lenses are believed to act as a barrier to the propagation of oil slicks. River runoff produces freshwater lenses, creating significant horizontal density anomalies and horizontal pressure gradients in the near-surface layer of the ocean; as a result, these lenses can spread and propagate as gravity currents, possibly interacting with wind stress. This work aims to reproduce some of the observable fine-scale features of freshwater lenses using computational fluid dynamics tools. We have been able to reproduce generic features of the lens spreading and interaction with wind using a 3D computational fluid dynamics model developed with ANSYS Fluent software. The freshwater lens spreading as a gravity current produces a so-called gravity current "head". An interesting phenomenon revealed by the model is the development of coherent structures at the frontal edge of the spreading freshwater lens (head), which apparently intensify mixing. These structures resemble a complex pattern of three-dimensional water motions in the leading edge of the gravity current and trailing fluid, previously reported by Özgökmen *et al*. (2004) and Soloviev *et al*. (2015). The model is consistent with measurements conducted during SPLASH in the vicinity of the leaking Taylor Energy Platform as a part of the GoMRI Consortium for Advanced Research on Transport of Hydrocarbons in the Environment. These results have a number of practical applications including the prediction of the propagation of oil spills or other anthropogenic pollutants in coastal waters.

How Critical is the Choice of Droplet Size Probability Distribution Law for Oil Spill Modeling?

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Knowledge of the droplet size distribution (DSD) is one of the most important characteristics of the flow to understand and to model the trajectory and dispersal of oil following uncontrolled deep-sea spills. The 2010 Deepwater Horizon (DWH) blowout released an estimated five million barrels of live oil into the northern Gulf of Mexico (GoM), and eight years later, there is still an ongoing debate on the volume median size (d_{50}) of the oil droplets because no direct measurement is so far available. Therefore, DSD estimates have been the focus of analytical work with the jet-droplet formation model VDROP-J and the modified Weber number and laboratory work under high-pressure and cold-temperature using sapphire cell and jets experiments. While analytical methods predicted a large range of droplet sizes (0.5-8 mm), laboratory experiments found much smaller droplets (<500 μm), matching the few *in-situ* observations acquired during two dives near the Macondo well. Regardless of the estimated median droplet size, there is so far no consensus either on the probability density function (PDF) of the oil DSD. Although the assumed PDF such as log-normal and Rosin-Rammler (RR) are fairly similar in shape, their distributions' edges drastically differ and may impact the vertical distribution of oil. Here, we applied an integrated formulation of the buoyant velocity of droplets to estimate the maximum potential effect of arbitrary PDF selection from published studies. We then use the oil application of the Connectivity Modeling System that tracks individual multi-fraction oil droplets in a 3-D space grid in the far-field. For each, we compute the depth center of mass of key subsets of the DSD (e.g. the quantiles 0.05, 0.5, and 0.95) and show that the surfacing time of the largest droplets may have been underestimated by ~30%. Moreover, the lower tail of the largest d_{50} estimated for untreated live oil (d_{50} > 2 mm) could have been trapped in the deep plume. The choice of initial PDF of DSD for far-field modeling is therefore far from neutral.

Where the Oil Goes and How Much: Converting Lagrangian Trajectory Modeling Output to Eulerian Grid Products

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A common approach to oil modeling involves Lagrangian-based methods to advance oil droplets in horizontal and vertical direction, based on environmental conditions, droplet buoyancy, and several individual-based oil fate algorithms. One of such Lagrangian applications, Connectivity Modeling System (CMS), is used to simulate the Deepwater Horizon 2010 deep-sea blowout in the Gulf of Mexico. The modeled output trajectories indicate where do the oil particles advance, but not necessarily the amount of oil that corresponds to the real-case blowout scenario that is of great concern for the purpose of first-response, mitigation efforts, damage assessment, or toxicity studies. We therefore present here the post-processing algorithm that translates the trajectories output of oil droplet depth and horizontal location, droplet size and density, into oil concentration fields on the Eulerian grid. Additional data needed for accurate oil concentration estimates are the following: assessment of the oil flow rate, modeled oil droplet size distribution at the release time, and the droplet size distribution representative of the blowout conditions. The post-processing is based on oil mass conservation, and uses a variable transformation method for the probability distribution functions.

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

Modeling Gas Seep Bubbles Through the Continental Slope within Hydrate Stability Zone

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When a hydrocarbon bubble is released from the seafloor, the bubble dissolves into seawater as it rises and expands as the pressure decrease through the water column. The bubble tends to become smaller due to the dissolution and tends to become larger due to the expansion. The combination of dissolution and expansion determine the shrinkage rate of a rising bubble in the ocean. Additionally, if a hydrocarbon bubble is released from the deep ocean, a hydrate shell may form on the surface of the bubble. The formation of the hydrate shell on the bubble slows down the dissolution of gas from the bubble to the ambient water. Hence, a bubble released below the Hydrate Stability Level (HSL) could be able to survive longer and rise higher because of the reduced dissolution rate by the hydrate. Submarine gas seeps located in the deep ocean are often observed to rise to the HSL independent of the source depth from acoustic measurements for anomalies of seeps. It remains a challenge to explain the significant flare heights within the Hydrate Stability Zone (HSZ). In this study, we apply the complete bubble model, which includes the hydrate effects on the dissolution, to predict the fate of gas bubbles from seeps on the continental shelf below the HSL. The model handles the change of dissolution rate due to the hydrate formation on the bubble surface and simulates different types of dissolution rates for a clean bubble, a dirty bubble, and a transition bubble due to the hydrate skin formation. We simulate the several sizes of bubbles released at the different water depths and estimate the final rise height of bubbles within the HSZ. The results of this study explain the observed data that the final rise heights of seep bubbles are usually located around the HSL with the acoustic measurements, even though bubbles are released at the different depths on the continental slope. Also, the results show that if the initial bubble is larger than 8 mm in diameter, the bubble would be able to survive from any depth to HSL with considering the transition time-scale due to hydrate formation. The model explains the observed extreme bubble rise height up to HSL only when we consider the transition of dissolution rate by the hydrate in the simulation. Hence, we confirm that the model with a transition time has a capability to make correct predictions of the fate of bubbles within the HSZ.

Mapping Spatial and Temporal Variation of Seafloor Organic Matter D14C and d13C in the Northern Gulf of Mexico following the Deepwater Horizon Event

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Following the Deepwater Horizon (DWH) oil spill of 2010, large amounts of biodegraded oil (petrocarbon) sank to the seafloor, previously traced through radiocarbon and hopane analysis. Our objectives were to 1) determine post-spill isotopic values as the sediments approached baseline 2) determine the relative importance of sea floor seepage to sediment isotopic composition and 3) to track the recovery of DWH-affected sediments through time following the event. Median values for

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sediment $\delta^{13}C$ and $\Delta^{14}C$ for non-seep sites, excluding 2010 samples, were -21.2‰ and -213.8‰, averaging -21.2±0.9‰ and -219.9±65.6‰. We hypothesized that surface sediment radiocarbon signatures would recover over time, shifting back towards more ^{14}C-enriched background values. We employed Inverse Distance Weighting interpolation of surface sediment $\Delta^{14}C$ values over an area of $5x10^9m^2$to calculate the mass of petrocarbon in surface sediments and track its recovery over time. There was a decrease of 47% in the total mass of petrocarbon in the surface sediment within this area, from $1.2x10^{10}$g in 2010 to $6.37x10^9$g in 2014. We estimated a rate of loss of $-2x10^9$g of petrocarbon/year, 2-11% of the degradation rates in the water column. Despite the observed recovery in sediments from 2010-2017, lingering degraded oil residue in the surface sediments was evident seven years following the blowout.

Taylor Energy's Efforts to be the Most Responsible, Responsible Party at MC20

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The MC-20 platform was toppled by an unforeseen underwater sea floor event that occurred as Hurricane Ivan (September 2004) passed approximately 60 miles to the east. With both exceptional maximum wave heights and peak wave periods, Ivan's intensity coupled with preconditioning of the seafloor for failure (slope over-steepening, sediment under-consolidation, and biogenic gas production), resulted in an exceptional combination of factors that caused a regional slope failure. The platform now lies on its side, partially buried in mud, approximately 550 feet down slope of its original location. There continues to be sheen expression on the surface at MC20. The complex nature and duration of this response effort is unprecedented and as Incident Commander for Taylor Energy, I will present information on past, current, and future response activities. These will include the original state and source identification and control operations, including drilling nine intervention wells and installation of containment domes. The goal is to provide a foundation for understanding conditions and information related to MC20 and the ongoing response efforts.

Physics of Bubble Plumes from Natural Seeps

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Natural oceanic seeps are an important methane source on the Earth's surface. Understanding the physics of bubble plumes from natural seeps is relevant to climate dynamics and oceanic biogeochemistry. We present a series of laboratory and field studies on physical characteristics of seep bubble plumes. Using the experimental data, we illustrate how bubble plumes spread out in the water and how the ambient water interacts with the rising bubbles. These characteristics are analyzed to quantify of the evolution of the volume flux of ambient water and the associated fluxes of momentum and buoyancy. We particularly demonstrate that seep bubble plumes are weak in shear entrainment and lack the normal coherent entrainment present in classical multiphase plumes, such as those observed from subsea blowouts. This work also shows the transition behavior from the classical

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multiphase plume to a weak bubble plume in an infinite height of rise, which addresses the mechanism as to how the subsea blowout plume reaches its far field in the ocean.

Visual Quantification of Oil and Gas Bubbles from MC20

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Persistent oil slicks have been observed within Mississippi Canyon lease block 20, near the toppled Taylor Energy well jacket, following Hurricane Ivan's passage through the Gulf of Mexico in 2004. Acoustic surveys have observed prominent plumes of gas and oil rising from near the well jacket to the surface. The objective of this research was to qualitatively evaluate these plumes and to quantify the density and size frequency of bubbles. An oil and gas bubble collecting and imaging device (bubblometer) was constructed, featuring a calibrated visualization chamber (30x30x20 cm), transparent collection tube, and four sample cylinders. The bubblometer was mounted on the lower platform (skid) of the Comanche ROV. In its retracted position, the lower opening of chamber was closed; a hydraulic actuator extended the bubblometer beyond the skid so that the chamber was open at the bottom. Location of the plumes was determined by a NOAA acoustician, allowing the ROV operator to navigate to the site and position the bubblometer within the plumes. Video of bubbles passing through the bubblometer visualization chamber was recorded with an HD video camera calibrated to resolve 4 pixels/mm. Video frames were analyzed with ImageJ software to determine bubble sizes and to count the bubbles in the chamber. Bubbles were typically 5-10 mm or greater and comprised gas, oil, and mixtures of the two.

Forensic Analytical Investigation of the Persistent Sheen Surfacing in Block MC20 GOM during 2017

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A plan was developed in January 2016 and implemented in March and April 2017 by the Sheen Source Location Working Group, chartered by the Unified Command and comprised of representatives from Taylor, BSEE, BOEM, NOAA and CG, to determine the subsurface location(s) that are causing the persistent surface oil sheens in the vicinity of the Taylor Energy Company platform that toppled in 2004. In order to minimize the uncertainty of the analytical results caused from surface oil weathering, discrete recently surfaced sheen samples that were time-stamped and geo-referenced, were collected in Teflon nets. This sampling approach was augmented with simultaneously acquired geo-referenced acoustic and physical observation at the site, thus enabling integration of the chemical analyses with physical and visual field observations. This forensic oil spill operation collected 65 surface oil sheens over nine different days. Fifty-seven of these sheen samples contained petroleum residues, including normal and branched alkanes, two to six ringed PAH compounds and their C1 to C4 alkyl homologs, two families of sulfur-containing PAHs, and the hopane and sterane forensic petroleum biomarker compounds, all analyzed by GC-FID and GCMS analytical techniques. Analytical data was subjected to a four-tiered approach to identify the similarities and differences between 2017 sheen samples. None of the compositions of the 2017 sheens were identical by forensic matching standards, however they were all from oils that were moderately to more severely weathered. In addition, it is clear that on

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some days, a biogenic source was identified that could be linked to some observed differences in estimates of surface sheen amounts. These data indicate that a single input term of oil is not creating the surface sheen and that whatever the processes put forth must include an explanation of the extreme heterogeneity found in the 2017 samples (and those observed by the CG in 2012/2013).

Transport Pathways and Fate of Surface Oil Slicks around the MC20 Site

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Since 2004 and the destruction of an oil platform by Hurricane Ivan, surface oil slicks have been regularly observed around the MC20 location southeast of the Mississippi Delta. We present results from the combined use of remote sensing (satellite, drones), in situ measurements (surface drifters, cruise data), as well as modeling (ocean circulation and oil fate), that have allowed us to improve the characterization of the oil transport and fate around the MC20 site. In particular, we performed multiple-platform observational campaigns in 2017, which involved the use of 3 vessels near the MC20 site, drifters, drone surveillance and high-resolution satellite imagery. The analysis of this unique dataset illustrates the different pathways the oil from the MC20 area can follow, specifically highlighting the influence of the Mississippi River plume and its induced fronts on those pathways. In addition, the repeated satellite images allow characterizing the evolution of the spatial extension of the surface slick over time, which depends on the sea state and the winds, in addition to the river plume. The combined use of remote sensing images, drifter trajectory data, and outputs from oil spill modeling using high resolution hydrodynamic simulations, allows refining the estimated residence time of the oil at the surface, which is necessary for estimating the flux of oil.

Elevated Atmospheric Methane Concentrations at MC20

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A preliminary characterization of methane (CH_4) concentration in the air at 3m over the ocean surface was made at the Mississippi Canyon 20 (MC20) lease block in September 2018. Several inspections of the site have confirmed the release of hydrocarbons in plumes of gas and crude oil that rise from near the toppled well jacket to the surface. Although surface oil slicks in the MC20 site have been frequently monitored, the flux CH_4 to the atmosphere has not previously been measured. CH_4 concentration in the air, in addition to water vapor and acetylene ($C2H_2$), were measured using a Picarro 2200 Cavity Ring Down Spectrometer (CRDS) connected to a Global Navigation Satellite System (GNSS) Trimble Pro Series GPS. CRDS and GNSS reading were logged into an ASCII file using the Tera Term software. Ambient CH_4 concentration in the air consistently fluctuated in between 1.8 to 1.9 ppm. However, reading of CH_4 near where gas and oil plumes were detected in the water column ranged from 2.5 to 9 ppm, with a peak of 12.8 ppm, which was observed where gas bubbles were seen reaching the water surface. The elevated CH_4 concentrations over the ocean surface in the MC20 site were generally focused where bubbles reached the surface. This indicates a rapid rise of CH_4 through the water column. However, during periods of strong current and low wind (5 to 6 knots), elevatedCH_4

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concentrations was detected as far as 786 m NNE of the well jacket. Analysis of the CRDS data provides estimates of the flux of greenhouse gas from the MC20 site.

Characterization and Source Identification of Gas Seepage Observed at Mississippi Canyon Block 20 in the Gulf of Mexico

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An oil sheen and gas bubbles have been observed to be continuously seeping from the seabed in MC20 several kilometers offshore of Louisiana. Gas, oil, sediment, and water samples were collected by scientists and technical staff through a collaborative effort by BSEE, NOAA, and TDI-Brooks International aboard the R/V Brooks McCall in early September 2018. The hydrocarbons were extracted and then analyzed and quantified via gas chromatography and mass spectrometry at B&B Laboratories in College Station, Texas. The concentrations and carbon isotopic ratios of the light hydrocarbon gases were determined to discern if the gas originated from thermogenic seepage or is biogenic and was produced by microbes.

DNA Analysis of Surfactant Associated Bacteria in the Sea Surface Microlayer Collected in Oil Seeps and on a Coral Reef During SAR Satellite Overpasses

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The sea surface microlayer is an important boundary covering the world's oceans, where many biogeochemical processes occur. It is distinct from the water below and highly variable due to constantly changing physical processes. Many organisms influence the composition of the sea surface microlayer from production of surfactants, which accumulate at the surface and create slicks. Oil from natural seeps and accidental releases can also create slicks. Slicks can be visible to the eye and in synthetic aperture radar (SAR) satellite imagery. This study focuses on surfactant-associated bacteria in the near-surface layer and their role in slick formation near a targeted accidental oil seep in the Gulf of Mexico. An innovative technique using polycarbonate membrane filters has been improved from previous experiments to reduce contamination during sample collection and DNA extraction. During the SPLASH experiment in April 2017, over 150 sea surface microlayer and sub-surface water samples at seven locations were collected near a known oil seep in the Gulf of Mexico during coordinated SAR overpasses. Samples have been analyzed after DNA sequencing at Argonne National Laboratory using Illumina MiSeq technology. All sites sampled in an oil slick have a greater abundance of surfactant-associated bacteria in the sub-surface water than the sea surface microlayer. Sites sampled in low wind speeds have a greater abundance of surfactant-associated bacteria than sites sampled in moderate wind speeds, showing that meteorological conditions have a significant impact on the microlayer composition. In July and early August 2018, over 200 water samples were collected on the Looe Key, FL in coordination with SAR satellite overpasses. We plan to perform DNA sequencing on these samples and analyze the abundance of surfactant associated bacteria in a biologically productive environment

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between day and night. The project results are expected to help distinguish oil spills from look-alikes in SAR.

Molecular Characterization of Differentially Weathered Surface Oil from Taylor Energy Oil Spill

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Following Hurricane Ivan, the Mississippi Canyon 20 lease block has been continuously releasing oil. The resulting surface oil sheens stretch for miles and are visible from space. Fingerprinting oil as it is freshly released into the marine environment and further characterization, as it weathers with time following an incident, is critical to understanding the oil's fate, transport, and associated toxicity to affected marine organisms and habitats. However, conventional GC-based techniques to characterize oil in the environment do not adequately characterize the weathered and otherwise degraded oil transformation products, including the highly oxygenated compounds that can have important roles in oil fate, transport, and toxicity. Electrospray ionization (ESI) Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR-MS) combined with GC × GC analysis, correlates bulk chemical properties to elemental compositions of oil-transformation products as a function of time, and can provide much more information about these abundant, highly polar and low volatility (e.g., environmentally persistent) oxygenated transformation products.[1,2] Here, we follow a consistent subsurface source of oil from its surfacing point of origin along its surface trajectory and sampled along the way to determine the degree of weathering and associated changes in composition through time and distance. Samples were collected ranging from non-oiled control sites, to freshly surfacing sources, to surface oil samples distanced several miles from the freshly surfacing oil source. The study offers a unique opportunity to analyze petroleum transformation products and compare the changes in composition with time and distance from the source. Work supported by NSF Division of Materials Research through DMR-11-57490, a grant from the Gulf of Mexico Research Initiative, and the State of Florida. **References**: 1. Chen, H. *et al*. *Environ Sci Technol* 50, 9061-9069 (2016). 2. Aeppli, C. *et al*. *Environ Sci Technol* 48, 6726-6734 (2014)

Regulation of Methanotrophy in Ocean Environments

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We investigated aerobic methanotrophy across a range of environments, including a natural seep in the Gulf of Mexico (GC185), a site impacted by anthropogenic inputs in the Gulf of Mexico (Taylor Energy) and a natural seep along the Atlantic Margin (Pea Island). The three study areas were in shallow water (<500m water depth) and were characterized by contrasting nutrient regimes. The two seep sites - GC185 and Pea Island - were more oligotrophic than the Taylor Energy site, which receives nutrient inputs from the Mississippi River. At all sites, methane concentrations were highest near the seabed but concentrations throughout the water column were well above those predicted from atmospheric equilibrium. Methane oxidation rates were impacted by methane concentration, nutrient availability, and competitive substrates (e.g. methanol, ammonium). Methane oxidation rates were

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variable but were consistently high at the Taylor Energy site, potentially because of elevated nutrient concentration fields in the area. The Pea Island site is quite different from natural seeps in the Gulf of Mexico as very high methane concentrations (>100 nM) persisted to the base of the thermocline. The potential for methane consumption exceeded *in-situ* rates and methanotrophic microbial communities at each site were unique and appeared to be tuned to local conditions. Together, these results underscore the complex suite of factors that regulate oceanic methanotrophy and illustrate the need for long term interdisciplinary studies to advance the understanding of methane cycling in the ocean.

A Multi-Sensor Remote Sensing Approach to Assess Oil Spill from the MC-20 Site

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Medium- to high-resolution (10-30 m) optical remote sensing imagery was used to systematically assess the oil spills near the MC-20 site for the period between 2004 and 2016. Image analysis detects no surface oil in 2004, but ~40% of the cloud-free images in 2005 show oil slicks, and this number increases to ~70% in 2006-2011, and >80% since 2012. For all cloud-free images from 2005 through 2016 (including those without oil slicks), delineated oil slicks show an average oil coverage of 15 km^2/image, with an estimated surface oil volume ranging from ~50 to ~1700 barrels/day, and a cumulative oil-contaminated area of 1900 km^2around the MC-20 site. Further analysis is conducted to use Sentinel-2 MSI (10-20 m resolution) multi-band imagery to assess whether oil emulsions can be detected.

Probing the Genetic Capacity for Hydrocarbon Biodegradation in the GOM and Global Oceans

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The rapid response of pelagic Gulf of Mexico (GOM) microbes to the Deepwater Horizon oil spill, together with the long history of natural and anthropogenic hydrocarbon inputs to the GOM that may foster a standing stock of hydrocarbon-degraders, prompts questions of whether the GOM is uniquely primed for hydrocarbon biodegradation. Here, we address this question using 770 publicly available marine metagenomes from the GOM and the global oceans, comparing the distributions and phylogenetic affiliations of two key genes for aerobic hydrocarbon biodegradation: alkane hydroxylase (AlkB) and ring hydroxylating dioxygenases (RHDs). The enzymes encoded by these genes catalyze the first steps in the aerobic degradation of the two major oil hydrocarbon groups, n-alkanes and polycyclic aromatic hydrocarbons (PAHs). Using Hidden Markov Modeling profiles, we found that both of these genes were detected in more than 80% of the metagenomes, but with significant taxonomic variations between coastal/open, shallow/deep, and latitude. To better understand what drives distributions of these genes, we implemented Random Forest regression models to predict the relative abundances of AlkB and RHDs on the marine global scale, using environmental factors acquired from the World Ocean Atlas 2013_v2 1° × 1° grid dataset as predictive variables. This “big data” approach to mapping the oceans’ genetic capacity for hydrocarbon biodegradation exploits the large volume of marine metagenomic data that has become available in the past 2 decades, with the goal of predicting the response of different oceanic provinces to chronic and catastrophic releases of hydrocarbons.

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