Abstracts for Poster Presentations

Session 001: Oil Spill Response and Mitigation Agents

Evaluation of the Oil Removal Efficiency of Three Shoreline Cleaner Products
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Oil spill mitigation protocols allow for responders to implement multiple technologies during spills. Surface washing agents (or shoreline cleaners, SLC) are chemicals applied in specific situations where it is desired to remove stranded oil from substrates such as shorelines, seawalls, or vegetation. There are a number of products that are classified as SLC products, yet few studies have characterized the oil removal efficiency of individual products. The objective of this study was to determine the oil removal efficiency of three SLC products (Accell Clean SWA, Cytosol™ and PES-51). The products were selected to represent different chemical constituents. Accell Clean SWA is a surface washing agent containing a combination of surfactants with non-enzymatic proteins. CytoSol is a surface washing agent derived from vegetable oil and animal fat methyl esters. PES-51 is listed as a miscellaneous oil spill control agent and consists primarily of d-Limonene. Artificial substrates in the form of ceramic tiles were selected to represent hard substrates. Multiple ceramic tiles were oiled using Louisiana Sweet Crude oil and allowed to weather in a greenhouse. A baseline measurement for the total oil mass on the tiles was determined. Shoreline cleaners were then applied to oiled tiles, allowed to soak for 30 minutes, and then rinsed with seawater. Oil removal efficiency was measured by solvent extraction (hexane and dichloromethane) of the tiles followed by quantification of Total Extractable Hydrocarbons (mg/tile) using gas chromatography mass spectrometry. Removal efficiency was determined by comparing to oiled-unwashed tiles and oiled-seawater alone tiles. The results of this study provide new data on oil removal efficiencies for three SLC products. Understanding SLC effectiveness is an important facet of oil spill response and results from this study will assist response managers in making environmentally sensitive decisions.

Water Oil Spills Cleanup Using Oleophilized Peanut Hulls as Sorbent
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The suggested remediation process is based on the utilization of Oleophilized Peanut Hulls (OPH 28) as an organic sorbent. A natural biodegradable organic sorbent is prepared from raw peanut hulls. Physical characteristics of the sorbent are detailed, in addition to preliminary laboratory tests under different conditions. The industrial process to produce the sorbent is disclosed. A pressurized underwater injection or aerial dispersion of a water/sorbent mixture is proposed. The possible utilization of the sorbent as a physical dispersant is discussed based on laboratory tests results that reproduce the evolution of the oil/sorbent mass into sea water throughout time. The possible application of the sorbent as complementary tool of the in-situ burning cleanup methodology is also proposed. Finally, the sorbent behavior in front of heavy oils is assessed as a precursor in the formation of tarballs that allow the handling and collection of the pollutant as semi-solid mass offshore.

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Pipe Cutting and Plugging Device
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This paper refers to a device for cutting and plug subsea fluid conductors under high pressure. The device can be used as an emergency plugging tool to stop leaking fluid into the environment from a damaged oil well. The device works by fixing its housing parallel to the pipe axis with hydraulic clamps. A cutting saw on the end of a rotating arm is activated to cut transversely to the pipe axis. A conical plug concentric with the cutting saw is fixed to the hollow shaft of the hydraulic motor that rotates the saw. After cutting, the plug can be centered by the arm with respect to the axis of the pipe and the plug moved along that axis and inserted into the cut pipe. The fluid drains through the hollow shaft of the hydraulic motor and a swivel to a hose connected to a tank vessel at the surface.

Toxic effects of oil and dispersant on growth of the toxic dinoflagellate *Karenia brevis*
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Karenia brevis is a toxic dinoflagellate species commonly associated with harmful algal blooms in the Gulf of Mexico. The potential effects of oil spills on toxic dinoflagellate blooms are not well understood. We examined the effects of dispersed crude oil on the growth of *K. brevis*. The Texas Gulf coast experienced a bloom of this toxic dinoflagellate in late summer of 2015. Samples of this natural plankton community were exposed to low and high concentrations of dispersed crude oil and incubated in the laboratory for 7 days. Two culture methods using closed Erlenmeyer's flasks or open beakers were tested in the same condition and for all treatments. The toxic effects of the dispersant/ crude oil mixture on the growth of *K. brevis* were measured by direct cell counts. In addition, potential morphological changes were observed using a continuous imaging flow cytometer (FlowCAM). Growth of *K. brevis* was markedly inhibited by the dispersant/ oil mixture at the highest concentration tested (50ppm). The low concentration treatment (10 ppm) using open beakers showed results similar to the control experiment - the use of open beakers reduces the exposure to the volatile fraction of the crude oil. In contrast, high growth inhibition effects were observed for 10 ppm exposure using closed Erlenmeyer's flasks. However, morphological changes were observed in the 10 ppm treatment in open beakers; the size of the organism increased and the general shape of the cells were more convoluted, diverging from the typical, more circular shape. Overall, the results demonstrated significant differences depending on the open or closed culture method, and that higher concentrations of dispersed crude oil inhibits the growth of *K. brevis*, while lower concentrations only affect cell growth in closed containers that retain volatile compounds.

Sublethal Effects of Crude Oil Dispersants on a Tidal Creek Crustacean
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Oil dispersants are often used to mitigate the environmental damage of oil spills with over 2 million gallons used alone during the Deepwater Horizon oil spill in 2010. The growth of oil dispersant use has raised concerns with their long-term effects on the environment and crucial marine organisms and has led to increased research on these issues. In this study, the concentrations of two biomarkers in larvae of the grass shrimp *Palaemonetes pugio* were measured as a function of oil dispersant concentration

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and exposure time. *P. pugio* play an important role in transporting energy via the food chain in salt marshes and is commonly consumed by economically important fish. The larvae were exposed to two different oil dispersants, Corexit® EC9500A and Finasol® OSR52, in research experiments for 24 hours and 96 hours at various concentrations below lethal levels. The biomarkers of interest were the hormone 20-hydroxyecdysone (20-HE) and the enzyme acetylcholinesterase (AChE), which were measured using the enzyme-linked immunosorbent (ELISA) assay and the acetylcholinesterase assay respectively. These assays gave absorbance values that were then used to calculate concentration and enzyme activity. The hormone 20-HE regulates molting in arthropods. AChE facilitates neurotransmission by cleaving the neurotransmitter acetylcholine but also functions in a developmental role by regulating cell growth and differentiation. Data collected from the 20-HE assay indicated a generally declining trend of 20-HE concentration in *P. pugio* larvae after 96 hours exposure to oil dispersants, suggesting negative effect on growth. The AChE assay did not indicate any significant effect with exposure to dispersants.

Capture and Densification of Floating Crude Oil by Granular Materials
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Densification and submergence of floating crude oil in the water column reduces the impact radius of a spill and its mobility, preventing direct contamination of beaches, coastal flora and fauna. Surface application of dry granular materials (quartz sand, limestone) on top of the floating oil layer increases the density of the floating oil phase and leads to formation of relatively large and stable aggregates with a significant amount of oil. The aggregates separate from the floating hydrophobic phase and settle by gravity. The granular densification process has been studied by our research group during the last three years and the summary of the main findings will be presented. The objectives of the series of experiments conducted were to determine the oil removal efficiencies and optimal particle to oil ratio, effect of salinity and the application rates, as well as to study the effects of particle size and particle porosity. In addition to crude oil (South Louisiana crude, MC 252) we analyzed aggregation of quartz sand with other hydrophobic liquids (alkanes and aromatics) to investigate wetting characteristics and relation of aggregation rates to physical properties of liquids, and to investigate dissolution rate constants of the submerged hydrophobic liquids. Classification of the main types of particle-oil aggregates was developed based on the formation characteristics of the oil-particle aggregates and application rate of the granular particles. Moreover, under specific conditions, unique oil-particle interactions occurred (bowl formation and roping) at the hydrophobic liquid-water interfaces, as well as formation of granular encapsulated air bubbles. These concepts can be used to control surface mobility of floating oils, especially during the initial stages after the oil spill while the floating oil layer is intact and dispersant application may not be suitable near coastal areas, where transport of floating oils can significantly impact coastal ecosystem.

Wicking of Floating Crude Oil by Waste Tires
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Pulverized rubber obtained from waste tires can be an effective sorbent for capturing floating crude oil by wicking of the oil phase. Capillary theories were used to analyze oil-particle interactions. Experiments were conducted using pulverized tires with different particle sizes (0.075 - 0.600 mm) and South

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Louisiana crude oil (MC 252). The sorptive oil capture performances of tire particles were compared with that of powdered activated carbon (AC). Despite significant differences in their material structure, both AC and pulverized tires performed well for capturing floating crude oil. Sorption of oil by waste tire particles occurred rapidly within less than 10 minutes, indicating strong capillary action. For small tire particles wicking is a significant mechanism for oil sorption, whereas lateral aggregation is more noticeable for larger particles. The waste tire particle-oil aggregate could be easily removed from the water surface while retaining their structural integrity. The pulverized tires have the potential to improve existing oil response and treatment methods (e.g., compression of agglomerate phase to recover oil or burning for energy recovery). Considerations of the cost of AC vs waste tires, as well availability and recycling potential make waste tires a feasible alternative material for capturing floating oil slicks and industrial applications.

Oil emulsification in seawater using aqueous lecithin/Tween 80 self-assemblies

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Phospholipids have been extensively used to prepare oil-water emulsions in the food and pharmaceutical industries. Recent studies have shown that phospholipids, as well as mixtures of food-grade phospholipids with Tween 80, can also be used to disperse oil as oil-in-water (O/W) emulsions. In this work we describe a new strategy of forming O/W emulsions in synthetic seawater using lecithin-Tween 80 (LT) self-assemblies (vesicles and disk-like micelles) as emulsifying agents. We show that LT assemblies can emulsify gasoline or crude oil with greater than 90% emulsion (or dispersion) efficiency at a total surfactant concentration that allows for complete coverage of the oil droplet interface. Comparing the experimental results with theoretical results based on geometric surfactant packing indicates that lecithin and Tween 80 packed tightly at the oil/water interface as a monolayer with near-ideal mixing behavior. When compared to Corexit 9500A, emulsions formed with LT assemblies were significantly more stable against coalescence. Aqueous dispersants such as the LT assemblies can be prepared on demand and may prove effective for emulsifying (dispersing) oil phases under conditions of high mixing energy.

Screening and Isolation of Novel Biodemulsifier Producers from Petroleum Hydrocarbon Contaminated Sources in North Atlantic Canada

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Emulsions are common in petroleum industry and are sometimes undesirable as they dramatically increase the pumping cost and enhance the corrosion. Demulsifiers are included to mitigate emulsion formation. Biodemulsifiers are superior alternatives to their chemically synthesized counterparts due to their high efficiency and biodegradability. The application of bioemulsifier is still at a preliminary stage with the primary challenges of the limited availability of bioemulsifier producers and the absence of methods to effectively screen such producers. To face the challenges, this study screened and isolated novel bioemulsifier producers from oil contaminated marine sources in Atlantic Canada for the first time. During the screening process, isolates with surface active properties were evaluated with oil drop collapsing test (ODC), oil spreading test (OS), surface tension measurements (ST), critical micelle dilution test (CMD), emulsification index (EI), and cell hydrophobicity test (CH). The obtained test results were analysed with their emulsion breaking ratios (EBR). Eleven novel demulsifier producers belong to genera

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of *Halomonas*, *Bacillus*, *Acinobacter*, and *Rhodococcus* were reported. Among them, *R*. *erythropolis* N4-1A achieved 98.9% emulsion breaking ratio within 12 hr. Its crude demulsifying product was recovered, characterized and showed superiority in efficiency and biodegradability. On the other hand, strong correlation was found between CMD and OS as well as ST and ODC as shown in the correlation matrix (Figure 1). Among the 6 tests used for the screening, OS and CH showed significant contributions to the EBR according to ANOVA analysis. The dataset was fitted into the model of EBR=8.64+6.57*****OS+0.24*****CH. The response surface graph was shown in Figure 2. The oil spreading test combined with cell hydrophobicity test was recommended for the fast screening of biodemulsifier producers. The screening strategy, the novel producers and their products have promising potential to practical applications in petroleum industry.

Synthesis, Characterization and Bacterial Compatibility of Polypeptoid Functionalized Halloysite Nanotubes

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Halloysites nanotubes (HNTs), a class of naturally occurring aluminosilicate ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) clay nanotubes, were previously shown to effectively stabilize oil-in-water emulsions. The HNTs are absorbed at the oil-water interface with desorption energy that is dependent on the particle size and wettability. The steric and electrostatic barriers created by HNTs between oil droplets inhibit the coalescence and coarsening of the oil droplets. In contrast to surfactants, pristine HNTs do not significantly reduce the interfacial tension. To further control the wettability and interfacial activity of HNTs, we investigated the functionalization of HNTs with amphiphilic polypeptoids, a class of new biocompatible peptidomimetic polymers. Assessment of the effect of the polypeptoids on the proliferation of oil-degrading bacteria has also been conducted.

The polypeptoids are random copolymers comprised of hydrophilic N-methyl glycine and hydrophobic N-butyl or decyl glycine segments in varying composition, thus allowing for control of the hydrophilic-lipophilicity balance (HLB) characteristics. Functionalization of HNTs was achieved by a “grafting to” approach, which involves the covalent attachment of pre-synthesized polypeptoid to HNT surfaces. The polypeptoid-functionalized HNTs have been characterized by a combination of analytical methods to verify the grafting content and surface morphology. The biocompatibility of these polypeptoids with the alkane-degrading bacteria (*Alcanivorax borkumensis*) was tested at concentrations from 10-100 µg/mL, concentrations 100-1000 times higher than what the bacteria are expected to encounter while in contact with functionalized HNTs. None of the copolymers inhibited *A. Borkumensis* over the 24 h test period. Supported by GoMRI.

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Session 002: Decision Support and Integration Tools for Response and Restoration

Investigations of Assessment Methods for Restoration Projects in Louisiana's Coast
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Louisiana's coastal ecosystem is a dynamic environment that is continuously under the influence of human manipulation, environmental disasters, storm events, climate change, and riverine and marine processes. This coastal ecosystem is vital not only to local communities and economies, but also to the state and the nation. The condition of the rapidly deteriorating coast has resulted in a sense of urgency among communities and policymakers, alike, to restore coastal Louisiana. Over the next 50 years, the Coastal Protection and Restoration Authority of Louisiana (CPRA) has been tasked with implementing restoration and protection projects to slow land loss and conserve coastal ecosystems. These restoration and protection projects are estimated to cost $50 billion, as part of Louisiana's Comprehensive Master Plan for a Sustainable Coast. An important part of CPRA's restoration work is assessment of progress. In our current study, we investigate methods of assessment for coastal restoration projects in regards to human (flood risk, economy, and culture) and natural systems (land, water, wildlife and fisheries). In particular, we have focused on a river diversion project, the Davis Pond Freshwater Diversion, in the Barataria Basin, in southern Louisiana. Findings from this assessment are expected to help guide future decision making as well as provide vital information to the community.

VulnToolkit:An R Package for Accessing Public Tide Data
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We present an R package, VulnToolkit, that streamlines and improves access to public databases of water level and tide data managed by the National Oceanographic and Atmospheric Administration and the Permanent Service for Mean Sea Level. Vulntoolkit also includes analytical tools that can be used for analysis of tidal flooding regimes. We apply these tools to conduct a meta-analysis of vulnerability to sea level rise and generate insights about the relationship between elevation and tidal flooding regimes. Tidal marsh surface elevation is often considered a master variable controlling the eco-geomorphic feedbacks that maintain marsh stability. However, the relationship between elevation and flooding is a complex, non-linear one. In examining data from 102 stations, we found that the extent of flooding - at a fixed elevation - varied up to five-fold among sites; differences in tidal range were responsible for much of this variation. Likewise, there were large differences in tidal vulnerability to drowning, which we defined as the increase in flooding that will be caused by a given elevational deficit. We applied these parameters to a case study of a drowning marsh, and found that an unfavorable tidal regime - caused by its up-river location - may play a role in drowning at this site.

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Session 003: Understanding Ocean Surface Currents in Relation to Oil Spill Response

An algorithm for drogue-loss detection during LASER
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The LAgrangian Submesoscale ExpeRiment (LASER) was designed to study surface flows during winter conditions over the region of the Deepwater Horizon spill. More than 1000 biodegradable drifters were launched, but some of these lost their drogues due to intense winter storms during the exceptionally-strong El Nino period. An algorithm is developed to identify the drogue status of the LASER drifters for the first 50 days following their launch. It is composed of two stages: A first guess is produced by identifying drifters with both unusual GPS transmission and strong downwind or Stokes-related displacements. The wind Stokes drift calculations are based on a coupled atmospheric-wave-ocean model that was used operationally during LASER. In the second stage, the high drifter density throughout the experiment allows to deduce the status of the remaining 1/3rd by comparing their relative velocities to the nearby drifters of the first stage. It is found that 7 weeks after the start of LASER (March 8), about 40% of the drifters lost their drogues, and the drogue loss coincides with storm events resulting in steep waves. The separation of drogued and undrogued drifters provides an unprecedented opportunity to quantify the differences of material dispersion in the upper 60 cm and 5 cm of the ocean's surface. This is exceptionally valuable for oil spill response.

Non-local Transport in LES of Langmuir Supercells under Tidal Forcing
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Langmuir supercells (LSCs) in coastal oceans consist of parallel counter rotating vortices engulfing the water column in unstratified conditions. These cells have been observed in continental shelf regions 15-30 meters deep during the passage of storms. LSCs are aligned roughly in the wind direction and are generated via interaction of the wind-driven shear current and Stokes drift velocity induced by surface gravity waves. LSCs have been determined to be an important contributor to the suspension of sediments and their overall transport across shelves. As such, these cells may play an important role in sedimentation. In this presentation, results from large-eddy simulations of LSCs in flows driven by a surface wind stress and a constant crosswind pressure gradient (representative of crosswind tidal forcing) are analyzed in terms of LSC structure and budgets of turbulent kinetic energy and Reynolds shear stress. It is shown that tidal forcing distorts and weakens LSCs through mean crosswind shear in the bulk of the water column and through crosswind bottom boundary layer turbulence in agreement with previous computations [Kukulka T., A.J. Plueddemann, J.H Trowbridge and P.P Sullivan, 2011, *J. Geophys. Res*., **116**, C08005] and field measurements [Gargett A.E. and C.E. Grosch, 2015, *J. Phys. Oceanogr*., **44**, 44-69]. Although a crosswind tidal current stronger than the wind-driven current and the tidally-driven bottom boundary layer turbulence are able to break up the LSCs giving rise to smaller scale, weaker Langmuir cells (LCs), analysis of Reynolds shear stress and turbulent kinetic energy budgets reveals that non-local transport remains significant relative to flow without wave effects (i.e. without LCs). This demonstrates the need for a non-local transport term in Reynolds shear stress and

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turbulent scalar flux closures accounting for Langmuir turbulence in coarse scale simulations of coastal flows.

Modeling of Turbulence Underneath Non-Breaking Waves

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The turbulence underneath regular (non-breaking) waves at a water surface predicted by the Reynolds-averaged Navier-Stokes (RANS) equations and the k-epsilon turbulence model is investigated. The waves are resolved via the volume of fluid method. The waves are characterized by a height of 0.15 m, a wavelength of 1.56 m and a period of 1 s. Predictions of the aqueous turbulence generated by this wave field are consistent with the wave tank results of Babanin and Haus (2009) [*J. Phys. Oceanogr.*, **39**, 2675-2679] and related turbulence characterization of Babanin (2006) [*Geophys. Res. Lett.*, **33**, L20605]. The characterization is based on a depth-dependent wave-amplitude Reynolds number (Re_a) defined as $Re_a = a^2\omega/\nu$, where ν is kinematic viscosity of water, ω is surface wave frequency and a is the depth-dependent amplitude of wave induced motions (i.e. $a = a_o e^{kz}$ where a_o is surface wave amplitude and k is surface wave wavenumber). In the computations, levels of turbulent kinetic energy (TKE) and TKE dissipation are significant at depths where $Re_a > 3000$. The latter is a critical value indicative of wave-induced turbulent motion, introduced by Babanin (2006) based on field data analysis and later confirmed in the Babanin and Haus (2009) laboratory experiments. For depths where $Re_a < 3000$, the simulation predicts negligible or zero TKE and TKE dissipation corresponding to laminar motion. Furthermore, model predictions of TKE dissipation are consistent with the laboratory experiments following the relation $\varepsilon = 300 a_o^p$ where ε is TKE dissipation measured close to the water surface and $p = 3 \pm 1$. The good agreement between the simulations and the laboratory experiments provides further support for the existence of wave-induced turbulent motions underneath non-breaking waves in contrast to the numerous works in the literature that have argued that such turbulence regime is non-existent. Future work should explore this flow field via direct or large eddy simulations.

A Biodegradable Surface Drifter for Ocean Sampling On A Massive Scale: Design, Calibration and Application

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Tracking oil spills requires high spatial and temporal resolution of the near-surface flow field that can only be achieved by deploying hundreds of drifters within a few hours. This poses new challenges to design in that drifters should be low cost, easy to assemble, and compact for reasons of space. In addition, one needs to determine exactly how the drifter behaves at the interface of winds, waves and near-surface currents. The drifter should be scalable to hundreds and thousands of units easily in order to sample as many degrees of freedom as possible in order to determine transport pathways in the ocean. As such, the drifter needs to be as ecologically friendly as possible. We introduce a novel drifter that is made of a marine biodegradable material. Its water-following characteristics are measured in laboratory settings, while its drift is compared with the CODE drifter in field tests. Finally, we produced and deployed a thousand units during the Lagrangian Sub-mesoscale Experiment in the northern Gulf of Mexico.

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Dispersion versus Clustering: Evolution of Drifter Distributions at the Ocean Surface
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The ocean surface has been observed to be dispersive. Yet it is also well known for its evolving regions of accumulation. Understanding where such dispersion and clustering occurs has the potential to drastically improve oil spill response. Here we will discuss the interplay between the two competing phenomena as it affects the distribution of a large group of drifters. Results will be presented from a regional ocean model in the Gulf of Mexico, as well as from the recent large-scale drifter deployment as part of the Lagrangian Submesoscale Experiment (LASER). Applying a rigorous definition for clusters, we investigate the time scales of cluster formation, as well as their evolution thereafter: disintegration, re-emergence, and exchange of members.

Differences of Langmuir Circulations in Open and Coastal Zones
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Langmuir turbulence is a microscale oceanographic phenomenon of the upper mixed layer that is relevant to mixing and vertical transport capacity. It is characterized as a resultant turbulent process due to the non-linear interaction of surface waves and wind-driven shear instability in the upper mixed layer forming streamwise-elongated, counter-rotating cells. Many previous studies of Langmuir turbulence have focused on the open ocean (McWilliams *et a*l., 1997: *J. Fluid Mech*., **334**, 1-30). When the bathymetry changes in coastal zones, there is additional shear associated with the bottom-boundary layer, which alters the spatial distribution of turbulent stresses and the kinematic properties of Langmuir circulations (Kukulka *et al*., 2012: *J. Geophys. Res*., **117**, 1-17; Tejada-Martinez *et al*., 2012: *J. Fluid Mech*., **699**, 79-93). This has been accomplished by solving the grid-filtered Craik-Leibovich equations, initially without Coriolis accelerations or buoyancy forcing. Coastal Langmuir cells are distinctly different from Langmuir cells in open-ocean regions, in terms of their structural stability, as they have well-defined crosswind scale. More importantly, for surface waves with higher values of wavenumber, we observe different sizes of Langmuir cells at upwelling and downwelling sites in coastal regions. Langmuir cell height at upwelling locations is controlled by the wavenumber, whereas Langmuir cells at the downwelling site occupy the depth of the water-column. We emphasize that the Langmuir cell morphology observed here is entirely different to open-ocean settings. This has implications for the vertical transport capacity and also the surface mixing layer depth. We also show how Langmuir turbulence in coastal zones responds to stable stratification, where the density profiles are selected to replicate ambient conditions in the coastal Gulf of Mexico, as measured via CTD deployment.

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A Coupled Nearfield and Farfield Large-Eddy Simulation for Oil Transport from Deep-water Blowouts - A Study of the Effects of Dispersant on Oil Plume Transport

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Deep-water blowouts generate plumes of oil droplets and gas bubbles that rise through, and interact with, various layers of the ocean. The different scales and physical processes governing the dynamics of the oil plume at each layer require different numerical simulation strategies. We develop a high-fidelity turbulence-resolving numerical model using the large-eddy simulation technique which consists of two modules targeting two distinguished stages of the oil plume dispersion: “nearfield” and “farfield”. The “nearfield module” simulates the dynamics of the multiphase plume containing gas bubbles and oil droplets originating from the oil well and rising through the 1.5 km stratified water column. The formation of deep-water intrusions and the separation of oil and gas plumes due to weak crossflow are captured by LES. As the oil plume approaches the bottom of the ocean mixed layer, the “farfield module” takes over and simulates the near-surface oil transport using a new numerical approach called ENDLESS (Extended Nonperiodic Domain LES for Scalars) to accommodate the fairly large horizontal extent of the plume. ENDLESS is a multiscale plume modeling approach, which permits simulations of oil plumes including effects of submesoscale eddies, surface waves, Langmuir cells, and 3D small-scale turbulence with reasonable computational cost. The two simulation modules are coupled, allowing the representation of the entire plume in a turbulence-resolving context. Simulations using idealized conditions are performed to elucidate the effect of dispersant application on plume dispersion. Simulation results show that the reduction in oil droplet sizes promoted by the application of dispersants can strongly affect the dynamic response of the oil plume to the complex oceanic flows. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

Lagrangian coherence of Loop Current rings as represented by ocean models

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Independent observational evidence (satellite altimetry, ocean color, and satellite-tracked drifter trajectories) was recently provided in support of the existence of coherent Lagrangian Loop Current rings in the the Gulf of Mexico. Such rings have material boundaries that do not filament or experience global break away for many months. As result they constitute very effective mechanisms for material transport. Here we investigate how high-resolution ocean general circulation models (with terrain-following and hybrid vertical coordinate) represent this process. Special attention is paid to the effects of data assimilation. Join work with M. Le Henaff and F. J. Beron-Vera.

Physical conditions associated with the coral mortality event of Summer 2016 at the Flower Garden Banks National Marine Sanctuary in the Gulf of Mexico

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In July 2016, the Flower Garden Banks National Marine Sanctuary (FGBNMS) experienced a severe mortality event that affected corals over a portion of its reefs. Observations show that this event is

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concurrent with the unusual spread of low-salinity, high Chl-a, turbid waters of river origin over the whole continental shelf in the Northwestern Gulf of Mexico. Analysis of observations and modeling outputs reveals that this spread of river waters took place because of the combination of various factors: 1. unusually large river discharge along the Texan coasts; 2. episodes of southerly and southwesterly winds that favored upwelling and offshore spread in the Ekman layer; 3. the presence of mesoscale eddies at the shelf break that entrained a portion of riverine waters offshore. These factors drove the spread of riverine waters during the summer of 2016, although events like this seem to be very rare. Nevertheless the summer 2016 episode illustrates how large-scale events in the Gulf of Mexico can occur in critical, 3-dimensional habitats. It illustrates the potential transport of coastal, polluted waters over large portions of the shelf and far offshore, in a region of industrial activities in Galveston Bay. This study case also helps expanding the understanding of near-surface circulation and thus of related potential oil pathways in an area of intense oil exploration. The proximity of marine protected areas such as FGBNMS, which is currently under review for an expansion of its boundaries, makes it crucial to understand ocean surface circulation patterns in the region. This presentation will provide an in-depth space and time characterization of the 2016 event.

Long Range Ensemble Forecasting in the Gulf of Mexico
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An extended range (~60 days) ocean forecasting system based on probabilistic (ensemble) methods has been developed for the Gulf of Mexico. A probabilistic prediction has the advantage of providing a forecast as well as the uncertainty about that forecast. The forecast system uses a set of possible forecast states (ensemble) generated by perturbing the initial state of the ocean field as well as the surface atmospheric forcing (winds and heat fluxes). The ensemble forecast system delivers a short range 24-hour forecast every day and a 60-day long range forecast once per week and has been running in real-time since January 2013. Forecast skill during 2014-2015 is highlighted due to the heightened energetic character of the Loop Current during this time period. Sensitivity to the data assimilation parameters is discussed. Various metrics have been calculated to assess the performance of the ensemble. Anomaly correlations have been calculated and used to quantify the forecast skill relative to the best corresponding analyses for the prognostic model variables at several depths. Output from the system is used to derive risk assessment products such as risk of strong currents or risk of combined error in the forecast. These are calculated from probability distribution functions over the length of the forecast and can be used for planning, risk mitigation, search and rescue, etc.

A New, Generalized Approach to Risk Maps for the Gulf of Mexico
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Using concepts from the theory of dynamical systems and 12 years of sea-surface velocity for the Gulf of Mexico (GoM), we construct a climatology of quasi-steady Lagrangian transport patterns. This climatology accurately describes high-profile events like the “tiger-tail” filaments observed during the Deepwater Horizon oil spill and the GLAD drifter experiment, the oil distribution observed during the Ixtoc blowout in 1979, among others. The climatology also accurately highlights regions with a high- or low-risk of impact given a generic oil spill --choosing the location of a pollution point-source is not

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needed with our method. Thus, we create monthly risk maps for the GoM, generalizing previous methods of developing risk maps that depend on the location of a pollution source. The risk maps are used as one of many inputs (layers) for the Spatially Weighted Impact Model (SWIM) developed at the National Energy Technology Laboratory, allowing us to evaluate the impact of an oil spill according to the current allocation of resources within the GoM.

Transport and Dispersion of Buoyant Tracers by Mixed Layer Turbulence
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Large Eddy Simulation techniques are used to model the transport and dispersion of buoyant tracers and surface trajectories to upper ocean turbulence. The effects of Langmuir circulations are examined by including the Craik-Leibovich vortex force to model the phase-averaged interaction between currents and the surface waves' Stokes drift. Under steady forcing by wind and surface buoyancy flux, surface trajectory velocities and the downwind transport of buoyant tracers increases with stabilizing surface heat flux, as expected from similarity theory. Including the effect of Langmuir circulation is found to reduce downwind transport because the additional Stokes drift shear is not as large as the near-surface current shear that the vertical mixing by Langmuir turbulence removes. These steady-state LES results for the effect of surface waves do not appear to generalize to more realistic variable forcing cases: With diurnal shortwave radiation forcing compensated in the mean by steady turbulent surface heat flux and forced by constant wind stress, the effect of Langmuir turbulence is instead to increase both the mean and variance of downwind transport through the daily forcing cycle. The impact of vertical mixing on dispersion is also evaluated for steady and variable forcing cases. Of particular interest is the larger role played by nonlocal vertical fluxes in Langmuir turbulence, and on methods of diagnosing and predicting them in turbulence closure models. Surface ensemble trajectories for Large Eddy Simulation cases with variable forcing will used to make predictions for comparison with results from the LASER experiment for mixed layer turbulence.

Qualifying the Summer NIWs Effect and Its Impact on the Oil Spill Events
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The effect of the vertical mixing in the water column leading by the resonant land-sea breeze circulation on the Northern Coast of Gulf of Mexico is investigated using a fully three-dimensional primitive equation model. Special attention is directed to the wind energy input to the surface near-inertial motions and subsequent change in the depth of mixed layer, seawater temperature, and the downward energy propagation into the deep ocean. We find from the model results showing that the near-inertial surface motions do be amplified by the diurnal wind forcing in the northern Gulf of Mexico; however, the summer stratification in the Northern Gulf of Mexico is too strong so that suppressing the growth of the vertical mixing.

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Shipboard imaging of mean square slope in Gulf of Mexico frontal zones
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Frontal zones, on the strength of their convergent nature, concentrate pollutants and toxic substances, such as oil, near the surface of the ocean. When considering the fate and transport of an oil spill in the upper ocean, understanding the physics of such boundaries plays an important role. The recent LaGrangian Submesoscale Experiment (LASER) in the Gulf of Mexico provides an opportunity to study the detailed manifestations of the fronts on the surface of the ocean. Benefitting from synchronous temperature, salinity and current profile data, the frontal zone at the front of the RV Walton Smith was sampled using optical techniques. High spatial resolution images of the ocean surface were obtained simultaneously from polarimetric cameras and analyzed in terms of the surface mean square slope (mss). Connecting the raw mss data to the air-sea fluxes and sub-surface velocities, the effect of fronts on short scale surface roughness will be discussed.

Surface Velocity Fields in the Gulf of Mexico Obtained Through LAVA Blending of Altimetry and LASER Drifter Data
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Thus far, the surface currents of the Gulf of Mexico have been vastly understudied and much of the variability of these currents on the order of 1 day to a few weeks is yet to be documented. Through the use of a large data set containing trajectories from over 1000 surface drifters from the LAgrangian Submesoscale ExpeRiment, LASER, that took place in January-February of 2016, this study's main focus is to map the surface currents over the majority of the Gulf of Mexico during the lifetime of these drifters. By blending the available drifter data with altimetry data, using the Lagrangian variational analysis (LAVA) approach, we aim to resolve large-scale to mesoscale flows with time and spatial scales on the order of weeks and 100km calculated from altimetry data, as well as the smaller scales flows using the data retrieved with the drifters, which intrinsically measure the combined effects of smaller scale processes including Stoke's drift, convection, Langmuir turbulence, and submesoscale flows. This blending of data leads to more accurate measurements of velocity fields while still maintaining a wide range of scales, which is vital in predicting the transport of oil throughout the Gulf.

Lagrangian Simulation of Oil Trajectories in the Florida Straits
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A region in the Florida Straits, northwest of Cuba, is being explored as a potential oil drilling site. The ability to predict what coastlines would be impacted in the case of a major release or spill can yield useful information to crisis managers and first responders. A stochastic Lagrangian Particle Model was developed to simulate the trajectory of surface oil by advecting leeway-corrected particles from 97 different initial launch locations in the proposed drilling area. Initial sensitivity tests with different parameter values were evaluated at 5 locations to tune the model and check for robustness of the results. The calculations were made for different seasons using (1) observed winds from NOAA's National Data Buoy Center (NDBC), the Citizen Weather Observer Program (CWOP), and a QuickSCAT 10-m winds seasonal climatology; (2) ocean currents from a new, drifter-based seasonal climatology; and

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(3) a Monte-Carlo oil weathering scheme. Additional runs for a hurricane scenario used blended model analysis, best track winds, and aircraft winds from Hurricane Andrew. The simulations revealed distinct seasonal differences in the percentage of particles beaching themselves or ending up in shallow water (less than 15-m depth), and substantial variation based on the initial launch location. The eastern initial locations resulted in a larger amount of particles on the Florida coast, while western launch locations resulted in particles spreading towards the Gulf of Mexico and Northern Cuba. Typical values are O(5-70%) for the winter and O(1-55%) for the summer cases. More of the oil ended up on the Cuban coast O(5-75%), compared to the Florida coast O(1-35%). Launch Locations closest to the Cuban coast showed values up to 95%. The simulations using hurricane winds showed particles beaching on the Florida coast O(2-15%) and the Cuban coast O(2-30%), as well. The particle distribution in summer is bimodal, whereas in winter, most particles remain in the vicinity of the Cuban coast. Simulations using NDBC/CWOP winds versus QuickScat winds had similar particle distributions. The results demonstrate that an oil spill in the proposed drilling area has the potential to reach nearby coastlines and coral reef communities in the Florida Keys, SE Florida, and Cuba.

An Improved Surface Velocity Climatology for the Global Ocean from Drifter Observations

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This study updates the methods of Lumpkin and Johnson (2013, JGR-Oceans 118) to obtain an improved surface velocity climatology for the global ocean using observations from undrogued and 15-m drogued Global Drifter Program (GDP) drifters. The new procedure includes the correction of the slip bias of the large number of undrogued drifters in the GDP dataset, and a new approach for decomposing Lagrangian data into mean, seasonal and eddy components, designed to reduce the smoothing of spatial gradients typical of data binning. The sensitivity of the results to method parameters, the method performance relative to other techniques, and the associated estimation errors, are evaluated using altimeter-derived geostrophic velocities subsampled at the drifter locations. It is demonstrated that (1) the correction of drifter slip bias produces statistically similar mean velocities for both drogued and undrogued regimes at most latitudes and reduces ambiguities between their variance estimates, (2) the proposed decomposition method produces pseudo-Eulerian mean fields with magnitudes and horizontal scales closer to time-averaged Eulerian observations than other methods, and (3) statistical errors underestimate the actual methodological errors by a factor of two. The improved decomposition method and the inclusion of undrogued drifters allows resolving details of the time-mean circulation not well defined in the previous version of the climatology, such as the cross-stream structure of western boundary currents, recirculation cells, and zonally-elongated mid-ocean striations.

Ocean Fronts as an energy sink in the Gulf of Mexico

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Although the energy sources are well understood to include wind stress, heating/cooling or precipitation/evaporation, the etiology of energy sinks have not been well delineated or properly characterized. The prevalence of frontal structures in the northern Gulf of Mexico (GoM) during the summer was further confirmed by the Grand Lagrangian Deployment (GLAD) conducted in August 2012 (Poje *et. al*, 2014). This result could have been an early indication of episodic or interannual variability

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since observations from the recent LAgrangian Submesoscale ExpeRiment (LASER) which was conducted in January-February 2016 (winter) sampled fronts and frontal instabilities. A source believed to be a driver for these oceanic fronts in the GoM arises from the basic seasonal inner shelf circulation pattern; where in the fall, winter and spring currents move from Louisiana to Texas (downcoast). The effects of the wind-forced behavior and entrainment of the coastal low salinity water, which is much cooler than offshore water, helps to reinforce these frontal instabilities that develop into vortices. The processes and instabilities occurring in the upper ocean surface in the northern Gulf of Mexico between 88.2°W-88.4°W and 28.2°N- 28.3°N are investigated via microstructure measurements which will allow a study seeking to properly characterize the fronts as an energy sink in the northern GoM. Vertical profiles in the upper 0.5-2m of the water column shows intense temperature stratification and dynamic temporal changes in vertical gradients. This study provides a framework capable of describing ocean fronts as an energy sink, through experimental and mathematical methods.

Available potential energy in the northern Gulf of Mexico in the LASER January 2016 experiment
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In our study from the field data, we calculate the available potential energy (APE), turbulent kinetic energy (TKE) dissipation rate. These quantities are important; because, mixing in the ocean plays a major role in the transferring materials, organism (Like phytoplankton) and energy. The mixing occurs at the smallest scales and will be studied from a variety of viewpoints. Kraig *et al*. (1995) studied about available potential energy (APE) in density-stratified water because of the importance of mixing in geophysical flows. The data used for our studying collected by lagrangian submesoscale experiment (LASER) in the northern Gulf of Mexico between 88.2°-88.4° W and 28.2° - 28.3° N during January 2016. The VMP instrument used to collect data before and after the front in northern Gulf of Mexico.

Flux Variability Observed Across Gulf of Mexico Frontal Boundaries
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Common features of dynamic sub-mesoscale fronts are that they have a distinct boundary in the ocean surface roughness and can also have a strong temperature gradient, both of these features can impact the atmospheric boundary layer. Additionally in swell-dominated conditions (as can happen in the open ocean during light winds), observations and numerical simulations have demonstrated a net upward momentum flux. Although sub-mesoscale fronts and swell-dominated regimes are clearly important to modeling air-sea interaction and surface layer transport, the relative contributions of current shear, temperature gradients and wave variability at frontal boundaries to the air-sea momentum flux are largely unknown. To address these issues, direct measurements of momentum, heat and water vapor flux were collected on the R/V Walton Smith during the LAgrangian Submesoscale Experiment (LASER) in the Northern Gulf of Mexico in January -February 2016. Twin flux towers were mounted on each of the prows of the R/V Walton Smith catamaran (10 m separation) and for each tower eddy covariance measurements of the fluxes were made at 3 vertical levels. Surface elevation was simultaneously observed from a bow-mounted array of five Ultrasonic Distance Meters (UDM). The data were segmented into 10 minute averaging intervals (for fluxes and wave spectra) and over the course of the 27-day observational period a total of 1,587 quality-controlled runs were analyzed. Wind speeds ranged from 2 to 18 m/s and processed directional wave spectra show a variety of wind-wave and swell

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conditions. Several individual periods of strong frontal action have been identified and analysis will focus on the along- and across-frontal variability of the fluxes and waves during these specific times. Preliminary results will be presented.

Retrieving Velocity Field from Lagrangian Observations Using Gaussian Process Regression

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The extensive drifter deployment during the Lagrangian Submesoscale Experiment (LASER) provided observations of submesoscale activity with high resolution in space and time. Estimating the Eulerian velocity field on a regular grid from this drifter data would be valuable to characterize the submesocales, as it provides means to compute strain rate, relative vorticity and divergence. We present a technique to infer the velocity field from sparse observations using Gaussian process regression (GPR), also known as Kriging. The novelty of our approach is in mining the LASER data to optimize, via a Bayesian procedure, the hyper-parameters specifying the space-time scales of the covariance function and the data noise level. The GPR also provides an estimate of the error of the regression, which can be verified with observations that are not used in the velocity reconstruction procedure. Here, we present the evolution of the velocity field during 24 hours windows, in 20 x 20 km^2 areas, along with estimates of relative vorticity, divergence and strain rate. Error maps of the velocity estimates are also shown and compared with errors obtained from observations which were not used in the procedure.

Observations of the Ocean Waves Directional Spectra and Stokes Drift across the Frontal Features Identified during LASER in the Gulf of Mexico using drifting Wave Buoys

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Analysis of the directional wave spectra and stokes drift obtained from the typical sets of surface wave data using drifting wave buoys are reported here. Data presented here is from three different deployments of wave buoys during LASER (Lagrangian Submesoscale Experiment) Jan-Feb 2016 in the Gulf of Mexico on board utility vehicle Masco-VIII and with the help of R/V *Walton Smith* of University of Miami. This is the first of its kind in situ wave data observations across the submesoscale dynamic frontal features with distinctly visible boundaries and strong temperature gradient, identified near the Mississippi plume in Northern Gulf of Mexico using Airborne SST and AEROSTAT observations. Theory and past observations shows that these fronts have a considerable effect on surface roughness and atmospheric boundary layer, which are of great importance for air-sea coupled modeling and surface layer transport. The observed wave spectra indicate that wave field is composed of high frequency sea waves travelling nearly in the wind direction and lower frequency swell waves from southwest-south. The parametrization of the wave directional spread shows that both local wind conditions and nonlinear wave-wave interactions have an effect on the shape of directional distributions. The data was compared with the observations from the X-band radar mounted on R/V *Walton Smith* and wave-number spectra obtained from AEROSTAT images and found to be in good agreement.

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Validation and Evaluation of a Polynomial Chaos based ensemble for quantifying uncertainties in the Gulf of Mexico circulation.

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Quantifying the uncertainties in ocean current forecasts is an important component of formulating a response to an oil spill, e.g. to compute the anticipated oil trajectories. Polynomial Chaos (PC) methods have recently been used to quantify uncertainties in the circulation forecast of the Gulf of Mexico due to initial conditions and wind forcing uncertainties. The input uncertainty was specified by decomposing the variability in those fields using Empirical Orthogonal Functions, and by regarding the amplitudes of the 4 dominant modes of each field as uncertain random variables; an ensemble of simulation were then launched to explore the ensuing parameter space. Two common issuesof all ensemble methods are whether the ensemble perturbations lead to realistic representation of the uncertainty and whether enough variability have been taken into account. Here, we: 1) validate the perturbation of the PC ensemble by comparing the ensemble to observational data; 2) leverage the ability of PC methods to deliver output PDF to quantify, using information theoretical measures, the variability lost by omitting sources of input uncertainty or variability. The surface and subsurface model data comparison shows that the observational data falls into the envelope of the ensemble and the modal decomposition delivers "realistic" perturbations. The quantification of model output variability lost suggests that adding additional sources of uncertainty is more useful than increasing the variance of uncertainty. For the center of Gulf of Mexico, two initial condition EOF modes are enough to capture the ensemble variability and additional wind forcing EOF modes are needed in order to capture the ensemble variability in the coastal zone.

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Session 004: Understanding Population Status, Trends and Connectivity of Gulf of Mexico Large Marine Vertebrates as Sentinels for Ecosystem Health in the Context of Restoration

Manatees, Sea Turtles, and Gulf Sturgeons: Comparative Analyses of Habitat-Specific Vital Rates in the Northern Gulf of Mexico

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Manatees, sea turtles, and Gulf sturgeon are iconic large mobile marine vertebrates of economic importance to the five states of the Gulf of Mexico Alliance and all are under federal and state protection. In the northern Gulf, these species groups use neritic habitat, including the coastal bays, for foraging and reproduction, and all three spend some portion of their annual ecological cycle nearshore and either on shore (nesting turtles) or up tidal river systems (manatees and sturgeons). Environmental stressors and management actions within these shared habitats can drive changes in survival, breeding, and movement rates, which can lead to changes in population growth rate, distribution, abundance, and population densities. We outline an integrated comparative approach to modeling and estimation of habitat-specific vital rates using mark-recapture demography models; and describe analyses specific to: (1) reference baseline estimates of past rates for comparison with predicted and realized future rates, (2) assessment of variation in vital rates in association with events such as cold, heat, drought, red tide, or hurricanes, and (3) movement among critical habitats. Our results will provide valuable information to federal managers responsible for the recovery of these species groups, while providing the broader community of researchers, managers, and stakeholders with information relevant to development of a long-term research and restoration program.

Sea Turtle Monitoring during a Seismic Survey by the R/V Maurice Ewing off the Northern Yucatan Peninsula, Mexico

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Observations for sea turtles took place as part of a monitoring and mitigation program during a Lamont-Doherty Earth Observatory (L-DEO) seismic survey off the Yucatán Peninsula during January-February 2005. The sound source was a 20-airgun array, with a discharge volume of 6970 in^3, and was towed behind the *R/V Maurice Ewing*. The monitoring and mitigation program was implemented to minimize potential impacts of seismic sounds on sea turtles and cetaceans. Mitigation measures included (1) ramp ups of the array, (2) shut downs of the array (or power downs to a single airgun) if a turtle or cetacean was sighted within the designated safety radius, (3) no seismic operations at night or in Beaufort Wind Force higher than 4. Observers watched for turtles from the flying bridge of the Ewing for a total of 434 hours or 4281 km. Twenty-nine turtles were observed, including 17 hawksbill (*Eretmochelys imbricata*), 2 loggerhead (*Caretta caretta*), and 10 unidentified turtles. Most were sighted within 200m of the vessel and its array. Seven turtles were seen during airgun operations. Although mitigation measures were implemented immediately, these turtles were likely exposed to sound levels >180 dB re 1 μPa_{rms} if they had been diving recently. The majority of turtles sighted during seismic and no seismic showed no

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relative movement with respect to the vessel, but were seen logging at the surface. Only one turtle was seen swimming away from the vessel during airgun operations; no other overt behaviors in response to the seismic vessel were observed. During this cruise, there were not any evident negative impacts on observed sea turtles while the airguns were operating; however, some temporary avoidance was likely. More research is needed on the potential negative impacts on sea turtles; meanwhile, implementing mitigation measures, as done during this cruise, is key for preventing negative impacts

The Nursery Role of Seagrass Meadows for Snapper and Grouper in the Northern GOM
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Over population scales, the nursery function of individual estuaries and specific estuarine habitats in contributing recruits that support fishery stocks remains poorly understood. From 2006-2011, we used a combination of intensive estuarine surveys and geochemical tags stored in the otoliths of fishes to determine the nursery contribution of northern Gulf of Mexico estuaries (Chandeleur Islands, LA - St. Joseph Bay, FL), and specifically seagrass meadows, in supplying recruits that join adult gag grouper, gray snapper, and lane snapper populations in the offshore artificial reef complex of Alabama. Significant differences in geochemical tags were observed across an east-west gradient in the northern Gulf of Mexico, reflecting the influence of freshwater input from the Mississippi River outflow. Our tagging results suggest that Alabama fisheries are highly dependent on seagrass meadows in FL as nurseries, with notable contributions from seagrass meadows in AL and MS as well. Despite extensive seagrass cover along the Chandeleur Islands, relatively few juveniles residing there recruit to adult habitats in AL waters. These findings have obvious management implications (i.e., coastal injury [such as oiling] in one state might have implications for fisheries in adjacent regions), and suggest that significant westward drift of fishes egressing from coastal estuaries may define population connectivity throughout the northern Gulf of Mexico.

Preliminary isotopic analyses of coastal seabirds collected from Louisiana in 2010 during the Deepwater Horizon Natural Resource Damage Assessment
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Understanding the diets and foraging ecology of marine vertebrate species is a critical first step needed to address their conservation and management concerns. Stable isotope analysis has become a common tool to estimate diets and resource use as marine predators “are what and where they eat” with isotopic abundance of animal tissues reflecting these same biomarkers in their diet and surrounding habitats. Using samples collected from coastal Louisiana from June to December 2010 by Deepwater Horizon Natural Resource Damage Assessment (NERDA) we seek to examine the relative foraging ecology of three coastal seabird species using stable isotope analyses: Brown Pelican (*Pelecanus occidentalis*), Laughing Gull (*Leucophaeus atricilla*), Royal Tern (*Thalasseus maximus*) and Black skimmers (*Rynchops niger*). Nitrogen isotopic values ($\delta^{15}N$) will be used to infer trophic level and diets, while carbon isotopic values ($\delta^{13}C$) help trace trends in inshore vs. offshore habitat usage. In addition, compound specific isotopic analysis of amino acids will be used to quantify the relative contribution of specific primary production sources to these species’ respective food webs. While sample analyses is ongoing, this

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research is expected to provide insights into foraging niche differences between species that may influences their response to environmental stressors.

Development of detection and classification algorithm based on the feature extraction for beaked whales in the northern Gulf of Mexico

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Currently the passive acoustic monitoring has been used to investigate and analyze the underwater acoustic signals produced by marine mammals, including sperm whales and beaked whales, etc. As for beaked whales, one of the research goals is an identification of different species of beaked whale based on variations in click characteristics. At present, traditional detection and classification methods rely on manual inspection by an experienced operator so that this method requires extensive manual work. Thereby, this approach becomes impractical as the volume of collected data increases. An advanced method of detection and classification based on the feature extraction is proposed in this work for beaked whale clicks. The method is applied to acoustic data collected in 2007, 2010 and 2015 at three different sites in northern Gulf of Mexico. The method uses a multi-stage detector. The first stage detector is based on multi-band energy comparison with baseline threshold. The Second-stage detector performs a multi-attribute analysis on the first stage detection events to classify potential detection as clicks from beaked whale family and separate them from dolphin and man-made signals. The third stage detector separates identified beaked whales into different species using clustering analysis algorithm based on the features of beaked whale clicks, such as duration, peak frequency, bandwidth, centroid frequency and slope, etc. In the proposed method, the beaked whales can be discriminated by automatic algorithm, the processed time for large volumes of acoustic data can be reduced obviously compared with other methods using operator involvement. [This research was made possible by a grant from The Gulf of Mexico Research Initiative. Data are publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC)]

Abundance, Distribution and Dynamics of Shark Populations in the Gulf of Mexico

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Shark species are a significant component of demersal and pelagic fish communities in the Gulf of Mexico. They exhibit varying life history repertoires resulting in a range of relative sensitivities to chronic and acute stresses afforded by anthropogenic and natural factors. Most shark species are highly vulnerable to increases in mortality beyond background levels, owing to the limited reproductive capacity of elasmobranchs. Using data from a Gulf of Mexico-wide, fishery-independent demersal longline survey, conducted in 2011-2016, I report on the relative abundance, community structure, size, and sex composition of sharks. Abundance of large coastal shark populations varies significantly among Gulf regions, likely due to variations in fishing intensity. Populations of small-bodies sharks show more consistency among regions. Implications for the management of large-bodies vertebrate populations and their supporting ecosystems in the Gulf are discussed.

* Student Presenter

Impact of an Oil Spill and Emergency Response on Thick-billed Murre Feathers

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This experiment investigated whether an offshore oil incident and emergency response involving the use of dispersants would impact the feather microstructure and mass of Thick-billed Murres (*Uria lomvia*), a widely dispersed and abundant seabird in the North Atlantic, and by extension the bird's very survival in the event of an oil disaster if its insulating feathers were compromised. I investigated this question by mimicking an offshore oil pollution incident and emergency response environment by exposing feathers to seawater only, an oil sheen on seawater, an oil sheen mixed with dispersant on water, and dispersant mixed with seawater. The experiment indicated that dispersants were harmful to the water-proofing of Thick-billed Murres' feathers, even if dispersants were perceived as necessary in mitigating the damage from an oil spill. The overall results of my experiment encourage further investigation into the use of dispersants as a way to mitigate oil spill disasters and add to the discussion about looking for alternative mitigation tactics in light of the changing legalities in dispersant usage.

Sperm Whale Sizes near the BP Oil Spill

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Echolocation clicks of sperm whales are composed of several short pulses, the first produced by the original pulse from the phonic lips (or so called museau de singe/monkey lips) of the whale followed by consecutive reflections from the frontal and distal air sacs that bound the ends of the spermaceti organ (Madsen *et al*., 2005). The interpulse interval may be used to calculate the size of the spermaceti organ, and from this the length of the whale may be estimated (Goold *et al*., 1996). The difference in the time interval between the p0 and p1 pulses compared with the difference in the time interval between the p1 and p2 pulses may give an indication of the size of the phonic lips in an individual whale. Average whale sizes and size changes are possible indicators of the health of the whale population. The Littoral Acoustic Demonstration Center - Gulf Ecological Measuring and Monitoring (LADC-GEMM) project collected underwater acoustic data in the northern Gulf of Mexico during the summer of 2015, returning to sites previously surveyed by LADC. Results presented here are produced using 2015 data recorded by Environmental Acoustic Recording Systems (EARS) buoys at the site closest to the BP oil spill. Determining the interpulse interval requires a high sample rate, and current calculated lengths can be compared to lengths from previous measurements with high enough sample rates as well as to suitable future measurements in order to determine changes in average whale size.

This research was made possible by a grant from The Gulf of Mexico Research Initiative. Data are publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) at https://data.gulfresearchinitiative.org.

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Assessing Beaked and Sperm Whale Movement Patterns Using Acoustics and Environmental Characteristics in the Northern Gulf of Mexico

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Acoustic data were collected at three underwater moorings using Environmental Acoustic Recording System (EARS) buoys in the northern Gulf of Mexico in 2007, 2010, and 2015. The target area includes three moorings near Deepwater Horizon oil spill site at locations: 28.65°N 88.53°W (North Site), 28.42°N 88.62°W (South Site), 28.40°N 88.99°W (West Site). Sperm and beaked whale daily activity and sea surface temperature data collected by the NASA Aqua/Terra satellites were used to correlate whale movement patterns with change in sea surface temperature. Currently, data analysis of the 2007, 2010, and 2015 deployments, at all three moorings, is taking place in order to provide a more complete understanding of how change in sea surface temperature may drive the movements of sperm and beaked whales near Deepwater Horizon oil spill site. Daily ambient noise level data are fused with temperature and detection data in order to further investigate environmental factors which may drive the regional movement patterns of sperm and beaked whales in the northern Gulf of Mexico. Results from this research will provide a better understanding of which environmental characteristics have the greatest impact on marine mammal movement patterns and how recent oil spill and underwater noise generated by the offshore industry are affecting marine mammal populations in the northern Gulf of Mexico. [This research was made possible in part by a grant from The Gulf of Mexico Research Initiative]

Localization and Tracking of Sperm Whales Observed near the BP Oil Spill

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Sperm whales produce very loud echolocation clicks that make them relatively easy to locate and track using sufficient detection locations. The Littoral Acoustic Demonstration Center - Gulf Ecological Measuring and Monitoring (LADC-GEMM) project collected underwater acoustic data in the northern Gulf of Mexico during the summer of 2015, returning to sites previously surveyed by LADC. Results presented here are produced using data recorded by Environmental Acoustic Recording Systems (EARS) at the northernmost of three sites, where three EARS buoys were deployed about 1 km apart, the location closest to the BP oil spill. Two hydrophones were separated vertically by 1 m on each mooring, allowing depth localization as well as horizontal. Sequential locations produce a track of the whale's motion. Locating specific whales can be used to help determine the number of whales present, for comparison with previous and future measurements. Tracking can also show whale activity. The number of whales and their activity are indicators of the health of the area and the marine mammal populations around the oil spill.

This research was made possible by a grant from The Gulf of Mexico Research Initiative. Data are publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) at https://data.gulfresearchinitiative.org.

* Student Presenter

Influence of oceanographic conditions on distribution and abundance of blackfin tuna (*Thunnus atlanticus*) larvae in the Gulf of Mexico.

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This study investigated the effect of mesoscale oceanographic features on the distribution and abundance of blackfin tuna larvae in the northern Gulf of Mexico (GoM). Ichthyoplankton surveys were performed in June and July over six years (2007-2011 and 2015) during the primary spawning period of this species. Blackfin tuna were commonly observed and widely distributed in our sampling corridor (26.5-28ºN, 88-93ºW), with frequency of occurrence ranging from 48% (2008) to 92% (2011). Interannual variability in density was observed with highest mean density recorded in 2009 (17.2 larvae $1000m^{-3}$) and lowest mean density in 2011 and 2015 (2.7 larvae $1000m^{-3}$). An intra-annual difference in density was also detected with higher mean densities in July (9.2 larvae $1000m^{-3}$) than June (4.3 larvae $1000m^{-3}$). Generalized additive models (GAMs) based on presence/absence and density were developed to examine the impact of mesoscale features and their associated physicochemical conditions (sea surface temperature, salinity) on blackfin tuna. Salinity and sea surface temperature were important explanatory variables, with higher densities of blackfin tuna present in areas of intermediate salinities (31-36psu) and higher temperatures (>29°C). Blackfin tuna were also strongly associated with convergent zones near the Loop Current and other anticyclonic features (eddies). Finally, habitat suitability maps developed based on GAMs and environmental conditions in 2011 and 2015 revealed that the amount of highly suitable habitat of blackfin tuna varied between months (June 6%, July 51%); however, blackfin tuna larvae were distributed in similar locations along the continental slope and at the margin of the Loop Current in the northern GoM.

Foraging Movement Patterns of Breeding Royal Terns (*Thalasseus maximus*) on the Isles Dernieres Barrier Islands Refuge in Southern Louisiana

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Royal Terns (*Thalasseus maximus*) breed annually in colonies on the remote Isles Dernieres Barrier Islands Refuge (IDBIR) in southeast Louisiana. Previous studies on the IDBIR have examined diet composition of Royal Terns, but there is a paucity of information on the location of important foraging areas or how much time terns spend away from the colony to search for food. Four mGPS-2loggers were attached to individual adult breeding Royal Terns (3 males, 1 female) in June 2014 (n=2) and May 2016 (n=2) and each device was recovered three days later. GPS loggers recorded location, speed, and elevation every 15 minutes. Foraging movements were analyzed for each bird where at least one GPS point was recorded off the island. Maximum distances from the colony ranged from 2.1 km to 47.8 km and round trip distances of foraging trips ranged from 4.3 km to 111.0 km. A kernel density analysis was used for each bird to identify areas where individuals were foraging 50 % and 95 % of the time during trips. Spatial distribution of GPS points revealed that Royal Terns used adjacent nearshore waters, salt marshes, and offshore areas for foraging. This is the first time that foraging areas used by Royal Terns in the Gulf of Mexico have been identified and may be useful for future management decisions and risk assessments from future disturbances, such as oil spills and adverse weather events.

* Student Presenter

Comparing performance of bottom-moored, glider, and unmanned surface vehicle towed PAM platforms for marine mammal detection

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Passive acoustic monitoring (PAM) is a more effective method of monitoring the distribution and abundance of deep-diving cetaceans than conventional visual surveys. Many species are highly vociferous and produce identifiable acoustic signals during echolocation and communication. Three different PAM platforms recorded data in overlapping time periods in the vicinity of the 2010 oil spill site: Unmanned Surface Vehicle towed array, bottom-moored buoys and subsurface glider-mounted hydrophone. These were compared for their efficiency in detecting marine mammals. Detection events were obtained using independent detectors for each platform and then compared by feeding data through a common detector. The results of this study aid in the development of cost-efficient PAM methodology for mitigation and environmental impact assessment purposes. “This research was made possible in part by a grant from The Gulf of Mexico Research Initiative, and in part by ONR and DoD. Data are publicly available through the Gulf of Mexico Research Initiative Information & Data Cooperative (GRIIDC) at https://data.gulfresearchinitiative.org.”

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Session 005: Recovery from the Bottom Up: Rates, Processes, and Connectivity in the Deep Gulf of Mexico

Larger Predatory Fishes of the Meso- and Bathypelagic Domains: Linking the Planktivores and Top Predators

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Mesopelagic fish biomass has been estimated at 7-10 billion metric tons, an order of magnitude higher than previous estimates. This upscaling has resulted from the acoustical quantification of net avoidance, particularly avoidance of smaller, research-sized nets such as rectangular midwater trawls (RMTs) upon which previous estimates were based. Net avoidance by fishes is size-dependent, thus our greatest underestimation is likely that of the larger deep-pelagic fishes. Here, we present results from a research program in the Gulf of Mexico that used a large, dual-warp pelagic trawl in concert with an opening-closing RMT to sample from 0-1500 m depth. A total of 129 quantitative samples were obtained with the large trawl, representing over 337 million cubic meters of water filtered. Results showed a stark difference in both the size class and taxonomic composition of fishes collected with the two gears. Some of the larger, predatory deep-pelagic fishes collected were dragonfishes, anglerfishes, great swallowers, pelagic eels, and snake mackerels. Aspects of faunal composition, abundance, biomass, and size distributions will be presented. These larger deep-pelagic fishes are preyed upon by top predators such as sharks, billfishes, tunas, toothed whales, and deep-demersal fishes. Thus, data from this study will help improve our understanding of the links between zooplanktivorous micronekton and apex predators. The inclusion of large deep-pelagic fish biomass should dramatically improve ecosystem modeling efforts aimed at understanding carbon flow in the deep ocean interior.

LADCP Observations during ECOGIG Cruise EN586

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During the ECOGIG EN586 cruise to the Northeastern Gulf of Mexico in summer 2016, a Lowered Acoustic Doppler Current Profiler (LADCP) system was used to collect full-depth profiles of the 3-dimensional oceanic velocity field, as well as of acoustic backscatter at 300kHz, at several seep and background stations, including profiles from the brine lake in Orca Deep. Due to a combination of strong surface currents (approaching 1m/s) and a light CTD rosette, the package angles in many of the profiles exceeded the hardware limitations of the ADCPs, requiring the use of an external attitude sensor system to obtain time series of valid pitch and roll. The external attitude package also provides measurements of the 3 components of the earth's magnetic field, which were used to determine a full compass calibration (for hard- and soft-iron effects) from in-situ data. Here we present results from an analysis of the resulting velocity data, with emphasis on interior processes, including subinertial vertical convergence, internal waves, turbulence and mixing.

* Student Presenter

Interactions between Bacterial Breakdown of Oil, Oxygen Consumption, and Macronutrient Availability in the Offshore Gulf of Mexico

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Oil introduced to the deep, offshore waters of the Gulf of Mexico by natural oil seeps is subject to breakdown by heterotrophic bacteria, consuming oxygen as one consequence. However, because oil contains little N or P, and macronutrient concentrations in offshore surface waters of the Gulf of Mexico are typically very low, degradation of oil by bacteria in offshore surface water is usually nutrient limited. Without a source of nutrients, oil degradation and bacterial growth following oil addition is negligible, regardless of oil concentration. By contrast, when N and P are added, oxygen consumption and bacterial growth are dose-response functions of oil concentration. Bacterial breakdown of oil from natural seeps in the offshore near surface waters is therefore predicted to be primarily dictated by nutrient availability, rather than oil supply. In this context, nutrients to the offshore waters are likely to either be supplied by vertical mixing, or by horizontal advection of the Mississippi river plume. Experimental additions confirm that oil breakdown proceeds without added nutrients in both deep water and river-plume influenced surface layers. For example, bacterial growth rates and oxygen consumption were higher following oil addition to deep water, despite lower temperatures, than when oil (without nutrients) was added to offshore surface waters. Extrapolating to anthropogenic oil spills, bacterial degradation of spilled oil in offshore waters would be rapid and concentration dependent in deep water, and in surface layers affected by the river plume. However, negligible bacterial oil degradation would be expected in low nutrient surface waters.

Monitoring Methane Transport and Sediment Total Oxygen Utilization in the Friction Layer at GC185, GC600 and GC767 in the Northern Gulf of Mexico

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Time-series, depth profiling measurements from free vehicle mini-landers (ML's) of methane and bottom currents in the friction layer at multiple hydrocarbon-rich lease blocks in the northern Gulf of Mexico reveal methane concentrations ranging from background values of less than 5 nM to over 4000 nM. The ML's were equipped with laser methane sensors, acoustic Doppler profiling current meters and multiple oxygen, temperature and pressure (depth) sensors. Continuous time-series methane measurements for periods of weeks within 10 m of the seafloor combined with current speeds and directions from acoustic Doppler profilers revealed large spatial methane concentration gradients near the seafloor and temporal variability in those gradients controlled by water transport from nearby hydrocarbon sources. Observed current speeds at Green Canyon (GC) locations ranged from less than 2 to over 30 cm/s within the friction layer from 2 to 30 m above the seafloor. Triangulation and downstream deployments of ML's around gas and oil seeps provide capabilities for long term monitoring and rapid responses to both natural and accidental hydrocarbon releases. Apparent total sediment oxygen utilization (TOU') estimates were calculated from continuous dissolved oxygen (DO) vertical concentration gradient and current speed measurements using open cylinder "chimney" chambers, equipped with with multiple DO optodes deployed from the ML's. The chimney TOU' measurements allowed continuous in situ monitoring of changes in sediment DO consumption in undisturbed or hydrocarbon-impacted sediments for periods of hours to months. TOU' values measured at background sites fall within the observed range of TOU values from upper slope environments around

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the world. Rapid deployment of open chimney-equipped ML's allows for fast responses to hydrocarbon "snow" events associated with accidental oil and gas releases.

Sensitivity of Deep-Water Column Micronekton to 1-methylnaphthalene

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Despite intense research effort into the ecological consequences of the Deepwater Horizon spill, many questions remain regarding the current health of the ecosystem, and what this disaster can teach us for responding to future spills. One important component of the Gulf of Mexico ecosystem that has received relatively little attention is the deep-water column micronekton and plankton inhabiting depths from 200 - 1000 m. These organisms are key trophic intermediates in deep-sea food webs, and represent a major trophic link between deep-water and shallow-water ecosystems. Here, the toxicity of 1-methylnaphthalene to several species is assessed in 48 h constant-exposure multi-concentration toxicity tests utilizing a passive dosing system. Acute effects are evaluated both during exposure and at the end of the 48 hour exposure period. This research is part of a series of studies for the Deep-sea Risk Assessment and Species Sensitivity to WAF, CEWAF and Dispersant project (D-TOX), designed to advance understanding of hydrocarbon toxicity in several ecologically important deep-sea zooplankton/micronekton. This data will be of immediate use to process-based studies in the Gulf by allowing more definitive incorporation of mesopelagic animals into data interpretation.

DEEPEND: Preliminary Results of Cephalopod Vertical Migration Patterns in the Northern Gulf of Mexico

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Cephalopods are important in midwater ecosystems of the Gulf of Mexico (GOM) as both predator and prey. Vertical distribution and diel migration patterns are not known for the majority of deep-water cephalopods. These varying patterns are of interest as they have the potential to contribute to the movement of large amounts of nutrients and contaminants through the water column during diel migrations. Two recent studies focusing on the deep water column on the GOM (2011 Offshore Nekton Sampling and Acoustics Program (ONSAP) and 2015-2017 Deep Pelagic Nekton Dynamics of the Gulf of Mexico (DEEPEND)) project, produced a combined dataset of over 12,500 midwater-cephalopod records for the northern GOM region. Cephalopod vertical distribution patterns will be highlighted from the ONSAP and DEEPEND cruises which utilized a Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS). Species accounts include those with synchronous (e.g. *Pterygioteuthis* sp.) and asynchronous (e.g. *Stigmatoteuthis arcturi*) vertical migration. Non-migration patterns of various midwater cephalopods (e.g. *Vampyroteuthis infernalis*) are also highlighted.

* Student Presenter

DEEPEND: Matching Unidentified Larvae to Adults Using Molecular Methods
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Many species of marine animals undergo major transformations and re-organizations of their appearance and physiology during metamorphosis from larval to juvenile or adult forms. These transformations are fascinating, but lead to problems of identification of the larval organisms involved. One method of determining which species an unusual larval actually is requires growing larvae in culture and observing the transformation as it happens. This is virtually impossible for deep-sea and oceanic animals. We have been using molecular genetics to match unusual larvae to their respective adult forms. Using leptocephali larvae of eels as an example, we can now demonstrate the identity of several problematic fish larvae and link oceanic larval life history phases to adults with previously unknown larvae.

Organic Carbon Remineralization Rates in the Deep Gulf of Mexico Estimated from Oxygen and Dissolved Inorganic Carbon and Its Isotopic Composition
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This study provides new data for the establishment of a carbon biogeochemical dynamics baseline in the deep Gulf of Mexico based on oxygen concentrations and carbon isotopes in dissolved inorganic carbon. We present the results from seven cruises that took place south of 25ºN in the Deep Gulf of Mexico from 2010 to 2016, during which vertical profiles of temperature, salinity and dissolved oxygen were measured and water samples were collected for laboratory analysis of dissolved inorganic carbon concentrations and its isotopic composition. We use the acquired data to estimate the residence times of the water masses present in the Deep Gulf of Mexico and the organic carbon remineralization rates. The water mass with the higher remineralization rate is The North Atlantic Subtropical Mode Water located from a 120 m to 240 m with an estimated organic carbon remineralization of 3.52×10^{12} g C per year.

The DEEPEND Pelagic Fauna Project: Contributions and Considerations for Science and Outreach
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In many ways the deep-pelagic environment is the “elephant in the dark room” - it is the Gulf of Mexico’s largest yet least known ecosystem. Engaging public understanding and empathy for its inhabitants through high-quality photo documentation has been a key element of the DEEPEND Consortium. Vivid images serve as a primary tool in education and outreach, opening up a diversity of platforms from which messages can be communicated to the public. DEEPEND images have appeared in the *Creep into the DEEPEND* virtual classroom missions, Smithsonian’s *Ocean Portal*, the book *Life in the Dark* (Fenolio, 2016), *Sport Fishing* magazine, all DEEPEND outreach displays and handouts, and countless social media and news stories world-wide. Photographic records have also served as quality control measures via image filename synchronization with field sample metadata. Further, images provide scientific-character data in the form of pigmentation, pattern, and colors that are quickly lost via the preservation process. These data are critical to taxonomists, behavioral ecologists and biologists

* Student Presenter

specializing in organismal communication. A system for recording busy, multi-day cruises was designed prior to time at sea. This system design reduced loss of time, the need to retake images, and the loss of valuable opportunities when rare specimens were captured. Pre-cruise preparations included a clear understanding of what each PI required photographically, establishing methods to properly capture key features of a diversity of wildlife, and an understanding education and outreach needs through discussions with specialists in that field. When properly implemented, photography can transform a project into a dynamic program with significant public engagement. In this presentation the DEEPEND Imaging Project Lead will discuss techniques, successes, and lessons learned from four DEEPEND expeditions in the deep Gulf of Mexico around the site of the Deepwater Horizon oil spill.

DEEPEND: Once bitten, twice shy: a cryptic species of Sloane's Viperfish (*Chauliodus sloani*) discovered in the mesopelagic waters of the Gulf of Mexico

R. I. Eytan[1], E. Paulus[2], M. Weber[3], T. T. Sutton[4]
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The deep-oceanic Gulf of Mexico (GoM) is one the highest diversity pelagic ecosystems in the world. The diversity GoM deep-sea fish fauna is exceptional, and rivals or exceeds that found in other deep-pelagic ecosystems. While some species of deep-sea fishes appear to be exclusively found in the GoM, a large portion of the deep-sea fish fauna is represented by species found in other basins. However, genetic methods have begun to unravel some of this traditional taxonomy, and have revealed unanticipated diversity and endemism in the deep-pelagic of the GoM. This is in the form of cryptic species, those that are closely related and morphologically similar to described taxa, but for which genetic data has identified as being novel lineages. One example is *Chauliodus sloani* or Sloane's viperfish, a mesopelagic predatory fish found throughout the earth's deep-pelagic waters. Our genetic surveys of viperfish samples using the mitochondrial barcoding gene *COI* has revealed two deeply divergent viperfish linages co-existing in the GoM, one apparently endemic to the GoM. These fishes live in sympatry, with no obvious ecological or morphological differences separating them. Nonetheless, there is over 11% pairwise sequence divergence between the two lineages, and species delimitation methods have identified them as two independently evolving lineages. Looking towards the future, we plan to perform further morphological and genetic work to better tease apart the evolutionary mechanisms responsible for the generation of this novel biodiversity and the maintenance of species boundaries in the deep-sea. This, in turn, will further our understanding of the generation of biodiversity in the GoM.

Quantifying Pelagic Habitat Use by Myctophid Fishes in the Northern Gulf of Mexico

R. J. Milligan, T. T. Sutton
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Deep pelagic ecosystems are some of the largest on Earth but are amongst the least understood. As human impacts on the deep oceans continue to increase, there is an urgent need to understand the processes that influence pelagic fauna, particularly in deep waters. One of the most globally-important taxa are the myctophid fishes, which are a ubiquitous component of the deep-pelagic micronekton and play key roles in the vertical and horizontal transfer of energy between ecosystems. In the present study, we analysed quantitative, depth-stratified trawl data to assess the distributions of the dominant myctophid species in relation to physical and chemical environmental variables in the northern Gulf of Mexico (GoM) during summer 2011. The data were collected through the NOAA-supported Offshore

* Student Presenter

Nekton Sampling and Analysis Program. The vertical distributions of the myctophids were strongly correlated with diel cycles relating to their vertical migration behaviours, but correlations with other environmental variables were generally weak, suggesting limited horizontal structure across the northern GoM. These results suggest that other processes such as migration, random dispersal, population growth or interactions between species may be more important in structuring myctophid communities at this spatial scale than physical or chemical changes in their environments.

DEEPEND: Relating Pelagic Habitat to Ocean Stratification

S. deRada
Naval Research Laboratory, Stennis Space Center, MS

The Gulf of Mexico Research Initiative DEEPEND (Deep-Pelagic Nekton Dynamics of the Gulf of Mexico) consortium's objectives include the characterization of biophysical variability in the water column. Observational and multi-model approaches are used to increase understanding of the dynamics of deep-pelagic (0-1500 m) fish assemblages at multiple temporal and spatial scales. To date, four DEEPEND cruises, conducted during 2015 and 2016, collected biophysical data in the Northern Gulf of Mexico. In an effort to make an initial assessment of the relationships of pelagic habitat to mesoscale surface dynamics and physical water masses, a 1/25° horizontal-resolution HYCOM ocean model simulation is used to complement these in-situ measurements. The observational data are matched up to model analyses for each cruise track and sampling station to examine the evolution of physical features, such as the mixed layer depth, the loop current, loop current eddies, and cyclonic (cold core) rings. In order to gain insight into the connections among biologically active zones, pelagic regimes, and physical hydrodynamics and stratification, water mass classification techniques are used to inspect the water column for each DEEPEND cruise. The analysis elucidates a platform for better understanding physical-biological interactions, their environmental drivers, and the implications of natural variability and anthropogenic load on pelagic habitat.

Geographic Distributions and Reproductive Seasonality of Oplophorid and Euphausiid Crustaceans in the Vicinity of the Deepwater Horizon Oil Spill

T. Frank, C. Fine, E. Burdett, A. Cook, T. Sutton
Nova Southeastern University, Dania Beach, FL

This talk will present the first description of the oplophorid (Decapoda: Oplophoridae) and euphausiid (Euphausiacea: Euphausiidae) crustacean assemblages around the site of the Deepwater Horizon Oil Spill (DWHOS). These are two of the most abundant crustacean groups in the Gulf of Mexico (GoM), and are important components of the pelagic food web. The data presented here are from expeditions that were conducted after the oil spill; no pre-spill assessments are available. This talk will present species' vertical distributions/migratory behavior, including the first comprehensive data on euphausiid distributions from depths > 1000m in the GoM, differences between slope (on the landward side of the 1000m isobath) and offshore (on the open ocean side of the 1000m isobath) assemblages, and an assessment of reproductive seasonality. These are the first data from this region, and will be compared, in the future, with DEEPEND data from 2015-2017 to assess possible temporal changes in the assemblages that may be correlated with impacts of, or recovery from, the DWHOS.

* Student Presenter

Ecological and Geophysical signatures of natural hydrocarbon seep sites in the Gulf of Mexico: A descriptive overview of sites GC600, GC574, GC857, and GC767

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The Modular Instrument Lander and Equipment Toolsled (MILET) was used to obtain geophysical and benthic ecological observations along transects in the Gulf of Mexico that surveyed natural hydrocarbon seep sites located in lease blocks GC600, GC574, GC847 and GC767. The survey areas were identified by combining satellite remote sensing with surface reflectance geophysical data. Continuous video stream and visible light photography taken at 10-second intervals quantify distributions of macrofauna, sedimentary deposits, and microbial mat assemblages on the seafloor. Continuous sub-bottom profile data using an EdgeTech 3200 Sub-bottom Profiling System revealed frequent disruptions in continuous sedimentary deposits via gas wipeout. Seep sites were characterized by large (exceeding 7 m^2) carbonate deposits with elongated crevasses, on which corals, tube-worms, and microbial mats assembled. Large clusters of muscle shells (exceeding 9 m^2) were observed within 100 m of observed carbonate deposits. The proximity of these features with respect to gas wipe-out zones will be evaluated. The MILET system offers a cost effective methodology for identifying sensitive chemosynthetic communities and monitoring potential effects of human activity.

Controls on Sediment Redox Depth in the GoM Following the 2010 DWH Event

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A suite of 132 multicores collected in the NE Gulf of Mexico (GoM) from 2010 to 2016 exhibit a distinct brown discoloration extending from the core surface to a maximum of 25 cm. This discoloration has been shown to be a result of manganese oxide precipitation in the oxidizing surficial sediment. The base of the discolored layer is represented by a 1-4 cm dark brown-black band corresponding to the redox boundary. In many cases a second dark brown-black band was detected above, which is interpreted to represent the upward jump of the original redox boundary in response to a sedimentation event (MOSSFA) triggered by the 2010 DWH oil spill (NE GoM). The Mn oxide layer thickness was measured and compared to water depth and distance from the DWH wellhead. An ArcGIS model was created to display the spatial distribution and down-core thickness of redox bands in the NE GoM. A direct connection between redox layer thickness and water depth is evident. Additionally, core sites further from the wellhead, within a uniform depth range, display a decrease in redox band thickness. We suggest distance from the wellhead and water depth both act as controls on redox band thickness. Analysis will continue to investigate the specific processes involved, as well as extend the study to the 1979/1980 IXTOC-I spill site in the SW GoM.

* Student Presenter

DEEPEND: Genetic Identification and Population Characteristics of Deep-sea Cephalopod Species in the Gulf of Mexico and Northwestern Atlantic Ocean

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Nearly all deep-sea cephalopod life history studies have been completed by examination of specimens at various life stages collected in the wild. Much of this work is like piecing together a puzzle; knowledge of the life history of many species remains fragmented and hence, taxonomically and phylogenetically confused. The combination of morphological and molecular approaches is a powerful tool for deciphering cephalopod life history and population dynamics. Use of molecular markers offers additional certainty for identifying specimens damaged during collection and can elucidate often cryptic, intra- and interspecific diversity. This study has three key objectives: [1] linking morphological identification with DNA barcoding of deep-sea cephalopods, [2] examining intraspecies variation and divergence estimates of deep-sea cephalopods at the regional level, across different stations in the Gulf of Mexico (GoM), and [3] examining intraspecies variation and divergence estimates of deep-sea cephalopods at the population level, comparing collections separated by the Florida Peninsula (GoM and northwestern Atlantic Ocean). We examined specimens collected in the Gulf of Mexico (GoM) over a two-year period through the Deep Pelagic Nekton Dynamics of the GoM (DEEPEND) project as well as specimens collected near Bear Seamount off of New England. Four marker genes were used to examine intraspecific population connectivity: two nuclear genes (ribosomal Internal Transcribed Spacer (ITS) and 28S rDNA) and two mitochondrial genes (16S rDNA and Cytochrome c Oxidase subunit I (COI)). By analyzing the gene pool and connectivity of deep-sea cephalopod populations, we will infer the amount of gene flow within several cephalopod species in the GoM and northwestern Atlantic.

DEEPEND: DNA Barcoding of Deep-Sea Crustaceans in the Gulf of Mexico

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The Gulf of Mexico is inhabited by a large and diverse group of crustaceans. As part of the DEEPEND consortium, we obtained DNA barcodes of deep-sea crustaceans to aid in identification efforts, adult-larval linkages, and new species discoveries. A genetic barcode is a unique section of DNA that can be used as a representative sequence for the corresponding species. Barcoding provides a standardized approach for species identification when traditional taxonomic methods are not possible, for instance due to cryptic species or damaged specimens. Crustacean specimens were collected from the Gulf of Mexico during 4 consecutive DEEPEND research cruises from 2015 to 2016. Processing the specimens involved identifying the specimen through traditional taxonomic techniques and extracting abdominal muscle tissue to extract DNA. We extracted DNA and subsequently utilized polymerase-chain reactions (PCR) to amplify regions of 16S and COI mitochondrial genes, which are the standardized genes for DNA barcoding in Crustacea. Due to the limited success of universal primers, new primers were designed to amplify both 16s and COI gene sequences for several lineages: Euphausiidae, Solenoceridae, and Sergestidae. These newly designed primers proved instrumental in obtaining high-quality DNA barcodes for the species in these families. The new and universal primers resulted in successfully barcoding of over 80 species from 22 families, across 4 orders of Crustacea. All barcodes are being deposited in open-source databases to serve as a genetic species inventory of deep-sea crustaceans. They will also be used in studies exploring adult-larval linkages, population connectivity, phylogenetics, and cryptic species

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complexes. This will ultimately contribute to a more accurate monitoring of the Gulf of Mexico's biota and provide a baseline for future studies in this highly important body of water.

Benthic Diatom Population Response to the Oiling of Coastal Waters
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The environmental impacts of the Macondo oil spill of April 20th, 2010 are still being assessed six years after the event. The goal of this study is to compare the assemblages of preserved edaphic diatoms in the sediments of Barataria and Terrebonne Bays in southern Louisiana. We examined three different sites to survey the living diatom populations in order to document potential differences in diatom diversity or absolute abundance between the sites. We predicted that there will be lower diatom diversity at the oiled sites due to a loss of less resilient species, but a higher abundance of the more tolerant forms. The results provide valuable information on how the benthic diatom community responds to oiling events.

Variations in the Parasite Fauna and Gut Contents of Vertically Migrating and Non-Migrating Mesopelagic Fishes of the Northern Gulf of Mexico
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The mesopelagic zone (200-1000 m) houses fishes that are important consumers of zooplankton and are prey to oceanic apex predators (e.g. billfish, tuna, cetaceans). Two dominant mesopelagic fish families, the lanternfishes (Myctophidae), and the hatchetfishes (Sternoptychidae) occupy a similar daytime depth and prey primarily upon crustacean zooplankton. Lanternfishes undertake diel vertical migrations, occupying the epipelagic zone (0-200 m) during the night before descending during the day. The hatchetfish genera *Sternoptyx* and *Valenciennellus* do not perform this action. Endoparasites progress up the food web via consumption by their hosts until they are able to reach maturity. The relationship between parasites and gut contents provides insights into ecological processes occurring within assemblages. This study examined the differences between the prey contents and parasite fauna of these two families. Prey contents were identified to family and placed into prey categories. Results showed that *Sternoptyx* fed upon a broader range of taxa than lanternfishes. Concordantly, *Sternoptyx* harbored a greater abundance of parasites than lanternfishes. Prey categories were organized by depth. Lanternfishes caught in the upper 200 m of the water column fed upon a more diverse network of zooplankton fauna and more prey items per fish than lanternfishes captured at deeper depths.

Faunal Composition and Spatiotemporal Dynamics of Tuna (Family: Scombridae) Early Life Stages in the Oceanic Gulf of Mexico
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Fishes within the family Scombridae (i.e., tunas, mackerels and bonitos) are of high economic and ecological value in the Gulf of Mexico (GoM), as they are heavily targeted by commercial and recreational fisheries. In coastal and open-ocean environments, adult tunas are top predators, while larval and juvenile tunas serve as prey for numerous species. Much is known about the distribution and

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abundance of adult tunas, but high taxonomic uncertainty and limited knowledge regarding the distributional patterns of larval and juvenile tunas have led to an "operational taxonomic unit" gap in our understanding of tuna ecology. This analysis examines the spatiotemporal dynamics of larval and juvenile scombrids collected across a wide swath of the northern GoM from April to September, 2011, as part of the NOAA-supported Offshore Nekton Sampling and Analysis Program. The distribution and relative abundance of several key tuna species (*Thunnus thynnus*, *T. atlanticus*, *Auxis thazard* and *Euthynnus alletteratus*) collected from the surface to 1500 m depth are characterized across the oceanic GoM (Louisiana to Florida) with respect to depth, time of year, and in relation to mesoscale oceanographic features. Integrating aspects of scombrid ecology in neritic and oceanic environments will improve management and conservation efforts for this highly important taxon.

Juvenile Assemblages of Families Lutjanidae and Serranidae in the Gulf of Mexico, with Respect to the Loop Current and other Hydrographic Features

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The Gulf of Mexico (GoM) is a uniquely dynamic environment with a variety of hydrographic features and oceanographic processes taking place. These features include; the Loop Current, long lived cyclonic and anticyclonic eddies formed as a result of the Loop Current, and the Mississippi River Plume. These hydrographic features are important drivers to many of the biological processes occurring in the GoM and are directly responsible for the extent to which the DWH Oil Spill was spread throughout the Gulf. The relationship that these features have on the long term community assemblages of Families Lutjanidae (snappers) and Serranidae (groupers) has been of great interest from both a biological and economic point of view. These families are home to some of the most economically important fisheries in the GoM and represent some of the larger predators found in reef ecosystems which are important when considering their ecological and trophic niches. Identifying the role these features play in the transportation of larval and juvenile nearshore species to offshore environments is vital to resource managers. This information will allow managers to account for future changes to the environment and the effect large scale disturbance events could have on these economically important fishes. Using historical data collected shortly after the DWH Oil Spill via the NOAA Natural Resource Damage Assessment (NRDA) in 2011 we plan to analyze the community assemblages of snappers and groupers in the GoM. In conjunction with this data, cruises conducted by the Deep Pelagic Nekton Dynamics of the Gulf of Mexico (DEEPEND) Consortium from 2015-2017 will be analyzed to identify the natural variability of species assemblages for snappers over the three year time line. In comparing these two analyses we hope to identify the potential long term affects the DWH Oil Spill may have had on these fish assemblages and also identify signs of recovery over time.

Effects of Rotation on the Dynamics of Single-phase and Multi-phase Point Plumes

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Motivated by the Deepwater Horizon oil spill in the Gulf of Mexico and by the effects of the Earth's rotation on the oil distribution in the ocean, we investigate the dynamics of single-phase and multi-phase plumes in a rotating and stratified environment through laboratory experiments and numerical simulations. We conducted small-scale experiments in the laboratory on salt water and bubble plumes

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in a rotating tank across a wide range of Rossby numbers. Rotation modifies entrainment into the plume and also inhibits the lateral spreading of the plume fluid which leads to various instabilities in the flow. In particular, we focus on the plume behaviour in the near-source region where the plume is dominated by its source conditions and study the effects of the source buoyancy flux, the nozzle radius and the rotation rate of the environment on the plume dynamics. One striking feature in our experiments is anticyclonic precession of the plume axis which leads to enhanced dispersion of the plume fluid in the ambient and which is absent in a non-rotating system. We observe that the anticyclonic plume precession scales linearly with the rotation rate of the environment. Complementary large-eddy simulations matching the laboratory parameters show a similarly strong influence of rotation on the plume dynamics. The numerical simulations are used to extend the laboratory experiments to a larger Rossby number, matching the plume from the Deepwater Horizon oil spill. An additional set of numerical simulations include a realistic background stratification and show a mid-depth intrusion. These simulations are used to examine rotational effects on the dynamics of the mid-depth intrusions. Based on the experimental and numerical results, simple models are developed to explain the influence of rotation on the plume and intrusion dynamics. These models also allow us to extend our analysis to subsurface oil plumes originating from a variety of natural and anthropogenic sources.

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Session 006: Processes in the Near Field of a Blowout

Shedding from Chemically-treated Oil Droplets Rising in Seawater

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The significance and degree to which droplet shedding (often referred to as tip-streaming) can modify the size of rising oil droplets treated with dispersants, has been a topic of growing interest in relation to subsea dispersion injection. Here we present both experimental observations and a numerical approach to predicting the extent to which oil droplets are subjected to shedding and secondary breakup, covering a wide range of oil viscosities and interfacial tensions. Observations of individual droplets, captured in a carefully controlled counter-current, demonstrate that droplets with interfacial tensions (IFT) associated with a 1% dispersant dosage can be subjected to tip-streaming. The tip-streaming processes are observed within a specific range of droplet sizes when the oil viscosity is sufficiently high and the IFT is sufficiently low. The affected droplets are observed to reduce in size, as smaller satellite droplets are shed, until the parent droplet reaches a stabile size. In agreement with previous studies, we confirm that the size limit of droplets that may be subjected to shedding of smaller droplets is related to the viscosity-dominated modified capillary number (Ca'), and that this remains the case for the low dispersant dosages typical of subsea dispersant injection. This, in combination with the IFT-dominated Weber number (We), enables a given droplet to be characterised into one of three states: 1) stable (Ca'<0.21 & We<12); 2) tip-streaming (Ca'>0.21 & We<12); 3) unstable and subject to total breakup (We>12).

Numerical studies of pure methane hydrate dissociation

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Gas Hydrates (GHs) are currently considered as one of the most important potential source for hydrocarbon fuel. These ice-like crystalline solid represent more than 50% of estimated carbonaceous fuel reserves and contain a high amount of natural gas per unit volume, being a clean alternative to other fossil fuels. One of the potential production systems of large scale natural gas hydrates is depressurization. This process is usually done by drilling a well into the hydrate reservoir, in order to lower the pressure and bring hydrate outside of the thermodynamic stability conditions. When this happens, hydrate starts to dissociate with consequent formation of water and gas. The transport phenomena involved during depressurization processes are poorly understood yet. In this study, we numerically model the dissociation of a pure methane hydrate (MH) cylindrical core due to depressurization. For the simulations, we consider a three-dimensional geometry. Using ANSYS Fluent®, supplemented with a User's Defined Subroutine (UDS), we solve the multiphase flow problem typical of hydrate dissociation processes. At one side of the geometry we set a value of pressure at which the hydrate is outside of the stability zone. At this location, hydrate forms a dissociation front that moves toward the other side of the geometry. We analyse how different values of outlet pressure and initial phase saturation influence the process, considering also the possibility of ice formation.

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Comparison of Meso and Large Scale Subsea gas Releases with Multiphase Eulerian-Lagrangian CFD Model

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Free gas at the surface harbors the potential to trigger major incidents. Thus, prediction of free gas at the surface and its subsequent dispersion in the atmosphere is of major concern when performing quantitative risk assessments (QRA) of offshore oil and gas activities. In a 2007 workshop the Norwegian Petroleum Safety Authority (PSA) identified that estimates regarding subsea migration of gas was the item associated with the largest uncertainty in current QRA analysis. Furthermore, for a multiphase blowout gas buoyancy can dominate the multiphase plume behavior and thus how oil is dispersed in the ocean column and how it surfaces. In response to this SINTEF has in a series of JIP's running continuously since 2008 developed a modelling framework for predicting the fate of large scale bubble plumes. The framework consists of a transient 3D CFD model employing an Eulerian VOF (volume of fluid) model for tracking the large-scale interface between the ocean and atmosphere coupled to a Lagrangian description of the dispersed bubble phase. The model accounts for gas compressibility, mass transfer, employs a dynamic bubble size model accounting for breakup and coalescence, damping of turbulence close to the ocean surface and ocean stratification. Here we compare results obtained using the CFD model to meso (~ 1 kg/s, 30 m) and large (~20 kg/s, 140 m) scale field experiments of starting plumes. We employed a novel sonar imaging system to image the evolution of the bubble plume throughout the water column, and an aerial imaging system to monitor the surface evolution of the plume as it surfaced. We investigate the effects of release rate on overall plume dynamics such as; rise time and plume angle, and compare CFD simulations with experimental observations. We find that progress in sonar imaging now allows subsea gas plumes to be visualized in detail and may prove a very useful tool in field situations. The CFD model presented captures all main features observed in the experiments. To our knowledge no studies have presented an equally detailed comparison of meso and large scale experimental observations with detailed multiphase CFD simulations. The developed model is implemented in a widely used commercial CFD code.

Simulating Deep Intrusion Layers in BLOSOM

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The Blowout and Spill Occurrence Model (BLOSOM) is a model developed by the National Energy Technology Lab (NETL), which simulates the 4-dimensional transport and degradation of oil after a spill or blowout event, including a dual-phase (oil and gas) buoyant plume. We have recently explored BLOSOM's ability to simulate Intrusion Layers following a deep blowout-- a formation which can be triggered by the presence of very small oil droplets--under conditions similar to those present during the Deepwater Horizon (DWH) spill. While the droplet sizes can be determined within the simulation parameters, the intention is to develop the capability of generating the small droplets from the introduction of dispersion agents. This presentation will discuss our simulations which replicate observations from the DWH and our progress in simulating the application of dispersing agents at depth.

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Reynolds Number Scaling to Predict Droplet Size Distribution in Dispersed and Undispersed Subsurface Oil Releases

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When modelling subsurface oil spills, the prediction of droplet size and distribution is important because of their direct influence on the fate and transport of oil in the marine environment. However, current knowledge and capability regarding these two oil droplet characteristics are still limited. One of the most recent and promising approaches for droplet size distribution is modified Weber number scaling developed by SINTEF, which was based on experimental results with Oseberg Blend crude. Still, the relationship between dispersant to oil ratio (DOR) and droplet size distribution has yet to be quantified. Our study aimed at testing the applicability of the modified Weber number scaling approach with another oil, Alaska North Slope (ANS), and developing a Reynolds number scaling approach for oil droplet size prediction for high viscosity oils. DOR and empirical coefficients were also quantified for the Reynolds number approach. Finally, a more feasible approximation, two-step Rosin-Rammler scheme, was introduced for the determination of droplet size distribution. Calculated and observed *d50*/*D* correlated well for prediction based on Reynolds number scaling. This new approach appeared more advantageous in avoiding the inconsistency in interfacial tension (IFT) measurements, and consequently delivered concise droplet size prediction. Furthermore, R^2 = 0.97 for the relation *A* = 10.97 ***** *exp*(-37.26 ***** DOR) between DOR and empirical coefficient *A* in Reynolds number scaling. The relation indicated that chemical dispersant played an important role in reducing the droplet size of ANS under different seasonal conditions. There might be thresholds for the dose of chemical dispersant, but this requires further experimentation. To better predict droplet size distribution, the proposed two-step Rosin-Rammler approach utilized two separate spreading coefficients: α_1 = 1.82 for *d*/*d50* <= 1 and α_2 = 1.65 for *d*/*d50* > 1, which gave more accurate results in most cases, especially for droplet sizes larger than *d50*. Together, the proposed Reynolds number scaling and two-step Rosin-Rammler approach provide a concise, reliable way to predict droplet size distribution, and support the decision of whether or not to apply chemical dispersant in an offshore oil spill.

Aerosolization of Oil Spill Matter: Experiments and Molecular Simulation

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We report laboratory aerosolization experiments and classical molecular dynamics (MD) simulations, with the objective of investigating the individual effects of the two Corexit surfactants Span 80 (nonionic) and dioctyl sodium sulfosuccinate (DOSS, ionic), on the aerosolization of oil spill matter to the atmosphere. Our simulation results show that Span 80, DOSS and the oil alkanes *n*-pentadecane (C15) and *n*-triacontane (C30) exhibit deep free energy minima at the air/seawater interface. C15 and C30 exhibit deeper free energy minima at the interface when Span 80 is present, as compared to the situation when DOSS or no surfactants are at the interface. These results suggest that Span 80 makes these oil hydrocarbons more likely to be adsorbed at the surface of seawater droplets and carried out to the atmosphere, relative to DOSS or to the situation where no surfactants are present. These simulation

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trends are in qualitative agreement with our experimental observations in a bubble-column setup, where larger amounts of oil hydrocarbons are ejected when Span 80 is mixed with oil and injected into the column, as compared to when DOSS is used. Our simulations also indicate that Span 80 has a larger thermodynamic incentive than DOSS to move from the seawater phase and into the air/seawater interface. This observation is also in qualitative agreement with our experimental measurements, which indicate that Span 80 is ejected in larger quantities than DOSS.

Hydrodynamics of Subsurface Oil Release without and with Dispersant: An Experimental and Numerical Study

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Experiments of horizontal underwater oil release were conducted from a 2.4 mm orifice in a tank flume at the Department of Fisheries of Oceans Canada. Two releases are reported herein: one without dispersant and one with oil premixed with dispersant at the dispersant to oil ratio of 1:20. High resolution camera and a Vectrino Profiler were used to measure the hydrodynamic properties of the jet. The results were modeled by solving the Reynold Average Navier Stokes (RANS) equations with the k-epsilon turbulence model. The engineering properties (e.g., velocity components, turbulent kinetic energy, turbulent dissipation rate) predicted by the model agreed well with the experiments. It was observed that the spread angle for pure crude oil jet was 20 °while it was 23° for oil with dispersant, which is close to the spread angle of miscible jet of 22.6 °. The effect of temperature of pre-heated oil (at 80℃) has negligible influence on the oil jet hydrodynamics. The centerline velocity and turbulent dissipation rate from the model compared closely with empirical correlation of single-phase (miscible) jet from the literature. The falling-off of the turbulent dissipation rate at $(x/D_0)^{-4}$ was noticed in agreement with observations. By combining experimental measurement and CFD, the results show a robust method to evaluate the hydrodynamics of underwater oil jets, which would provide valuable information for decision makers and researchers.

How to Select the Right Solvent for Oil-Spill Dispersants? Insights from Hansen Solubility Parameters

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Dispersants used in the mitigation of oil spills are mixtures of amphiphilic molecules in a solvent. The recent large-scale use of dispersants has raised environmental concerns regarding the safety of these materials. In response to these concerns, we have previously reported a class of eco-friendly dispersants that utilize food-grade amphiphiles such as the phospholipid lecithin (L) (from soy) and the nonionic surfactant Tween-80 (T) to effectively disperse oil into seawater. The initial solvent used for the above LT dispersants was ethanol, which is relatively nontoxic but is also quite volatile (low flash point). Typically, solvent choice has been based on factors like the volatility or viscosity of the overall mixture; however, solvents are considered to have minimal effect on dispersion efficiency. Here, we firstly show that the solvent can have a *dramatic impact on dispersion efficiency*, i.e., on the extent to which a thin layer of oil is dispersed in the water column for a given amount of LT dispersant. For example, the dispersion efficiency (as measured by the conventional baffled flask test) can range from > 75% in one solvent to < 10% in another. Thus, the solvent has an independent role to play in oil dispersion over and above the amphiphiles. Next, we were interested in devising a systematic procedure to select the

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optimal solvent. In this regard, we turned to Hansen Solubility Parameters (HSPs), which are 3-D representations of solvent properties. We assessed the quality of dispersion for a large range of solvents through a low-energy dispersion test and plotted the results on the above 3-D plot. A systematic trend is seen, with optimal solvents clustering around a particular region of the plot. Through this analysis, we have identified solvents that combine high dispersion efficiency, good solubility of the LT amphiphiles, and also have a low toxicity profile.

Effects of Bubble and Drop Dissolution on the Plume Dynamics in a Stratified Ambient Ocean

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The present study uses a horizontally integrated model to study the dynamics of oceanic plumes rising under the action of bubbles and drops injected at the ocean floor in a stratified ambient. Since the bubbles and drops are partly soluble, the plume density changes as they rise due to the addition of dissolved material. The project focuses on various factors affecting the plume dynamics and, in particular, the effect of dissolving hydrocarbons and their mixing with the plume water. It is found that this mixing has a very significant effect on the plume rise and the so-called peel height, namely the maximum height reached by the plume. A parametric study of the sensitivity of the plume to the size of bubbles and drops, to the rate at which they are injected at the base of the plume and to the ambient stratification is also conducted. It is found that the plume is very sensitive to many of these parameters, particularly when the ambient is weakly stratified. In practice, therefore, the plume evolution will depend on the specifics of the situation under which it is generated. For the same reason, it is very difficult to make quantitative predictions of general validity except in extreme cases. [Supported by the BP/The Gulf of Mexico Research Initiative through the University of Texas Marine Science Institute, DROPPS II consortium]

Hydrocarbon biodegradation in deepsea sediments exposed to high pressure

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The Deepwater Horizon (DWH) disaster represents the largest accidental marine oil spill in human history. One of the unique characteristics of the DWH spill is the depth at which it occurred, approximately one mile below the sea surface. At that depth, overlying water leads to high hydrostatic pressure, equivalent to 150 times that of atmospheric pressure. Our understanding of the impacts of hydrostatic pressure on the structure and function of sedimentary microbial communities remains in its infancy. Previous studies, largely conducted in pure cultures, have shown that high pressure impacts membrane fluidity, enzyme activity, and DNA replication and translation. However, to the best of our knowledge, no ex situ experiment has reported on the role of high pressure in hydrocarbon biodegradation in sediments not associated with natural seeps. The objective of this study is to understand the impact of high-pressure on rates, metabolic pathways, and controls of microbially-mediated hydrocarbon degradation in deepsea sediments. Sediment samples were collected from the deepsea in the northern and southern Gulf of Mexico. Sediments from multiple sites were incubated in specially designed high-pressure incubation chambers, with or without oil addition and in comparison to parallel incubations at atmospheric pressure. The final analysis will combine respiration data and oil analysis along with interrogation of extracted RNA to reveal the metabolically active microbial

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populations that mediate biodegradation. This research will provide biodegradation rates for improved oil plume modeling.

Effective Wind Turbine Design Towards Oil Spill Response Equipment Park Concept
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Session 007: Use of Ecological and Socioeconomic Indicators to Demonstrate Ecosystem Recovery

Using a Comprehensive Indicator Suite to Measure the Ecosystem Effect of the Deepwater Horizon Oil Spill
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We have developed indicators to assess the holistic ecosystem status of the Gulf of Mexico by incorporating metrics from all levels of the Driver-Pressure-State-Ecosystem Service-Response (EBM-DPSER) framework (Kelble *et al*., 2013). Indicator status and trends were first reported in the 2013 Ecosystem Status Report (Karnauskas *et al*., 2013) and a subsequent publication examined how climate cycles cause ecosystem reorganization in the Gulf of Mexico (Karnauskas *et al*., 2015). In our update of the ecosystem status report to be released in March 2017, we are refining our biophysical indicator suite and increasing our human dimensions indicators to include greater representation of ocean economy, social connectedness, and community metrics. We examine the behavior of these indicators before, during, and after the Deepwater Horizon Oil Spill to determine which, if any, of these indicators potentially showed a measurable response to this event. The indicators that had a measurable effect were further analyzed to quantify how they behaved in the 5-years following the Deepwater Horizon oil spill. Lastly, we zoom in temporally and spatially on the areas of the Gulf of Mexico impacted by the spill to test potential hypotheses about how the spill affected the ecosystem and how these changes in the ecosystem affected the human community in these areas of the Gulf of Mexico. These longitudinal data/indicators allow us to monitor and advance our understanding of the linkages between ecological systems and human communities. Moreover, the indicators were designed to measure the condition of the holistic Gulf of Mexico ecosystem; thus, changes that may be attributable to the Deepwater Horizon oil spill could be used to measure the percentage of ecosystem components affected. Similarly, we can use these indicators to measure the trajectory of affected indicators for five years after the spill to determine if and when they return to pre-spill conditions.

Enhanced Monitoring Products of Dynamic Environmental Conditions in the Gulf of Mexico to Enable Optimal Sample Collection
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A series of dynamic anomaly products of ocean-circulation models, satellite ocean color products, and in situ measurements integrated using Google Earth aims to provide researchers and managers enhanced monitoring capabilities for the Gulf of Mexico (GOM). Weekly VIIRS satellite sensor derived properties

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(e.g. chlorophyll-a, absorption, and euphotic depth) and output from the 3km NCOM (Navy Coastal Ocean Model) AMSEAS circulation model (e.g. Currents, salinity, temperature) are compared to recent-mean conditions (8-week means) to identify physical drivers associated with significant surface variability. The dynamic anomalies indicate changing conditions relative to recent variability, highlighting the migration and mitigation of abnormal conditions that are not typically apparent in standard variable fields. Combined, the recent variability fields and the anomalies can enable managers and researchers to identify comprehensive sampling schemes, to interpret *in situ* data collected within the context of environmental conditions, and to identify data gaps due to undersampling. As a case study, preliminary results for the week of August 21, 2015 compare the derived dynamic anomalies with NOAA SEAMAP acoustic measurements collected in Gulf of Mexico cruises (2013-2015). The comparison results illustrate how acoustic scattering (proxy for relative biomass) is linked with environmental conditions and suggests that understanding this link could guide future sampling plans. The anomaly fields reveal the elevation of chlorophyll along the edges of the northern Loop Current as anticyclonic circulation increases in strength and gets closer to the riverine inundated shelf waters. A comparison with products from the same time period in 2013 shows the interannual variability and the need for rolling means of marine conditions in addition to the more typical annual and seasonal means.

Age and Growth of a Subtropical Marsh Fish: The Gulf Killifish, *Fundulus grandis*

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Fundulus grandis, the Gulf killifish, is an abundant fish species throughout the marshes of the Northern Gulf of Mexico. Its wide distribution and high site fidelity makes it an ideal indicator species for brackish and salt marshes, which experience a variety of anthropogenic disturbances. Despite the ecological, commercial, and scientific importance of *F. grandis*, little is known of its growth pattern, and age determination methods have not been validated. By combining a tag-recapture study with a chemical marker to stain otoliths, we validated an ageing method for *F. grandis* (49-128 mm TL) using whole sagittal otoliths and determined growth rates of recaptured *F. grandis* in winter (n = 58) and summer (n = 36) in Louisiana. Mean somatic growth in length was significantly greater during the winter (0.085 mm per day) than the summer (0.054 mm per day). In contrast, mean otolith growth was significantly greater during the summer (1.37 µm per day) than the winter (0.826 µm per day). The apparent uncoupling of somatic and otolith growth is attributed to warm summer temperatures which led to enhanced otolith growth while simultaneously reducing somatic growth. *Fundulus grandis* were aged to a maximum of 2.25 years. The parameters of the Von Bertalanffy growth model were estimated as: $L\infty$ = 87.27 mm, k = 2.43 year^{-1}, and t_0 = -0.022. These findings reveal essential age and growth information for *F. grandis*, demonstrating faster growth and a shorter lifespan than its congener, *Fundulus heteroclitus*.

Determining Bioindicators for Coastal Tidal Marsh Health using the Food Web of Larvae of the Greenhead Horse Fly (*Tabanus nigrovittatus*)

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Coastal habitats of the Gulf of Mexico are of ecological and economic importance, generating > $10 billion/ year in revenues from seafood harvest and tourism. Current methods to determine the health of

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marshlands after ecological disasters like the 2010 Deepwater Horizon oil spill in the Gulf of Mexico are expensive and time-consuming. Our study focuses on identifying invertebrate bioindicators for the impact of oil spills. The greenhead horse fly *Tabanus nigrovittatus* Macquart is native to coastal marshlands from Texas to Nova Scotia. The larvae are apex predators and their development is dependent on the food web in the soil. Surveillance of *T. nigrovittatus* after the 2010 oil spill showed population crashes of adults and larvae. We hypothesize that the food webs of larvae can be used as bioindicators of marsh health. We used 18S metagenomics to identify taxa in the larval guts and the surrounding sediments in locations both affected and unaffected by the oil spill. Firstly, comparing the food webs in both locations will lead to identification of disturbed taxa which will be correlated with oil toxicity studies. The predominant classes in sediments at both affected and unaffected locations were Liliopsida, Insecta and Malasseziomycetes. Overall, affected locations had greater class diversity than unaffected locations. The larval guts contained primarily species from the classes Insecta and Malasseziomycetes. Secondly, taxa absent in the affected locations but present in unaffected locations and vice-versa will be analyzed for their bioindication and biomonitoring potential. We found phyla that were unique to affected locations and classes that were unique to unaffected locations. Since the range of *T. nigrovittatus* is associated with *Spartina* marshes that span from Texas to Nova Scotia, this study could lead to cost and time efficient detection techniques (via PCR) that can be used to monitor the health of coastal marshes of the entire eastern United States.

* Student Presenter

Session 008: Ecosystem Structure, Function, and Services: Legacies of the Deepwater Horizon Oil Spill

Shrimp Stock Reproductive Potential as a Conservation Tool
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One of the biggest concerns in a large oil spill event is the impact on fishery resources. Shrimp fishery is one of the most important fisheries in the entire Gulf of Mexico due to its economic and social value The effect of oil spills on shrimp fishery are analyzed in the northern and southern GoM. Population responses of Pink and White Shrimp to two mega oil spill: Deepwater Horizon (2010) and IXTOC I (1979) are reviewed. Shrimp fisheries did not show a population collapse during and after oil spill in both areas. Recruitment and spawning stock indexes were found between natural annual variations. Shrimp reproductive strategy with two annual generations results in a high reproductive potential and resiliency if stocks are not overharvested. White and Pink shrimp stocks were relatively "healthy" in both oil spill events. Pink and White Shrimp Stock-Recruitment Relationships models show a high capacity to stand/recover from natural and man-made impacts by taking advantage of good environmental conditions. Not heavy oiled nursery areas was another key issue in both spills for protecting recruitment. Keeping Shrimp Spawning Stocks at safe limits is a good way to maintain its reproductive potential that could assure populations resiliency and may allow fishery resource conservation in the case of an eventual oil spill disaster.

Remote Sensing Phytoplankton Functional Types in the Northern Gulf of Mexico
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As the base of the food web, knowledge about the composition of the phytoplankton community - Phytoplankton Functional Types - is key to understanding the provisioning of nutrients and transfer of carbon and energy up the food chain. Recent advances in bio-optical models have allowed the development of a variety of approaches to use satellite ocean color data for mapping phytoplankton functional types. Six field surveys conducted in late Spring and summer of 2011-2016 in the Northern Gulf of Mexico have provided a wealth of in-situ data on phytoplankton functional types and size classification to validate satellite data. The ALFA, a dual laser fluorometer that uses spectral deconvolution analysis to quantify phytoplankton biomass using total chlorophyll a concentrations as well as the relative contributions from phycourobilin and phycoerythrobilin rich cyanobacteria, was plumbed in-line with the ship's flow-through system to provide surface maps of phytoplankton functional types. In addition, water from the CTD rosette was used to analyze for *Synechococcus* and *Prochlorococcus* cell counts using a flowcytometer as well as phytoplankton pigment concentrations using an HPLC. In-situ Particle Size Distribution was measured using a LISST. Level 1A ocean color data for the Northern Gulf of Mexico on dates where in-situ data is available was processed to produce maps of phytoplankton functional types for the region. We present the results of the validation of these satellite maps with the in-situ data and discuss the distribution of phytoplankton functional types in the Northern Gulf of Mexico.

* Student Presenter

Uptake, Depuration and Residence Time of Polycyclic Aromatic Hydrocarbons in Red Drum (*Sciaenops Ocellatus*) Exposed to South Louisiana Crude Oil

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Six years after the Deep Horizon (DWH) oil spill, the complete effects this contamination has had on the environment, and more specifically, on the species of fish important to commercial fishing of the Gulf Coast, is still unclear. Polycyclic aromatic hydrocarbons (PAHs) are components of crude oil which are considered carcinogenic. The concentration of PAHs found in fish after exposure and the length of time they reside is therefore crucial to understanding the range of potential impacts of the spill on the health of exposed organisms, and ultimately, on the humans that eat contaminated fish. A controlled exposure study was carried out to examine the rate of uptake and depuration of PAHs in juvenile red drum (*Sciaenops ocellatus*), during and after exposure to chemically enhanced water accommodated fractions (CEWAFs) of oil. Red drum were exposed to a CEWAF solution at 1ppm (TPH) using Corexit 9500 and Louisiana Sweet crude oil (surrogate for DWH oil) for 4 days then allowed to recover in untreated, clean seawater for 6 days. During this time, two fish were sacrificed every day for the first four days, then every other day through Day 10. The remaining fish were tagged and released in grow-out tanks to be sacrificed three months later. Fish livers were analyzed for PAH concentrations using GC-MS and total PAH amounts were compared. The results of the uptake, depuration and residence time of the PAHs will be discussed.

Spatiotemporal Dynamics in Sediment Nitrogen Cycling in Salt Marshes Impacted by the Deepwater Horizon Oil Spill

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Humans have dramatically increased the amount of reactive nitrogen (N) in the environment with negative ecological consequences, including eutrophication in coastal marine ecosystems. Salt marshes can help remove excess N in surface waters through microbially mediated processes such as denitrification, anaerobic ammonia oxidation (ANAMMOX), and dissimilatory nitrate reduction to ammonium (DNRA) that occur in the sediment. However, anthropogenic disturbances, such as sea level rise, species invasion, and oil spills can alter salt marsh functional capacity. In particular, oil spills may alter rates of N removal by reducing plant biomass and altering microbial functional composition. The objective of our study is to determine the effect of oiling on N cycling in salt marsh sediments over the course of a year. This work is being conducted in the Chandeleur Islands, a chain of barrier islands off the coast of Louisiana which were subjected to a gradient of oiling following the Deepwater Horizon oil spill. We collected sediments from three sites subjected to a range of oil loads and measured potential N fixation and denitrification rates. Preliminary results indicate that the site with the highest oil load had decreased denitrification potential rates but higher potential N-fixation rates. Additional work will address spatial and seasonal patterns in N cycling and microbial community response at these sites.

* Student Presenter

Sub-lethal Responses Linked with Reproduction as Predictive Tools for Understanding the Long-term Effects of Oil on Marine Teleosts

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Exposure to oil can potentially damage fisheries by reducing the reproductive potential of fish stocks. Studies on teleosts have documented oil-related impacts on reproduction, which can disrupt the endocrine system and lead to the suppression of reproductive hormones, inhibit gonadal development, and reduce egg and larval viability. There is limited information on cause and effect relationships of both short and long-term exposure to oil on reproductive fitness in fish, and ultimately on fish population size or structure. Short-term effects of oil spills are generally clear and readily documented. Long-term effects and recovery processes of impacted species and ecosystems are much more difficult to recognize and demonstrate. Thus, the question is not if petroleum affects reproduction in fish, rather the critical questions are (1) how can reproductive effects be effectively and efficiently assessed?, (2) what mechanisms lead to reproductive incompetence?, and (3) what are the population level impacts of such an exposure? In order to establish causal linkages, and relate physiological responses on fish reproduction and reproductive success, we carried out fish oil exposure mesocosm studies using adult Florida pompano (*Trachinotus carolinus*). Pompano were exposed to chemically enhanced water-accommodated fractions (CEWAFs) via two-12 hr declining exposures, each followed by a 24 hr no exposure protocol. Fish were then photothermally conditioned to mature and spawn, and placed into individual spawning tanks. After spawning, aspects of reproduction were assessed including oocyte maturation, egg and sperm viability, lipid composition of eggs, fertilization and hatching success, deformities, gonadal somatic indices, reproductive hormone characterization, gonadal histology and 3-day survival. We will present results of this study and discuss the implications for wild fish populations.

Comparison of select monohydroxylated PAH metabolites in red drum, *Sciaenops ocellatus*, following intraperitoneal and aqueous exposures

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Chemical exposure routes affect the bioavailability, metabolism, distribution and storage of toxicants in aquatic organisms. This study compares the phase I biotransformation products of select polycyclic aromatic hydrocarbons formed in juvenile red drum, *Sciaenops ocellatus*, following intraperitoneal and aqueous exposures. Juvenile red drum were exposed to DWH crude oil by intraperitoneal injections as well as chemically enhanced water accommodated fractions <CEWAF>. Bile was analyzed for the confirmation and quantification of monohydroxylated naphthalene, phenanthrene and fluorene using gas chromatography triple quadrapole mass spectrometry operating in multiple reactions monitoring (MRM) mode. Comparative knowledge on exposure routes and the subsequent influence on the uptake, biotransformation and toxicity of persistent organic compounds, such as PAHs, is critical for ecotoxicological risk assessments and toxicokinetic modeling efforts.

* Student Presenter

Sediment oxygen demand in shallow seagrass beds in the Chandeleur Islands

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Sediment oxygen demand is an aggregate measurement of numerous ecosystem functions, including photosynthesis by seagrasses and benthic microalgae, respiration by a diverse microbial community, respiration by meio- and macro-fauna, and enhanced microbial metabolism due to irrigation by macrofauna. We measured sediment oxygen demand at four sites in the Chandeleur Islands, northern Gulf of Mexico, with varied oil contamination from the DWH using light and dark custom-built metabolism chambers. Data were collected across a range of ambient oxygen concentrations resulting from a strong diurnal oxygen cycle in this shallow environment, and sampling was conducted twice annually over two years (June 2015 - Sept. 2016). Results are being analyzed for dependence on ambient oxygen concentration, sediment PAH at the 4 sites, seasonal and annual differences, and infaunal community biomass. This study aims to assess the impact of oil contamination on sediment ecosystem function in the context of natural daily, seasonal, and annual variability in a dynamic ecosystem.

Ecosystem Services of the Food Web along a Salinity Gradient in Louisiana Marshes

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Louisiana marshes provide valuable habitat & food sources for many organisms of commercial & recreational importance. However, the MR also carries pesticides, high levels of nutrients, metals, and other toxins into the marsh from the watershed (Antweiler *et al*. 1995, Goolsby & Pereira 1995). Therefore, our research group focuses on studying the effect of those “disturbances” on food webs - the birds, plants, insects (ants), & fishes in the marshes of Barataria Bay & Breton Sound, Louisiana. Our research has shown that fish, important for both commercial & recreational industries, may be viable for *extensive - as opposed to intensive* - commercial farming for commerce within diversion areas & adjacent borrow pits. A model for this is documented at Veta la Palma, Spain, where reestablishing hydrology led to wetland creation providing enhanced opportunities for fishery production (Medialdea 2012, Walton *et al*. 2015). Historically, the Guadalquivir River in Spain was impounded in similar ways to the Mississippi River. In 1990, an 8000-acre extensive fish farm was created surrounded by 12,000 acres of marshland. Veta la Palma fishery produces more than 1000 tons of sea bass, grey mullet, bream, and shrimp per year. Similarly, our project would serve as a global model for successful restoration and increases in fisheries production. We show that fishes are different at each salinity and there are unique bird and plant species. Ants are an indicator of widespread disturbance because they are present in similar numbers across the ecosystem.

A Temporal Study of Nitrogen Cycling in a Deepwater-Horizon Impacted Coastal Marsh System

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Coastal wetlands are critical to the exchange of nitrogen and other nutrients between land, sea and the atmosphere. Knowledge on the effects of anthropogenic activities (e.g., oil spills), on nitrogen (N) cycling and the N-cycling marine microbial populations in coastal wetlands is needed so as to better understand

* Student Presenter

how to affect restoration and recovery of such vital habitats. The impact of the Deepwater Horizon (DWH) oil spill disaster on N-cycling microorganisms, particularly denitrifiers, in northern Gulf of Mexico marsh systems is a surprisingly understudied area of research to date. Denitrification is a key ecosystem function that contributes to nitrogen removal in coastal marine ecosystems. The objective of this current study was to investigate N cycling and associated microbial populations in marsh sediments including subtidal sediments at locations in the Chandeleur Islands, Louisiana, that were previously exposed to oil from the DWH disaster. The research approach included measurements of nutrient fluxes and denitrification rates along with a molecular ecology functional gene-based approach to assess the impact of the spill on the denitrifying microbial community. Denitrification rates were measured by the isotope pairing technique and functional gene abundances were determined by quantitative PCR. Results highlight that denitrification rates were higher in marsh sediments as compared to the unvegetated sub-tidal habitat. Denitrification biomarker gene abundances indicated variations in population sizes based on season and sample type. We will discuss how our results can provide greater insights into the long-term impacts of oil spills on N cycling in vital coastal wetlands.

Effects of plant species and genetic diversity on wetland functional responses to oiling

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Plant genetic and species diversity positively influence wetland functions, such as primary productivity and the abundance and diversity of fauna that use the plants as habitat, with greater abundances often in areas of higher plant diversity. Theory predicts that the effects of diversity on ecosystem functioning may be strongest in the presence of disturbance or changing environmental conditions. Thus, diversity in wetlands may be critical for the maintenance of multiple ecosystem functions in the aftermath of disturbance caused by oiling, but this hypothesis remains to be tested. Here we compared several salt marsh functions, including primary productivity, nutrient storage and habitat provisioning in two areas with no to little oiling and two areas with moderate to heavy oiling in the Chandeleur Islands, LA. We also quantified plant diversity in these areas to determine its role in modulating functional response to oiling. In each area, measurements were taken in uniform salt marsh (*Spartina alterniflora* dominated), uniform black mangrove (*Avicennia germinans*), and *Spartina*/*Avicennia* mixed plots in June and September of 2015 and 2016. Measurements included stem/tree height, canopy width, percent cover and shoot/pneumatophore densities, above- and below-ground plant growth rates, plant nutrient contents, and the abundance and species composition of benthic epifauna. Preliminary results show that oiling has produced minimal negative long-term effects on plants or epifaunal communities. *Spartina* genetic diversity did not differ among oiled and unoiled plots, but genetic diversity positively correlated with *S. alterniflora* stem density and percent cover. Thus, although oiling effects were not apparent in the areas studied, our results offer evidence that plant genetic diversity can enhance salt marsh function.

* Student Presenter

Epigenetic Inheritance of PAH Resistance in larval zebrafish (*Danio rerio*)
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Individual fish often can muster only partial acclimation, if any, to oil exposure. Adaptation through evolution, on the other hand, is too slow to aid fish populations dynamically exposed to oil. However, short-term epigenetic inheritance of oil resistance across a few generations may act as a "bridge for survival" while oil dissipation occurs following a spill. We used the zebrafish (*Danio rerio*) as a model organism to test this hypothesis. We first assessed the proximate effects of PAH exposure in the P_0 generation, and then determined whether there was any transgenerational, epigenetic transfer of PAH resistance from the P_0 to F_1 generation. After a 2 week acclimation period, adult zebrafish P_0 were fed for 21 days with commercial flake food spiked with water, 10, 50, or 100% HEWAF solution. The adults were then bred to produce F_1 larvae, which were subsequently exposed to PAH via water at the yolk sac stage. Dietary PAH created no differences in adult body length, body mass or condition factor. The F_1 larvae (6 days) from adults exposed to the higher levels of PAH (10, 50 and 100% HEWAF) showed poor survival (up to 42 % decrease) in clean water compared to those larvae derived from control adults not exposed to PAH in their diet. However, when challenged by a waterborne PAH exposure, 6 day old F_1 larval offspring whose parents had been exposed to PAHs showed a dose-based enhancement of PAH resistance (up to a 30% increase in survivorship) compared to F_1 larvae from the control group of P_0 parents. Non-genetic transgenerational inheritance of PAH resistance in the F_1 larvae ("epigenetic inheritance", broadly defined) can thus arise from low levels of parental dietary PAH exposure. This process of "epigenation", sitting between individual acclimation and species adaptation, may help fish populations survive across a small number of generations while PAH levels naturally dissipate in an oil spill area.

Photo-induced Toxicity of Deepwater Horizon oil: Applications and Future Directions
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A comprehensive toxicity testing program conducted during the Deepwater Horizon (DWH) Natural Resource Damage Assessment showed that ultraviolet (UV) light greatly affected the toxicity of DWH oil to early life stage fish and invertebrates. In bioassays conducted on 10 species of early life stage fish and invertebrates, the toxicity of DWH oil increased by one to two orders of magnitude with co-exposure to natural levels of UV light. The tests also suggested that sensitivity of organisms to UV light is not uniform; some organisms were more sensitive to photo-induced toxicity than others. We incorporated meta-analyses of laboratory test results with data from field sampling, weather stations, satellite imagery, and scientific literature to develop a model of likely effects of oil exposure during the oil spill. In this presentation, we will discuss progress in characterizing photo-induced toxicity of oil and further development of our photo-induced oil toxicity model. Finally, we will also discuss logical future directions and research needs on this topic.

* Student Presenter

Oil Spills and Dispersants Can Cause the Initiation of Red Tides

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Red tides or harmful algal blooms (HABs) have been frequently observed after oil spills and dispersant applications, for example after the Ixtoc I and DWH spills in the Gulf of Mexico. However, the link between oil spills and HABs is unknown. We determined the effects of crude oil, dispersant-treated oil and dispersant alone on the structure of natural plankton assemblages of coastal and offshore waters in the Northern Gulf of Mexico. In coastal waters, large tintinnids (*Favella* sp) and/or oligotrich ciliates (*Laboea* sp), major grazers of phytoplankton, were negatively affected by the exposure to dispersed oil and dispersants, whereas bloom-forming dinoflagellates (*Prorocentrum texanum*, *P. triestinium* and *Scripssiella trochoidea*) increased their concentration. The removal of ciliates due to oil and dispersant disrupts the predator-prey controls that normally function in planktonic food webs. This disruption on grazing pressure opens a "hole" that allows some dinoflagellates species with higher tolerance to oil and dispersants than ciliates to grow and form blooms. In offshore waters, most plankton, including dinoflagellates, responded negatively to crude oil and dispersants. Our results demonstrate that, in coastal areas, when there is not nutrient limitation, and when ciliates and tintinnids exert strong grazing pressure on dinoflagellates, oil and dispersants can disrupt the grazing control on dinoflagellates, which can cause the initiation of harmful algal blooms after oil spills.

Magnitude and Spatial Variability of Large Siliceous Particles on the Mississippi-Alabama Shelf during Spring

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The efficient transfer of primary production to higher trophic levels is important for sustaining fisheries biomass. Currently, it is assumed that even in the most productive systems, multiple trophic steps are required for movement of phytoplankton organic matter to small fish or larvae (e.g. gulf menhaden). Diatoms are an important coastal phytoplankton group as they can dominate algal biomass (e.g. chlorophyll) and the rate of primary production in some of the most productive regions for fisheries. Additionally, they are the only major phytoplankton group to have a shell made of biogenic silica. While individual diatoms are relatively large among phytoplankton (e.g. ~0.02 - 0.10 mm), they are typically too small for many fish or larvae to consume directly; however, some diatom species have the adaptation of forming chains, such a size increase may allow them to be directly ingested by small fish or larvae. We present data from size-fractionated mesozooplankton samples from the Mississippi-Alabama shelf during a spring bloom period demonstrating that a measurable quantity of the biogenic silica, presumably from diatoms, was retained by the zooplankton net ranging in size from 0.2 - 4.8 mm. There were no statistically significant differences in silica among five size fractions suggesting that siliceous particles (e.g. diatom chains) may be larger than 5 mm. Our results indicate that a small, but quantifiable proportion of the siliceous particle assemblage can occur in large units (>5 mm). The potential occurrence of phytoplankton in this size range suggests a mechanism by which the number of trophic steps within the local food web may be reduced, thereby increasing transfer efficiency of organic matter to higher trophic organisms.

* Student Presenter

Contribution of Petrocarbon to Pelagic Food Webs in the Gulf of Mexico
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Natural seeps provide a constant but spatially variable input of oil and gas to the water column of the Northern Gulf of Mexico, but the fate of this petrocarbon in the water column and its impact on the structure and function of planktonic communities remain poorly understood. The assimilation of petrocarbon into planktonic biomass is a critical and potentially important sink for oil and gas released into the environment, and the contrast in $\delta^{13}C$ between average marine organic matter (ca. -20‰), oil (ca. -27‰) and methane (ca. -57‰) provides a robust tool for exploring the pathways and mechanisms of assimilation of petrocarbon into both phyto- and zooplankton. We used the carbon stable isotope composition of particle and zooplankton samples collected during annual field campaigns to major seep fields in the Gulf of Mexico to assess the incorporation of petrocarbon into biomass at seeps of varying water depth. Particle samples collected through the water column provide a proxy for phytoplankton and detrital material, while size-fractionated zooplankton collected in depth-stratified tows with a MOCNESS provide insight into the pathways of petrocarbon movement through the planktonic food web. Here we build on prior research documenting low $\delta^{13}C$ values in suspended particles and zooplankton in the two years immediately following the Deepwater Horizon (DWH) spill in 2010. Our measurements provide a multiyear record of the contribution of oil and gas to the planktonic food web at seeps of varying water depth and petrocarbon release rates, a critical part of any baseline assessment of hydrocarbon impacts in offshore waters of the Gulf of Mexico.

Six Years After Deepwater Horizon: Diet Analysis of the Seaside Sparrow (*Ammodramus maritiums*) Using DNA Barcoding
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Seaside Sparrows (*Ammodramus maritimus*) live year round in the coastal marshes along the Gulf of Mexico from Florida to Texas and face many anthropogenic challenges that have resulted in endangered status for one subspecies (the Cape Sable Seaside Sparrow) and extinction of another (the Dusky Seaside Sparrow). While populations of Seaside Sparrows in Louisiana are not currently considered to be of conservation concern, the 2010 Deepwater Horizon oil spill posed (and may still pose) a serious risk to these birds, the food webs they play a role in, and the fragile saltmarsh ecosystems they rely on. This project will evaluate the lasting impacts of the oil spill on these birds and their community by examining sparrow diet from fecal, gut, and ligature samples collected on both oiled and unoiled sites. DNA barcoding of the COI mitochondrial gene will be used to identify prey items in these samples. Once prey items are identified, dietary makeup will be compared across sites (oiled vs unoiled) to evaluate the potential impact of oiling on prey consumption during the six years following DWH. If we can better understand the lasting implications of oil spills on the organisms that make up the saltmarsh community, we can begin to fully comprehend the effects oil has had on these fragile habitats.

* Student Presenter

Evidence in Otoliths for Food Web Impacts from the Deepwater Horizon Oil Spill

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Effects of the Deepwater Horizon Oil Spill (DWH) on the northern Gulf of Mexico (nGOM) food web have been documented from plankton to fishes to marine mammals. We examined stable and radioisotope data compiled for red snapper to assess the temporal distribution of DWH-related food web impacts. Red snapper muscle tissue $\delta^{15}N$ showed a significant increase after DWH, which is consistent with an observed diet shift (n = 1,255 stomachs analyzed) from lower trophic level pelagic prey to more benthic and demersal fishes after the spill. Trophic position and diet composition returned to pre-spill values by year-5 post-DWH. Muscle petrocarbon signatures were ephemeral due to tissue turnover, but analysis of otoliths of age-0 red snapper suggests that ^{14}C-depleted organic C in the food web was incorporated into these $CaCO_3$ structures, thus providing a permanent, time-referenced recorder of DWH food web impacts. Red snapper muscle tissue did not display depleted ^{13}C or ^{14}C values until the second year post-spill, which reflects tissue turnover rates that are on the order of 200 days. However, age-0 red snapper otoliths had depleted ^{14}C values in fall 2010 given the more direct pathway of metabolic carbon incorporation into otoliths. There was a significant linear relationship between otolith $\Delta^{14}C$ and longitude for age-0 red snapper captured off Alabama (88W) to Texas (96W), thus indicating a dilution by distance of petrocarbon in the nGOM food web. Results from this study demonstrate the utility of using otoliths as permanent natural biogeochemical markers of DWH food web impacts.

From Marsh to Mangrove: How Do Vegetation Shifts in Coastal Louisiana Affect Species Composition, Trophic Dynamics and Carbon Flow in Estuarine Food Webs?

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Coastal ecosystems are vulnerable to climate change due to shifts in atmospheric carbon dioxide, air and water temperatures, rainfall, and relative sea level. In coastal Louisiana, the range of black mangroves (*Avicennia germinans*) is projected to expand due to reduced frequency and duration of winter freeze events and increased rate of droughts. The transition of salt marsh habitat to mangrove has the potential for ecologically diverse effects. For juvenile consumers, this modification in food and refuge resource may ultimately affect fishery populations. Shifts from salt marsh grass (*Spartina alterniflora*) to black mangrove creates an additional basal carbon source, which may alter trophic linkages and the structure of estuarine food webs. The goals of this study are to compare the species abundance and diversity as well as examine shifts in basal carbon sources across three habitat types in Grand Isle, LA: *Spartina*-dominated, *Avicennia*-dominated, and a transition or mix of the two. To accomplish these goals, we sampled juvenile nekton species using fyke nets and minnow traps in each habitat to examine species composition. We also collected primary carbon sources (emergent vegetation, phytoplankton, benthic microalgae, submerged aquatic vegetation, and soil organic matter) and consumers (blue crabs, brown shrimp, grass shrimp, periwinkle snails and ribbed mussels) at each habitat type and used stable isotope analysis ($\delta^{13}C$, $\delta^{15}N$) to identify trophic level, basal carbon sources, and assess how mangrove carbon is incorporated into food webs. While data analysis is ongoing, preliminary results indicate that basal carbon sources supporting some marsh consumers (e.g. periwinkle snails) shift between habitat

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types, while others remain static (e.g. grass shrimp). This research will further develop our understanding of how climate induced change in vegetation influences valued marsh-dependent consumers, such as blue crabs and brown shrimp. By filling in this data gap, we seek to inform coastal management and fisheries policy on the effects of mangrove expansion within the estuarine ecosystems of Louisiana.

Crude Oil and Dispersant Impair the Grazing Impact of Heterotrophic Dinoflagellates on Phytoplankton
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The Deepwater Horizon oil spill in 2010 was one of the most catastrophic events in the history of oil spills in the ocean. An estimated $6.7x10^8$ kg of Louisiana Sweet Crude oil was released from around 1500 m below the ocean's surface into the Gulf of Mexico, covering as much as $7.5x10^4$ km^2 within one month. Approximately $7x10^6$ L of Corexit dispersant was applied for mitigation. Exposure to dissolved components of crude oil and dispersant, and consumption of chemically and physically dispersed oil droplets have been demonstrated to lead to lethal and sub-lethal effects in planktonic organisms. Microzooplankton, the most important consumers of primary production in the sea, have been shown to be negatively affected by dispersant-treated crude oil by having reduced growth rates. To better understand the effect of oil spills on the top-down control on primary production by microzooplankton, we conducted grazing experiments in the laboratory. Monocultures of the heterotrophic dinoflagellate *Oxyrrhis marina* and the autotroph *Isochrysis galbana* were used as grazer and prey, respectively. Grazing impact and algal growth rates in treatments of 1) crude-oil-only; 2) dispersant-only; and 3) dispersant-treated-crude-oil were estimated using the dilution method with 24-hour incubations. The initial concentrations of crude oil and dispersant in treatments were 10 µL L^{-1} and 0.5 µL L^{-1}, respectively. Compared to crude-oil-only and dispersant-only treatments, a combination of crude oil and dispersant has the most negative effect on both the *I. galbana* growth rate and *O. marina* grazing rate. Unexpectedly, dispersant alone has no obvious negative effect on either grazer or prey when compared to the control group. These results suggest that top down control of primary production by micro-grazers is impaired by oil contamination. Furthermore, the application of dispersant for mitigation might interfere with the trophic transfer within planktonic food web in the ocean.

Species and functional diversity of apex and mesopredators in the Northern Gulf of Mexico
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High biodiversity can enhance the resiliency of an ecosystem and hasten the recovery of collapsed populations. Apex and mesopredators often overlap trophic niches, and thus can facilitate the ability of an ecosystem to rebound from a disturbance. To investigate the species and functional diversity of apex and mesopredators across the northern Gulf of Mexico in response to the Deepwater Horizon Oil spill, we initiated a spatially stratified bottom longline survey in inshore and offshore waters. Species diversity was calculated from catch data using standard diversity indices while functional diversity will be determined through ongoing analyses of the stable isotope ratios of carbon, nitrogen, and sulfur sampled from white muscle and blood plasma. Preliminary species diversity results show that overall, offshore sites in Louisiana have the highest diversity while offshore sites in Mississippi contain the lowest diversity. Inshore sites in Alabama encountered the highest number of species whereas offshore Alabama sites encountered the fewest number of species per region. Initial data from spring 2016 shows

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variability in these preliminary diversity trends, as well as differences among the dominant species in each region. Early evidence of high predator diversity across a small spatial scale indicates that the ecosystem may be resilient in the face of environmental disturbances, which are not uncommon in the northern Gulf of Mexico. Investigating the potential for this system to recover from environmental disasters is critical for both preemptive management and post-disaster mitigation strategies.

Trophic Ecology and Growth of Short Bigeye, *Pristigenys alta*, a Model Small Demersal Reef Fish in the Northern Gulf of Mexico

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Small demersal reef fishes are ecologically significant in the transfer of energy from low to higher trophic levels in many reef food webs, yet little is known about their ecology on reefs off northwest Florida shelf. This lack of data is of greater issue given declines in these communities following the Deepwater Horizon oil spill, as well as the rapid invasion of red lionfish which preferentially prey upon small demersal reef fishes. Therefore, we began an extensive study in 2015 to examine trophic structure, community, and population ecology of small demersal reef fishes in the northern Gulf of Mexico (nGOM). Here, we focus on a model species within this community, the short bigeye, *Pristigenys alta*, to detail our approach to investigating this community. Short bigeye (n=69) were collected by scuba divers at natural reefs on the nGOM shelf during 2015 and 2016. Stomach contents consisted primarily of zooplankton, benthic invertebrates, and small fishes. Analysis of muscle stable isotopes revealed a phytoplankton-based food web. Age was estimated with otoliths, with max age being 55 years. Von Bertalanffy growth parameters were Linf = 277 mm TL, k = 0.47 y-1, and t0 = -0.06. Current work is focused on validation of annual otolith opaque zone via biogeochemical methods, as well as examining trophic differences between short bigeye and other small demersal reef fishes. Results of the broader study will be utilized in ecosystem models being constructed to examine ecology processes and test effects of anthropogenic stressors on reef ecosystems in the region.

The Effects of Planting and Fertilization on Native Soil Microbial Community in Louisiana Coastal Marshes Affected by the Deep Water Horizon Oil Spill

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This study is part of a larger project that evaluates the decadal impacts of the Deep Water Horizon (DWH) event on the plant-microbial-benthic marsh system and the effectiveness of remediation treatments on accelerating recovery rates. Remediation test sites were established and maintained to study the effectiveness of vegetation plantings and fertilization on recovery, resilience, and longterm sustainability of the DWH oil-impacted coastal marshes in Northern Barataria Bay. Responses of indigenous soil microbial community structure and composition to the planting of *Juncus roemerianus* or *Spartina alterniflora*, with or without application of the control-released N, P and K fertilizer, were determined through Illumina 16S metagenomic sequencing. The microbial data will be correlated with soil and plant variables that were collected simultaneously within the same experimental designs to produce a comprehensive interpretation of remediation-assisted recovery on microbial dynamics DWH oil-impacted marshes.

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Spatial distribution, abundance and life history characteristics of golden tilefish and deep-water grouper species in the Gulf of Mexico

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The Deepwater Horizon spill had a catastrophic impact on aquatic organisms throughout the Gulf of Mexico, a number of which are economically important. We have sampled many of these species contributing to Gulf fisheries in approximately 300 locations distributed throughout the Gulf in the six years following DWH. Sampling was done using a demersal longline system with 450-500 baited hooks in depths from 20-600 m. Using data from these surveys, I report on the distribution, abundance, and population dynamics parameters of golden tilefish, yellowedge, and snowy groupers. Aspects of the population biology of these species are compared and contrasted among the species and among sub-regions of the Gulf. Little is known about the life history of these species, especially on a Gulf-wide scale. Therefore, an analysis of the population ecology of those three demersal species will be beneficial to understanding the sensitivity and therefore resiliency of populations to anthropogenic perturbations and natural variations in productivity.

Around the Gulf in Seven Biomarkers: A Multivariate Analysis of Golden Tilefish Health, 2015-2016

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Surveys of baseline health and resiliency of fishes in the Gulf of Mexico are complicated by the varying levels of oil and natural gas industrialization, exposure to contaminated river effluent, and the fluctuating degrees of fishing pressure, found throughout the region. When the layers of biological and molecular complexity that govern eukaryotic life are added to this, it becomes evident that a thorough examination of population health and potential contaminant impacts must involve multiple biomarkers. In 2015 and 2016, long-line surveys were conducted throughout the entire Gulf of Mexico, along United States and Mexico coastlines. Sampling stations included hypothesized pristine locations off the Yucatan peninsula and Florida shelf, heavily industrialized sites in Campeche Bay, Mexico and in the vicinity of the Deepwater Horizon oil spill, and in areas impacted by Mississippi River runoff. A subset of 131 Golden tilefish (*Lopholatilus chamaeleonticeps*) were selected from these efforts and their blood and tissues were analyzed with seven biomarkers to quantify: an active immune response (lysozyme and differential white blood cell counts), exposure to polycyclic aromatic hydrocarbons (ethoxyresorufin-0-deethylase), genotoxicity (nuclear abnormalities), oxidative stress (thiobarbituric acid reactive substances and superoxide dismutase), and liver damage (serum sorbitol dehydrogenase). Biomarker fluctuation was assessed in different tissue matrices, when possible, and evaluated both individually and in conjunction with other markers. Multivariate analysis was performed to determine whether there were significant correlations between biomarker response and tilefish size, sex, and geographic location. These data will form the basis for selecting groups of tilefish for an upcoming transcriptome study, in order to identify novel genetic markers for contaminant exposure and resiliency.

* Student Presenter

The modeled effect of the Deepwater Horizon oil spill on Ecosystem Services

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The Deepwater Horizon (DWH) event highlighted the need to identify and quantify the ecosystem services provided by the Gulf of Mexico (GoM) deep-sea ecosystem to fully understand the impacts on human well-being. The goal of this project was to begin to explicitly connect the structure, function, and processes of the offshore environment to human well-being in a manner that is scalable and transferable, while considering the potential changes in the system as a result of the DWH event in the GoM. This was achieved by: 1) building an *Ecopath with Ecosim* model considering the "system" as a whole, rather than a particular bio-physical feature or habitat (e.g., banks, reefs, etc), 2) running simulations to test how biomass has changed because of the DWH blowout, 3) improving the model's predictability to reflect observational data, and 4) incorporating ecosystem services into the model to determine how services have changed following the DWH blowout.

DEEPEND: Determinants of genetic diversity and historical demography in deep-sea fishes

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Deep-sea fishes remain poorly studied, due in large part to the difficulty of accessing the environment in which they reside. Genetic data for many deep-sea fishes is still absent or restricted to a small sample size from a limited geographic range. Here we collected DNA sequence data from the estimated 500 deep-sea fish species present in the pelagic environment of the Gulf of Mexico. Currently, 4700 individuals representing 481 species have been sampled using MOCNESS trawls sampling at as deep as 1500 meters. We used our molecular data to characterize the population genetic diversity and historical demography (i.e. population size changes) of these hundreds of fish species. This were done comparatively, so that species that differ in life history traits such as migration, feeding, generation time, and reproductive mode were contrasted with one another, and correlates between life history traits and population genetic parameters were tested. This allowed us to make inferences on how the life histories of hundreds of these understudied species contributes to the historical process that have generated the genetic diversity we observe today.

Characterization of the Sediment Microbial Community in the Chandeleur Islands: Five Years after the Deepwater Horizon Oil Spill

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Benthic subtidal and intertidal microbes play an important role in nutrient cycling and primary production in benthic marine ecosystems. In June and September of 2015, triplicate sediment cores were collected from four field sites and over three ecologically distinguishable habitats (salt marsh, bare sediment, and seagrass) in the Chandeleur Islands representing a gradient of oiling based on NOAA

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Shoreline Cleanup and Assessment Technique Surveys conducted in 2010. Following collection, cores were carefully cut into six sections (0-2cm from the surface, 2-5cm, 5-10cm, 10-15cm, 15-20cm, and 20-30cm) and homogenized for DNA extraction. High-throughput sequence analysis was conducted on DNA extracted from sediment samples to assess the effect of habitat and oiling history on the community structure and function. The majority of samples were dominated by Proteobacteria at the phylum level with the Deltaproteobacteria representing the largest fraction. In many stratified cores, Chloroflexi and Spirochaetes increased with depth while the relative abundance of Bacteroidetes, Acidobacteria, and Alphaproteobacteria decreased with depth. Overall, analysis of the community composition showed no significant differences in phyla found in oiled and non-oiled sites which may indicate that this system was at an advanced point in recovery and/or the plasticity of the microbial consortia are able to respond and stabilize post-disturbance on rapid time scales. These studies provide a strong foundation for microbial research on oil resilience in the future.

Depth Strata Partitioning by Mesopelagic Alepisauroid Fishes in the Northern Gulf of Mexico

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We examined depth strata partitioning among various mesopelagic fishes of the suborder Alepisauroidei in the northern Gulf of Mexico post Deep Water Horizon oil spill, many species of which have been poorly studied. Worldwide, numerous mesopelagic organisms have been demonstrated to partake in the largest known daily migration: ascending from the deep, disphotic layers of the ocean to the epipelagic every night and descending back to the depths at dawn. This migratory ecology is the trophic basis of a complex pelagic food web that supports many important fisheries as well as deep diving cetaceans and sharks. In addition, some evidence points to this system playing a potentially important role in global oceanic carbon cycling. By using deep pelagic trawl survey data collected from the northern Gulf of Mexico by the National Oceanic and Atmospheric Administration (NOAA) and the research consortium Deep Pelagic Nekton Dynamics of the Gulf of Mexico (DEEPEND) important ecological inferences are being made by analysis of species presences and abundances at given depth strata as determined by Multiple Opening and Closing Net and Environmental Sensing Systems (MOCNESS). This data will be the first of its kind examined for some mesopelagic Alepisauroid families in the gulf, especially for the family Paralepididae, for which our data also constitute first reported occurrences of several species in the Gulf of Mexico. This work elucidates some crucial aspects of the basic ecology within a group of trophically important mesopelagic fishes and contributes to our meager understanding of lower latitude, mesopelagic ecosystems in general and the deep Gulf of Mexico in particular.

Effect of Oil Exposure on Predator-Prey Interactions in Northern Gulf of Mexico Nekton

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The Deepwater Horizon Oil Spill exposed approximately 1773 kilometers of shoreline in the Northern Gulf of Mexico to crude oil, impacting coastal fish and crustacean communities through a variety of pathways including habitat loss and reduction in secondary production. Though recent research has covered a variety of effects that oil exposure has on the biota of the region, small-scale effects on local food webs have not been documented. Here, we report on the findings of a study that investigated

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impacts of oil exposure on coastal food webs through sensitivity and predator-prey experiments involving polycultures consisting of grass shrimp (*Palaemonetes* sp.), juvenile blue crabs (*Callinectes sapidus*), and diamond killifish (*Fundulus xenicus*). Sensitivity experiments exposed polycultures to pulse (single inoculation) and press (repeated inoculation) oil exposure for 72 hours. No mortality was observed in non-oiled and pulse treatments. However, an average of two shrimp per tank were lost in press conditions. These same polycultures were used in 24-hour predator-prey experiments. Predators selected for these trials included sub-adult blue crabs, Gulf killifish (*Fundulus grandis*), gulf toadfish (*Opsanus beta*), and juvenile red drum (*Sciaenops ocellatus*). Predator identity and oil exposure both significantly reduced the number of total number of prey recovered compared to control treatments ($p < 0.001$ and $p = 0.004$ respectively, two-way ANOVA). However, oiling did not significantly affect recovery in all predator treatments nor did it affect the recovery of all individual prey species the same. Our results indicate that oil can have an impact on predator-prey interactions in coastal systems, but not all species are affected equally. Exposure tolerances and behavioral changes are still being investigated to elucidate changes in trophic structure induced by oil exposure.

Effects of Macondo 252 Crude Oil WAF on Microplankton

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Microbial response to crude oil ranges from stimulation to inhibition. Conflicting reports of effects on eukaryotic microplankton reflect this range of reactions, and while extensive studies have been conducted on prokaryotic responses, information on eukaryotic microplankton remains sparse, and limiting to developing food web models of plankton effects. We used the water accommodated fraction (WAF) of Macondo crude oil generated in sunlight as source material for determining the relative inhibition of Macondo 252 crude oil on autotrophic and heterotrophic microplankton, particularly diatoms and ciliates. For short term exposures, variable amounts of WAF were added to plankton samples enriched for growth with autotrophic flagellate *Pavlova* sp. Cell numbers and sizes reflected short term (0-4 hours) inhibition at 15, 20, and 25% WAF additions for the planktonic ciliate *Strobilidium* sp. WAF added at 10% dilution in 3 day enrichment cultures showed relatively little inhibition of diatoms and mixed effects on planktonic ciliates that may be species specific. This presentation will summarize know crude oil effects on microplankton and present new data from our experiments under C-IMAGE II.

Estimating surface salinity in the northern Gulf of Mexico from satellite ocean color measurements

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Sea surface salinity (SSS) is an important parameter to characterize physical and biogeochemical processes, yet its remote estimation in coastal waters has been difficult because satellite sensors designed to “measure” SSS lack sufficient resolution and high-resolution ocean color measurements suffer from optical complexity when used to estimate SSS. Here, this challenge in the northern Gulf of Mexico is addressed through modeling, validation, and tests in contrasting environments. Specifically, using extensive SSS datasets collected by many groups spanning > 10 years and MODIS (Moderate Resolution Imaging Spectroradiometer) and SeaWiFS (Sea-Viewing Wide Field-of-View Sensor) estimated remote sensing reflectance (Rrs) at 412-667 nm and sea surface temperature (SST), a multilayer perceptron neural network-based (MPNN) SSS model has been developed and validated with

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a spatial resolution of ~1km. The model showed an overall performance of root mean square error (RMSE) = 1.225, coefficient of determination (R^2) = 0.86, mean bias (MB) = 0.022, and mean ratio (MR) = 1.005 for SSS ranging between ~1 and ~37 (N=3640). Validation using an independent dataset showed a RMSE of 1.098, MB of 0.043, and MR of 1.003 for SSS ranging between ~27 and ~37 (N=412). The model with its original parameterization has also been tested in the Mississippi-Atchafalaya coastal region, Florida's Big Bend region, and in the offshore Mississippi River plume, with satisfactory performance obtained in each case. Comparison with concurrent Aquarius-derived SSS maps (110-km resolution) showed good agreement in offshore waters but the new 1-km resolution SSS maps revealed more finer-scale features as well as salinity gradients in coastal waters. The sensitivity of the model to realistic model input errors in satellite-derived SST and Rrs was also thoroughly examined, with uncertainties in the model-derived SSS being always < 1 for SSS > 30. The extensive validation, evaluation, and sensitivity test all indicated the robustness of the MPNN model in estimating SSS in most, if not all, coastal waters and offshore plumes in the northern GOM. However, the model showed limitation when applied to regions with known algal blooms or upwelling as they both lead to low Rrs in the blue bands that may be falsely recognized as caused by low SSS.

Effect of surface oil plumes on upper-ocean light field - a numerical study

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Crude oil plumes released from subsea oil well blowout can spread over a large upper-ocean area and last for a considerable period of time till being restored or biodegraded, inducing significant impact on the ocean ecosystem. Crude oil, as indicated by its dark color, has strong capability of absorbing sunlight. Therefore, surface oil slicks and suspended oil droplets in the upper ocean can block sunlight from penetrating into subsurface region where phytoplankton live, significantly reducing the rate of ocean photosynthesis. In this study, the effect of surface oil plumes on upper-ocean light field is studied using high-fidelity numerical simulations. In particular, the ocean flow and temperature fields as well as the oil plume dispersion are simulated using large-eddy simulation (LES), and the sunlight transport is simulated using Monte Carlo (MC) method. The simulation results show that oil plumes of different droplet sizes are dispersed very differently by the ocean turbulence, with large oil droplets concentrating in confined regions near the ocean surface, while small oil droplets being diluted widely over the upper-ocean mixed layer. The differences in oil droplet size and dilution rate yield different inherent optical properties for the mixture of oil droplets and seawater, resulting in very different light absorption rate for different ocean flow and oil plume conditions. The ocean LES part of this research is made possible by a RFP-V grant from The Gulf of Mexico Research Initiative. The MC model development and simulation are supported by DY's start-up funds at the University of Houston. The authors also acknowledge the use of the Opuntia Cluster from the Center of Advanced Computing and Data Systems and the advanced support from the Research Computing Center at the University of Houston.

Net Production of Diatom Silica on the Louisiana Shelf

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Diatoms are a critical phytoplankton group in coastal ecosystems. They have an obligate requirement for dissolved silicic acid (dSi) which they use to build their shells of biogenic silica (bSi); thus, DSi potentially

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controls diatom growth. The documented decreases in Mississippi River DSi (since the 1960s) suggests that Si now plays a more important role in diatom productivity within the coastal ecosystem it nourishes. However, no studies to date have reported data on water-column bSi production, making it difficult to understand the role diatoms play in this system and how it may change from low (e.g. oil spill) and high frequency disturbances. To determine the magnitude and spatial variability in diatom bSi production, samples were collected on the Louisiana shelf in summer 2016. Stations were targeted based on surface salinity characteristics, driven by proximity to the Mississippi River. Positive net bSi production rates indicate that diatom bSi production outpaces losses from bSi remineralization, whereas the reverse is true with negative net bSi production. Net bSi production rates were very high overall (2 - 60 mmol Si $m^{-2}d^{-1}$) and outweighed dissolution at nearly all stations. Net bSi production did not vary significantly with salinity or DSi, but increased over the course of the cruise as cloud cover and turbidity reduced. This suggests that factors affecting the light field in this region may play a larger role in regulating diatom bSi productivity than nutrients, even in high salinity zones with little riverine influence.

Long-term Production Increase of Swamp Forests Related to Freshwater Release

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Coastal freshwater wetlands can be negatively affected by rising salinity related to hydrologic alteration, anthropogenic water usage, salinity intrusion and climate-induced drought. Freshwater release from river diversions in Louisiana during the Deepwater Horizon incident had the potential of affecting wetland function, particularly if the release reduced salinity in these wetlands. We measured tree production and regeneration and compared these tree health indicators to water salinity and depth based on water gage information across the Gulf Coast of the United States in Louisiana, Texas and Florida. After the release of freshwater into the Barataria Estuary, LA, during the oil spill, tree production increased in Jean Lafitte National Historic Park and Preserve (LA) from 2010-14. As based on long-term water gages, 2010 had lower salinity and higher water levels than when compared singly or in groups to other years (2007−14). In contrast, in Big Thicket National Preserve (TX), salinity levels of tidal swamps rose in 2011−12 because of excessive water extraction and drought, so that freshwater tree species began to die and little regeneration occurred. These observations indicate that the increase in production in freshwater forests in Jean Lafitte National Historic Park and Preserve may be related to the freshening that occurred there in 2010. Hydrologic remediation may be a useful engineering tool to improve environments in impaired freshwater tidal forests. Even short−term releases of fresh water may benefit the health of freshwater species in tidal coastal forests, so that these water management tools may help managers to offset future conservation problems due to climate change and/or water extraction.

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Session 010: Impacts and Recovery of Benthic Marine Environments in the Aftermath of the DWH Event

Assessment of Oiling on the Biodiversity and Resilience of the Benthic Microbial Assemblages in Coastal Sediments of the Chandeleur Islands

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Marine sediment microbial communities play a critical role in primary production, sediment oxygenation, key biogeochemical cycles, and provide a nutrient rich food source for benthic invertebrates. While the photosynthetic organisms drive productivity at the surface, protists and other non-photosynthetic organisms dominate metabolic processes including hydrocarbon degradation in deeper sediments. In an effort to understand the response and recovery of benthic microbial assemblages in sediments we embarked on an intensive field survey in the Chandeleur Islands, an area impacted by the DWH spill. Field sites were selected representing an oiling gradient based on NOAA SCAT surveys over a range of habitats, including salt marsh, un-vegetated sand, and seagrass meadows. Triplicate sediment cores (0-40cm) were collected from each habitat across the four field sites in June and September of 2015 and 2016. Cores were sectioned and sub-samples taken for DNA sequencing and for the assessment of petrochemical contamination. Phylogenetic diversity was evaluated as a function of habitat, depth, petrochemical contamination, and relevant environmental parameters including water temperature, dissolved oxygen, turbidity, pH, salinity, and pore water nutrients. Interestingly sediment samples collected from our most southern site, which was classified as a moderately oiled site by SCAT surveys, had the lowest PAH levels at all depths and habitat types, and across all sampling periods. Conversely, a more central and protected site had significantly higher levels of PAHs compared to all other field sites at all core depths, and across all habitats ($p<0.001$). Comparisons of depth at all sites revealed a PAH spike in the seagrass cores at site B in the 15-20cm core sections in 2015 samples, but this spike was observed at the surface in 2016 sampling along with expansive developing tar mats, presumably brought to the surface during storm events.

Chlorophyll a Levels in Dichloromethane Extracts from Mesocosm Exposed to WAF, DCEWAF and CEWAF

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This research is part of the Aggregation and Degradation of Dispersants and Oil by Microbial Exopolymers (ADDOMEx) project. Water Accommodated Fraction (WAF) and Chemically Enhanced WAF (CEWAF) were prepared in 130 L tanks by adding Macondo surrogate oil or surrogate oil plus Corexit 9500 (20:1, V/V). Dilute CEWAF (DCEWAF) was prepared by an ~ 1:10 dilution of CEWAF with sea water. Experiments were with offshore and coastal seawater. All treatments were done in triplicate, and nutrients were added to all mesocosms. Water samples were taken at the beginning and then every 24 hrs. from each mesocosm. Water samples were extracted with dichloromethane (DCM) and analyzed for Estimated Oil Equivalent (EOE) concentrations and chlorophyll a (Chl-a) by fluorescence. Optimum wavelengths for chlorophyll a were λ_{exc}=434 and λ_{em}=671 nm. To the best of our knowledge it is the first time that chlorophyll has been determined in DCM extracts of oiled and chemically enhanced seawater.

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Variability between the triplicates was high, but clear trends can be seen. Chlorophyll a concentrations were about 100 times higher in coastal sea water than in offshore water. Chlorophyll was lowest in the DCEWAF treatment in both experiments, but concentrations were similar between the other three. In the coastal water experiment, chl-a concentrations increased over the full experiment for the Control and WAF treatments, but started to decrease between 24 and 48 hrs for the DCEWAF and CEWAF treatments. In the offshore water experiment chl-a concentrations decreased over time in all treatments. EOEs decreased over time for all treatments and for both experiments, and the relationship between EOEs and Chl-a changed. Chl-a always increased with respect to EOEs over time in the offshore water experiment, and it decreased for the Control and WAF treatments in the coastal water experiment. Chl-a increased and then decreased with respect to EOEs in the DCEWAF and CEWAF treatments in the coastal water experiment.

Effects of Oil and Dispersants on *Swiftia exserta*, a Structure-forming Deep-water Gorgonian Octocoral from Mesophotic Reefs in the Gulf of Mexico

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One outcome of the Deepwater Horizon (DWH) oil spill was the realization that no well-established toxicity thresholds exist for benthic taxa in deep water (>50 m). Surveys of mesophotic reefs along the Gulf of Mexico Pinnacle Trend in 2011 showed that large octocoral colonies below the oil slick exhibited significantly more injury than in years before the spill. *Swiftia exserta*, an octocoral species found throughout the West Atlantic at depths of 20-200 meters, was among the injured taxa. In the Gulf of Mexico *S. exserta* has white polyps, whereas populations in East Florida have red polyps; however, haplotype frequencies of mitochondrial gene *mutS* suggest no differences between the two populations. Live fragments of *S. exserta* from East Florida were exposed to varying concentrations of water-accommodated oil fractions (WAFs), Corexit® 9500 dispersant, and chemically-enhanced WAFs (20:1 oil-dispersant mixtures, aka CEWAFs) to determine the vulnerability of *S. exserta* octocorals to oil and dispersants. Following 96-hour toxicological assays, dispersant-alone and oil-dispersant mixtures were substantially more detrimental to coral health than any of the WAF concentrations tested. Complete mortality was observed within 48 hours for some fragments in the dispersant-alone (nominal 96h LC50 = 51.17 mg/L) and oil-dispersant (nominal 96h LC50 = 46% CEWAF) treatments, while the WAF and control groups remained relatively unaffected. This suggests that oil alone is less detrimental to octocorals than when it is treated with dispersants. This is the first toxicity threshold established for a mesophotic octocoral species subject to the DWH spill, and provides evidence of octocoral sensitivity to oil and dispersants, which should inform scientists and managers in the event of a future oil spill.

* Student Presenter

A Comparison and Validation of ^{210}Pb Chronologies of Deep Sediment Cores from the Southern Gulf of Mexico

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The IXTOC blowout in 1979, in the southern Gulf of Mexico, is considered to be an example of ecosystem impact and recovery from a major marine oi spill. Long-term time series are key to understand environmental processes, and these may be obtained from the sedimentary record. The sedimentary reconstruction of past environmental impacts requires a precise and exact time frame. To study the sedimentary records of oil pollution in the southern Gulf of Mexico (GoM), potentially impacted by the IXTOC event, sediment cores were collected with a multicorer and sectioned at 2.5 mm resolution, dated by ^{210}Pb and analyzed for several biogeochemical variables. Here we compare results of cores dated from the same multicorer, but different liners, in different laboratories. In one case, validation was provided through the independent artificial radioactive tracer ^{239}Pu. We also explored the impact on chronology of the high vertical resolution chosen. Finally, we discuss the different approaches used and propose the use of common laboratory practices and dating codes for projects were inter-regional comparison is important.

Light-induced Aggregation of Bacterial Exopolymeric Substances

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Exopolymeric substances (EPS) are colloidal macromolecules in excreted by microbes naturally, or in response to pollutant inputs (e.g. oil spill) into the ocean. They play important roles in the marine environment, e.g., in the formation of marine snow aggregates. While sunlight is considered to inhibit or disrupt the aggregation of marine colloids via cleavage of high molecular weight compounds into smaller, less stable fragments, the opposite can also happen. Some biomolecules such as proteins that can be excreted by bacteria are known in other systems to form aggregates via crosslinking mediated by radical oxygen species (ROS), produced by enzymes or by sunlight. To test whether light-induced aggregation can occur in the marine environment, we conducted irradiation experiments on a well-characterized protein-containing EPS from the marine bacterium *Sagitulla Stellata*. Our results show that after 1 h sunlight irradiation, the turbidity of soluble EPS was 62 % higher than that in the dark control, as well as removal of dissolved organic carbon (~10%) in that time. The relatively high protein content of the bacterial EPS compared to a non-protein containing EPS from phytoplankton, and the elevated ratio of amide to carbohydrate of the aggregate indicate that photo-oxidation of proteins may be responsible for the aggregate formation. ROS production, which was tested as well, was shown to have taken part in the photo-oxidation process. In addition salt and Ca^{2+} may have assisted aggregation as well. This light-induced aggregation provides new insights into polymer assembly and marine snow formation in marine environments.

* Student Presenter

Rapid macromolecular characterization and prediction of phytoplankton and marine aggregate's exposed to chemically enhanced (COREXIT) water accommodated fraction (WAF) of oil using Fourier Transform Infrared (FTIR) spectroscopy

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Microbes alter their extracellular composition of macromolecules in a response to changing environmental conditions. Often these macromolecular changes are quite consistent with the associated environmental conditions and can be potentially used as an indicator to predict the exposure of samples to given conditions. Fourier Transform Infrared (FTIR) spectroscopy is a powerful tool that can give a snapshot of macromolecular composition of a biological sample in the timespan of seconds. Here we used FTIR to characterize the changes in macromolecular composition using particulate matter (whole algal cells with associated bacteria and debris) obtained from three non-axenic algal cultures; *Skeletonema costatum*, *Emiliania huxleyi*, and *Navicula* sp. exposed to chemically enhanced (COREXIT) water accommodated fraction (CEWAF) and control F/2 medium. Analysis of the FTIR spectra using mean integrated areas of the biologically relevant bands of the raw spectra and principal component analysis on Extended Multiplicative Signal Corrected (EMSC) second-derivative spectra revealed major differences in carbohydrate and protein regions in CEWAF from control treatment samples. The resulting signature profile of macromolecular composition was then used to build a multivariate model using the Partial Least Square Discriminant Analysis (PLS-DA) which allowed for successful classification of COREXIT and control exposed samples. This model was further validated using aggregate samples obtained from a mesocosm (~100L) study. Overall we developed a robust multivariate model that can be used to identify whether a sample was exposed to CEWAF.

Response of the Louisiana Marsh Subtidal Macroinfaunal Communities to the Deepwater Horizon Oil Spill

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The estuaries of the northern Gulf of Mexico were some of the most affected areas during the 2010 Deepwater Horizon oil spill. Macroinfauna play a crucial role in making these estuaries a fertile ground for many resident and transient consumer populations. Macroinfauna are considered good indicators of ecosystem health due to their sessile mode of living. We used community composition along with ancillary parameters, including hydrocarbon concentrations to assess the impact of the Deepwater Horizon oil spill on the macroinfauna. Samples were collected from Terrebonne Bay where oiling in July 2010 was evident. Three sediment cores were collected from four different sites adjacent to marshes known to be oiled and unoiled during spring, summer, and fall of 2014 - 2015 at 1-m water depth. These macroinfauna samples were taxonomically enumerated to the lowest denomination possible to determine spatial variability among various diversity indices. Macroinfauna distribution patterns were analyzed using nonmetric multidimensional scaling. Principal component analysis and canonical correspondence analysis were used to understand the effect of various environmental factors, such as sediment hydrocarbon content, sediment total organic carbon content, sediment grain size, and salinity, on macroinfauna distribution patterns. Polychaetes dominated the abundance followed by peracaridean crustaceans, and molluscs. Filter/suspension feeding macroinfauna were the dominant feeding type representing the community. Our 2014 data analysis showed an increasing trend in abundance and diversity indices values from spring to summer, and from summer to fall. The number of species and

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number of individuals representing the community at each site has shown an increasing trend in successive years. Our data indicate gradual recovery of impacted macroinfaunal communities in the subtidal regions of Louisiana marshes.

Making Oil and Water Mix for ADDOMEx Mesocosms Marine Oil Snow Impact Experiments: a tale of WAF and CEWAF

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A process that may remove oil to the sediments is the production of marine oil snow. ADDOMEx used mesocosm experiments to study this process. Oil dosing experiments require making oil and water mix. We made water accommodated fraction of oil (WAF) and chemically enhanced water accommodated fraction of oil (CEWAF) using dispersants. This required over 300 L of WAF and CEWAF and was accomplished using upto 6 baffled 130L recirculation tanks: 3 for WAF and 3 for CEWAF. The WAF and CEWAF were prepared by adding 25 ml of Macondo surrogate oil or surrogate oil plus Corexit 9500 (20:1, V/V) per tank. The WAF and CEWAF were transferred into mesocosm (81 L each) for the experiments. Mesocosm experiments consisted of controls (sea water only), WAF, CEWAF and a 1/10 diluted CEWAF (DECEF). A total of 4 ADDOMEx mesocosum experiments have been done as triplicates except Mesocsm 1 that did not have replicates. Mesocosm 3 used offshore sea water and the others used coastal sea water. The estimated oil equivalents (EOE) were determined at the start, during and at the end of the experiments. Water samples were analyze for estimated oil equivalence (EOE) by fluorescence. The EOE at the start for the controls was below the detection limit for Mesocosms 1, 2 and 3 and at 0.04 mg/L for Mesocosm 4 due to an improved detection limit. The average WAF EOE were 3.6, 0.26, 0.73 and 0.29 mg/L for the four experiments respectively. The first experiment had higher EOE due to more vigorous mixing. The starting average EOE for CEWAF were 36.0, 41.5, 39.1 and 81.1 respectively for the four experiments. The DCEWAF starting average EOE were 3.6, 2.74, 6.17, and 8.13 mg/L for the four experiments respectively. It is obvious that there is heterogeneity between the experiments and within experiments. Marine snow and marine oil snow were produced it these mesocosum indicating it is a process whereby oil may be transported to the sediments.

Utilizing the Foraminiferal Index of Environmental Impact to assess benthic impacts and recovery following the Deepwater Horizon Oil Spill

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In April of 2010, the Deepwater Horizon (DWH) Oil rig exploded and released up to 200 million gallons of crude oil into the Gulf of Mexico (GOM). As a result, a Marine Oil Snow Sedimentation Flocculation Accumulation (MOSSFA) event occurred, which increased the organic carbon flux by approximately 4-fold and polycyclic aromatic hydrocarbon (PAH) concentrations 3-fold. Microbial respiration of the organic carbon enhanced reducing conditions in the surface sediments. These low-oxygen areas compounded with increased PAH concentrations were stressful to benthic communities such as benthic foraminifera (BF). BF communities have commonly been used as bioindicators of environmental change. Certain BF have been previously documented as indicator species of high organic input, low oxygen concentration and PAH contamination. The relative abundances of these indicator species were used to populate the Foraminiferal Index of Environmental Impact ($FIEI=(N_r+N_0)/N_{tot}$ X 100) in order to assess impacts and recovery of the GOM benthos following DWH. Communities of 300 BF (N_{tot}) were identified

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from surface sediment core subsamples (<5cm) taken at 7 time-series sites throughout the northern GOM (2010-2015). Pollution resistant species (N_r) were calibrated with known redox sensitive metal and PAH concentrations. Indicator species (N_0) were determined by comparing previous literature to the assemblages identified in the GOM. Sites with higher FIEI values are representative of high organic matter flux, hypoxia, or pollutants such as PAH's. Whereas the FIEI has primarily been applied to continental shelf environments, this study seeks to apply the FIEI to the continental slope system on a larger spatial and temporal scale. The overarching goal of this work is to provide baseline measurements and establish a useful benthic health measure that can be utilized in the case of any future subsurface petroleum releases.

Polycyclic Aromatic Hydrocarbons (PAH) Distributions of WAF, DCEWAF and CEWAF Treatments in Mesocosm Experiments

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This research is part of the Aggregation and Degradation of Dispersants and Oil by Microbial Exopolymers (ADDOMEX) project. Two experiments were carried out in August and October 2015, respectively. WAF and CEWAF were prepared in 130 L tanks by adding Macondo surrogate oil or surrogate oil plus Corexit 9500 (20:1, V/V). DCEWAF was prepared by a ~1:10 dilution of CEWAF with sea water. Gentle stirring was maintained for ~12 to 24 hours before the WAF and CEWAF were transferred to 80L mesocosms. All treatments were done in triplicate. Estimated Oil Equivalent (EOE) concentrations were determined by fluorescence throughout the experiment using Macondo surrogate oil as a calibration standard. Water samples were taken in 4L bottles at the beginning and the end of experiment. These samples were extracted with dichloromethane, purified with alumina-silica gel column chromatography and analyzed by GC-MS for polycyclic aromatic hydrocarbons (PAH). There was a significant variation among triplicates, but a generally decreasing trend can be observed for total PAH concentration. The control had low but detectable PAHs concentrations representing background PAH. For WAF and DCEWAF samples, total PAH fell to 20-22% of the starting concentration after 72 hours of treatment, while for WAF samples decreased to 28%-40%. When compared to WAF samples, DCEWAF and CEWAF samples showed a significantly higher amount of light residual PAHs (naphthalenes and fluorenes). This difference in PAH profiles may be due to the influence of exopolymeric substances (EPS) formation.

Planktic Foraminiferal Records of MOSSFA and Petrocarbon Incorporation Following the Ixtoc-1 and DWH Blowouts

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Following the Deepwater Horizon (DWH) oil blowout in 2010, a marine oil snow sedimentation and flocculent accumulation (MOSSFA) event occurred in the Northern Gulf of Mexico (NGOM). MOSSFA was a significant pathway for the delivery of oil from surface waters to the seafloor. Sedimentary evidence of the MOSSFA event includes 4-10 fold increases in bulk mass accumulation rates, a 3-fold increase in total petroleum hydrocarbon concentrations, increased concentrations of diatom 16S RNA and increased concentrations of bulk polysaccharides. The goal of this study is to utilize planktic foraminifera accumulation rates (PFAR) and stable isotope measurements from planktic foraminiferal tests ($\delta^{13}C$) as

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indicators of MOSSFA-related planktic flux and incorporation of petroleum carbon into foraminiferal biomass respectively. The NGOM records of PFAR and foraminiferal $\delta^{13}C$ will be compared to similar records from the Southern Gulf of Mexico (SGOM) to determine if a MOSSFA event occurred following the Ixtoc-1 oil blowout in 1979. A 2-to-4-fold increase in PFAR was documented in the NGOM following the DWH event (2010-2011) and work is ongoing to reconstruct similar records from the SGOM. Planktic foraminifera from the surface intervals of sediment cores collected ~40km northeast of the DWH wellhead had low $\delta^{13}C$ values relative to pre-spill (down-core) intervals by ~0.3‰. A similar depletion is evident in the Ixtoc-1 interval (1979-1980) from sediment cores collected in the SGOM, as far as 100km west of the Ixtoc-1 wellhead. In both cases, post-spill values are isotopically lighter relative to pre-spill stratigraphic layers, suggesting that petroleum carbon was incorporated into planktic foraminiferal carbonate. Sedimentary records of the Ixtoc event can potentially be used as an analog to validate whether MOSSFA processes are common following submarine oil releases as well as predict long-term ecosystem recovery from the DWH event.

The effects of removing carbon limitation on diatom aggregation and physiological responses when exposed to Macondo surrogate oil

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Ocean acidification is caused by the absorption of atmospheric CO_2 by seawater, and could reduce the stress of carbon limitation on silicifying phytoplankton known as diatoms. Diatoms play a key role in the marine carbon cycle due to their high primary productivity rates, and their contribution to marine snow formation through the production of exopolymeric substances (EPS). These organic matter aggregates can rapidly draw down nutrients and carbon rich substances through the water column to be consumed by bacteria or stored in the sea floor sediments. Phytoplankton are also thought to produce EPS as a means of protection from harmful substances, such as oil. While little is known about the effects of oil spills on phytoplankton, even less has been studied about the potential future implications of these events under low pH conditions. Using *Thalassiosira pseudonana*, a small centric diatom, we conducted a roller tank experiment to replicate sinking in the water column. Four treatments were used to examine the role climate change could have on diatom marine snow production: a control, enhanced pCO_2 levels, water accommodated fraction of oil (WAF), and enhanced pCO_2 with WAF. Samples were taken from the four parent treatment stocks at the beginning time point, and at the end when the tanks were removed from the roller tables. We measured *T. pseudonana*'s physiological responses including EPS production, the changes in WAF concentrations, and the changes in pCO_2. Relieving CO_2 limitation may provide insights on effects of future oil spills on phytoplankton.

FromLab to Sea Floor: Aquarium Experiments to Assess the Impacts of Marine Snow onFate and Effect of Benthic Oil

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This poster presents an overview of three aquarium experiments that were performed by the Dutch C-IMAGE team in 2016/2017. These aquarium experiments were designed to assess the impacts of marine

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snow on oil biodegradation and benthic invertebrates and to mimic the processes at the sea floor. During the Deepwater Horizon oil spill, a MOSSFA event (Marine Oil Snow Sedimentation and Flocculent Accumulation) brought large amounts of oil and marine snow towards the sea floor. To gain more insight into the effects of marine snow on the fate and effects of benthic oil, we performed three consecutive aquarium experiments, each increasing in complexity and providing a more realistic scenario. The first experiment used natural sediment and sea water without macro-invertebrates, to test the effect of marine snow on oil biodegradation. This experiment showed that the presence of marine snow inhibits oil biodegradation, most likely because of oxygen limitation. The second experiment was similar in setup as the first with the addition of three species of macro-invertebrates. This experiment showed that marine snow and oil separately reduced the survival of invertebrates. However, the combination of both marine snow and oil caused an even greater reduction in survival as well as in bioturbation. Presence of marine snow inhibited oil biodegradation. In the third experiment a more realistic gradual exposure of the invertebrates during a MOSSFA event was simulated and recovery of invertebrate populations after several weeks was assessed. This experiment showed that invertebrates could cope better with the more realistic exposure scenario, however oil toxicity still affected their survival. These three aquarium experiments provide insight into the mechanisms by which marine snow can affect the benthic and microbial community, bioturbation and oil biodegradation and demonstrates how a MOSSFA event can have serious and long-lasting effects for the benthic ecosystem.

PAH Concentrations in the Hepatobiliary Systems of Gulf of Mexico Demersal Fishes Following the Deepwater Horizon Oil Spill

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Understanding the effects of crude oil exposure on demersal fishes is particularly important given their direct interactions with persistent, polycyclic aromatic hydrocarbon (PAH)-contaminated sediments and their ingestion of benthic prey. However, the life history, physiology, and contaminant burdens of many demersal fishes is not well known due to the challenges associated with monitoring deep, marine environments. In this study, 19 PAHs, along with their alkylated homologs and metabolites, were analyzed in Gulf hake (*Urophycis cirrata*) and Southern hake (*Urophycis floridana*) to estimate PAH exposure in two non-migratory, bathydemersal species. From 2012-2015, approximately 150 bile and liver samples were collected during extensive longline surveys throughout the Gulf of Mexico (GOM). Biliary PAH metabolites were analyzed using high performance liquid chromatography with fluorescence detection (HPLC-F). Liver samples were extracted using a modified QuEChERS (Quick Easy Cheap Effective Rugged Safe) method, and PAHs were quantified with GC-MS/MS operating in multiple reactions monitoring (MRM) mode. Spatiotemporal trends, species-specific differences, and correlations with fish length and sex were evaluated in bile and livers. These results will help establish contaminant baselines for GOM benthos, improve our understanding of PAH partitioning in fish tissues, and contribute to our overall understanding of oil-related impacts and recovery rates.

Investigation of Petroleum Contaminants in Blue Crab, *Callinectes sapidus*, Megalopae in the Northern Gulf of Mexico using GC/MS

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We collected blue crab, *Callinectes sapidus*, megalopae five days per week over a six-month period in 2010 and 2011 at multiple sites across the Northern Gulf of Mexico, and one site in 2013. We used GC/MS to investigate if we could detect evidence of petroleum hydrocarbons in megalopae, and if detected hydrocarbons could be linked to the DWH oil spill. We compared the concentrations of long straight chain alkanes found in megalopae to the area overlap of oil within a 100km radius from each site. We also compared concentrations of alkanes in megalopae between years.

We detected long straight chain alkanes in megalopae in 2010 but not in 2011 or 2013. The highest concentration of alkanes was found in Grand Isle, suggesting that the alkanes are sourced from the DWH oil spill. No PAHs were detected in any year. Lack of correlation between the alkane concentrations in megalopae and spatiotemporal locations of surface oil slicks suggests that oil contamination in blue crabs was through sediment or indirectly through the food chain rather than directly from larval encounters with surface oil.

Sedimentary Signatures and Preservation Potential of the Post-DWH Depositional Pulse

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Following the 2010 DWH event, a depositional pulse was documented in bottom sediments in the NE Gulf of Mexico. This massive sedimentation event resulted in a ~1 cm thick surface layer deposited within ~5 months, recorded by a significant increase in excess ^{234}Th inventories and mass accumulation rates. The sedimentological signature of the depositional event was recorded differently in two sedimentologic regimes. On the western, siliciclastic-dominated side of the Desoto Canyon, the event was manifested as an initial increase in calcium carbonate content and silt-sized sediments. The eastern, carbonate-dominated side of DeSoto Canyon exhibited a decrease in carbonate content, and a significant decrease in silt-sized sediments. This sediment distrubution pattern is consistent with a massive sediment influx from surface waters in both sedimentological regimes, and is inconsistent with increased siliciclastic sediment input by the Mississippi River. Time series data over the past ~5 years exhibit excellent reproducibility in sediment grain size and composition throughout all but the surficial layers of the cores. Grain size over the surficial 2-3 cm of all cores is highly variable, with the greatest excursions from the downcore mean occurring in the first cores collected after the event. This pattern is consistent with a rapid deviation from pre-event sedimentation conditions, followed by a gradual return. These data also indicate that the sedimentological signature of the event has thus far been preserved. Continuation with time series and comparison with the 1979 IXTOC-I event will provide insight into the long-term preservation potential of the sedimentological signature of this event and similar depositional events, whether natural or anthropogenic, that may be preserved in the sedimentary record.

Effect of Crude Oil and Chemical Dispersant Exposure on Clearance Rates of Eastern Oyster

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Oysters play a crucial role in coastal ecosystems and are of significant economic importance. As a shallow water, filter feeding organism, oysters can be particularly vulnerable to exposure from pollutants such as oil spills. The Deep Water Horizon oil spill impacted a number of oyster beds along the

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northern Gulf of Mexico. The ability to filter large quantities of water is critical to an oyster's fitness and may also affect the community structure of coastal plankton. In this study, we examined clearance rates of the eastern oyster (*Crassostrea virginica*) after exposure to Louisiana Light Sweet crude oil, a chemical dispersant (Corexit 9500), and a combination applied at 20:1 oil to dispersant ratio at different concentrations and exposure intervals. *Isochrysis galbana* (500 cells mL^{-1}) was fed to oysters and five aliquots were taken and preserved during 30 minute feeding experiments. Cell counts and dry tissue weight were used to calculate filtration rate. Results show at low concentrations, oysters were able to return to a filtration rate equal to or above those of control oysters after brief exposures whereas at the highest concentrations tested, filtration rates did not return to rates observed in control oysters. These results suggest when exposed to low concentrations of oil and/or chemical dispersants, eastern oysters may not exhibit significant changes in feeding rates whereas brief exposure to higher sub-lethal concentrations may have lasting effects.

Abundance of Stained Benthic Foraminifera and Its Response to the Environmental Variability of the Gulf of Mexico

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Here we present new results on the benthic foraminifera distribution patterns in sediment samples collected from slopes and the abyssal plain of the Gulf of Mexico (GM) south of 25°N. Our observations show the importance of water depth and food availability to explain their abundance patterns. We used several cores extracted from stations ranging between depths of 1200 to 3800 m collected during three oceanographic cruises, XIXIMI-2, 3, and 4 aboard the research vessel BO/Justo Sierra during 2011, 2013 y 2015, respectively. From each station we sampled the first 3 cm at 1 cm resolution which were preserved in a 4% formalin sea-water solution to which we added Rose Bengal for the identification of the living or recently alive benthic foraminifera. We washed these samples back in the laboratory through a 64µm sieve, though we only used the >150µm size fraction for the picking of stained benthic foraminifera. Our results show a distinct enrichment in their abundances in cores collected from the slopes of the GM, where these abundances clustered around 37,000 stained benthic foraminifera/m^2. In contrast, the abyssal plain region showed abundance ranges around 19,000 benthic foraminifera/m^2. In general, there is a variability between the three cruises, specially in 2015. These observations suggest the influence of a higher flux of organic matter to the slope regions than to the abyssal plain sediments. Another pattern emerged in our observations related to the higher abundances of agglutinated foraminifera in the abyssal plain region in contrast with the slopes. This observation agrees with a similar one reported by Bernhard *et al*. (2008) in spite of the different treatment we carried in our sediment samples. We will explore several explanations for this observation that range from the carbonate saturation state in these deep waters to food availability to try to explain this important distribution pattern.

* Student Presenter

A comparisonof Sedimentary Redox Sensitive Metals following the Deepwater Horizon and Ixtoc Events in the Gulf of Mexico

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Following the Deepwater Horizon (DWH) blowout event of 2010, a marine oil snow, sedimentation and flocculent accumulation (MOSSFA) event occurred in the northern Gulf of Mexico (GoM). Subsequently, surficial sediments became more reducing as a result of the rapid consumption of oxygen caused by microbial degradation of MOSSFA material. How did sedimentary conditions change in the Southern GoM following the Ixtoc blowout of 1979? In an effort to correlate these changing reducing conditions in the Northern GoM with changing sedimentary conditions in the Southern GoM, redox sensitive metal analyses were carried out on deep-sea sediment cores focused around two priority sites: DWH01, a site in the northern GoM corresponding to the DWH event, and Ixtoc-1, a site in the southern GoM corresponding to the Ixtoc event. Select sediment samples underwent microwave acid digestion at high temperature and pressure, dilution, and filtration before being analyzed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). We present redox-sensitive metal concentrations for manganese, rhenium, iron, and several other metals as indicators of changing redox conditions in the sediment. This work compares the concentration of these metals at locations in the northern and southern GoM in order to establish the presence of a MOSSFA event following Ixtoc.

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Session 011: Human Dimensions and Activity of Oil Spill Response, Restoration, and Future Preparedness: Interdisciplinary Communications and Community Resilience from a Social Ecological and Systems Approach

Lardner's Point Park, Ecological Restoration of a Living Shoreline - An Athos Oil Spill Trust Fund Supported Project

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In the wake of the Athos Oil Spill on the Delaware River in 2004, a trust fund was established and seven years later ten projects were selected for funding and implementation. One of the selected projects funded was Lardner's Point Park along the North Delaware Riverfront in Philadelphia, Pennsylvania. The project was attractive to the Trustees for funding because it was a project located in the spill impact vicinity. Lardner's Point was designed to be an ecological park along the East Coast Greenway trail as a local community trailhead park for a section of the greenway known as the K&T Trail. The park was created on a post-industrial restored brownfields site providing a recreational open space and ecological amenity for the Tacony neighborhood that was underserved in term of publicly accessible green space providing outdoor recreation opportunities. The park was created with native habitats and landscapes, sustainable outdoor furnishings, porous walking trail connections, a refurbished fishing pier and interpretive signage. A critical element of the park was a natural/nature-based living shoreline treatment that restored a hardened and dilapidated stretch of shoreline to a functioning habitat and stabilization element. The park and shoreline have become an important and appreciated local amenity for the community. The living shoreline and riparian area are undergoing 5 years of annual monitoring to determine the ecological effects of the project, and to adaptively inform future living shoreline projects along the Delaware River Estuary.

Working Together to Facilitate Healing: How Lay Health Workers Can Aid Counselors and Social Workers Following a Disaster

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Disaster recovery personnel include counselors and social workers who are often called upon to help address the psycho-social effects of natural and technological disasters. Although previous literature examines the holistic and extensive utility of Lay Health Workers (LHWs) in expanding healthcare capacity in vulnerable communities, there is a deficit of knowledge on how LHWs can aid in disaster recovery. This poster provides a conceptual review of the utilization of LHWs in the aftermath of disasters, reviews relevant training topics, and explores the potential utility of LHWs in aiding recovery efforts following natural and technological disasters. We focus on two types of Lay Health Workers trained by University of South Alabama's Coastal Resource and Resiliency Center: 1) Volunteer Peer Health Advocates (PHAs), and 2) Community Health Workers (CHWs). PHAs and CHWs are well-equipped to aid in the aftermath of disasters because they are trusted members of their communities, speak the language of the people, know available local resources, and are familiar with area needs and vulnerabilities. Most importantly, these PHAs and CHWs are trained as "peer listeners" and have the skills to triage disaster survivors and provide referrals to needed resources, allowing recovery personnel, especially counselors and social workers, to do their jobs more efficiently.

* Student Presenter

Use of Chemometrics to Identify Active Constituents of Select Hepatic Toxic Responses to Crude Oils
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Generally, health effects of crude oil are based off of previous releases/spills. Observed hepatotoxic effects from crude oil exposure should vary in response according to the source and make-up of the various crude oils. We have determined values for several toxic effects of acute exposure to the following oils: LA Sweet, Nigerian 'Qua Iboe', Iraqi high sulfur, Venezuelan Merey and Leona, and Ecuadorian Oriente (all from ONTA, Inc., Toronto), and Deepwater Horizon (DWH) A010G4 "Surrogate", A0083Q "MASS Aug 15" and A001EP/EQ "SOB MAY 22" (AECOM, Inc., Fort Collins, CO). Female Sprague Dawley rats were treated with 2 daily doses (2.5, 5 mL/Kg, p.o.) and were bled 48hrs later for hematology, clinical chemistry, and necropsied. Rats treated with all oils had elevated relative liver weights and decreased albumin and glucose. For liver histopathology, 5um sections were cut from formalin-fixed, paraffin-embedded tissues and stained with hematoxylin and eosin using standard procedures. Hepatocytes of the treated animals showed visual differences in pathology, e.g., cellular swelling, sinusoidal disruption, periportal lesioning. The use of chemometrics to identify active constituents was employed using Partial Least Squares regression (PLS; NIPALS algorithm). We regressed peak areas of chromatograms from GC/MS (HP-5 column) on relative liver weights, albumin, and glucose. Among 80 selected peaks based upon shared area or identification between the various oils, the PLS algorithm gave the highest weighting factors for 2,6-dimethyl-octane, 2-methyl-decane, 4-methyl-decane, and 1-ethyl-2,4-dimethyl-benzene for albumin and glucose; 1-Ethyl-2,4-dimethyl-benzene and a trimethyl-napathalene isomer most influenced liver weights. These data support use of PLS regression as a tool for non-targeted, in situ identification of toxic constituents of crude oil and suggest feasibility of its wider application to complex mixtures.

Web-content personalization for resilience and risk communication
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The Consortium for Resilient Gulf Communities (GRGC) conducts research, outreach, and education activities aimed at investigating and addressing the public health, social, and economic impacts of the Deepwater Horizon Oil spill in the Gulf of Mexico region. The consortium seeks to understand and promote communities' resilience to adverse future events. To facilitate risk communication, we have designed and implemented a website with automated content-personalization capable of matching different user types (e.g., a policy maker or social worker) with the most relevant information concerning the oil spill impact and resilience-building strategies. This is accomplished through a recommender system that uses artificial intelligence to match user profiles to relevant information objects. This technique goes beyond facilitating document search by providing an ad-hoc and efficient method for retrieving significant information. The key challenge has been to model users' interests without leveraging passive data such as browsing behavior, which is currently unavailable on the specific areas of interest. We have instead based the matching criteria underlying the recommender system on more accurate and explicit data obtained through extensive stakeholder interviews conducted by the Consortium. Stakeholder represented government agencies, businesses, and community organizations. The interviews were loosely structured around a set of overarching questions regarding the oil spill, key decisions, knowledge needs, and community resilience. Interview transcripts were coded to extract

* Student Presenter

topics of interest. Based on these data, we have computed concept prevalence by stakeholder type, which served as a measure of relevance in the user-topic association rules guiding the AI algorithm. The website is designed in order to facilitate the inclusion of new content and has potential to become a powerful and extensive information hub for resilience of the Gulf.

* Student Presenter

Session 012: Deepwater Horizon Oil in Coastal Environments: Observations, Experiments and Predictive Modeling

The Effects of Oil Additions and Salt Marsh Vegetation Diversity on the Cycling and Removal of Nitrogen

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Coastal wetlands provide an important ecosystem service by permanently removing nitrogen through the process of denitrification. Understanding how anthropogenic activities such as oil spills affect nitrogen removal by marshes is critical. As part of a large-scale mesocosm study we aimed to understand the impacts of the Deepwater Horizon (DWH) oil spill on nitrogen cycling in coastal marsh environments. We examined nitrogen processes in oiled and control mesocosm tanks with different marsh vegetation as part of a larger study that is examining how vegetation diversity can contribute to ecosystem resiliency following an oil spill. Nitrate and ammonium fluxes were not significantly different among the oiled and unoiled treatments. Similarly, denitrification rates measured with the isotope pairing technique were also similar between the treatments. In contrast, potential denitrification rates (in the presence of 100 uM excess nitrate) were 3.5 times greater than rates in control treatments (215±41 μmol m^{-2} hr^{-1}) than in oil treatments (62±19 μmol m^{-2} hr^{-1}). In addition, nitrogen fixation was two orders of magnitude greater in oiled treatments (68.0±18.4 μmol m^{-2} hr^{-1}) than in control treatments (0.8±0.2 μmol m^{-2} hr^{-1}). We plan to further study the effects of oil on the different vegetation treatments in order to assess the role of diversity in plant communities and oil on nitrogen processes.

Mississippi River Plume Interaction with Surface Oil in the Northern Gulf of Mexico

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An understudied aspect of marine oil snow formation is the role of river plumes, which carry nutrients and suspended particulates that can act as aggregation kernels for phytoplankton-derived marine oil snow. Oil seeps have been connected to increased primary productivity relative to non-seep sites (D'souza *et al*., 2016), and increased TEP production at seeps is thought to facilitate marine oil snow formation (Ziervogel *et al*., 2014). Data from recent glider deployments near a natural seep site indicate simultaneous influence of fresh water and hydrocarbon inputs in the upper 200m on the continental slope; analysis of hydrographic and bio-optical data (backscatter, CDOM and chl-a fluorescence) collected by the glider suggests that large particles are formed below the phytoplankton max after the arrival of fresh water at slope sites with seep activity. We will explore the interaction of Mississippi River plume water with hydrocarbons near this natural seep site, taking advantage of a combination of satellite sea surface temperature, ocean color, and glider-derived subsurface data. Comparison to shipboard and laboratory experiments will be used to consider potential controls on this important but understudied aspect of marine oil snow formation in the northern Gulf of Mexico.

* Student Presenter

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 5.5 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 19.2 mm at 5.5 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. The extent and duration of oil in the water during the spill and the biological responses we measured indicates that *L. irrorata* were probably affected in their ability to carry out their life cycle on the marsh and/or in the water column at all study sites (including reference) for some period of time. However, variation in average shell length may indicate a chronic toxicity effect at oiled sites as the snails grow and feed on the marsh surface and on *Spartina alterniflora*.

Growth of *Alcanivorax borkumensis* using oil dispersed by food grade amphiphiles

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In our recent research, food grade amphiphilic molecules such as soybean lecithin and polyethoxylated surfactants have been shown to be effective emulsifiers and capable as substitutes for DOSS in the design of new dispersant systems. This presentation will describe the effects of such amphiphiles on the growth rates of *Alcanivorax borkumensis* (AB) during oil biodegradation and comparisons will be made to AB growth in the presence of DOSS. Experiments done in a Franz cell allow for clear monitoring of growth patterns in an aqueous subphase below an oil layer. Complementary experiments are also performed with dispersed oil in the absence of a surface oil layer, allowing us to continuously sample the aqueous subphase for droplet size and oil concentration analyses. Detailed imaging of the oil/water interface using optical microscopy and cryogenic electron microscopy allow for visualization of AB localization at the interface and the possible formation of biofilms as a function of surfactant composition. This work complements our research on the dispersion effectiveness of lecithin and lecithin/Tween-80 mixtures.

* Student Presenter

Effect of photodegradation weathering process on biomarker diagnostic ratios used for source oil identification

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When crude oil is accidentally released into marine environment, it undergoes various natural weathering processes including evaporation, dissolution, photodegradation and microbial degradation. Photodegradation is one of the major degradation pathways especially for higher molecular weight hydrocarbons present in the oil. Traditionally, the biomarker diagnostic ratios of hopanes and steranes are used for source oil identification as these groups of compounds are resistant to various weathering processes. But, several studies conducted in the past have concluded that hopanes and steranes are susceptible to microbial degradation. Very few studies have focused on photodegradation of hopanes and steranes. In this research, we focus on the effect of photodegradation on the biomarker diagnostic ratios of hopanes and steranes.

Crude oil concentration affects bacterial community structure and hydrocarbon degradation rates in surface water of the northern Gulf of Mexico

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The Deepwater Horizon incident resulted in the largest oil spill with different oil concentration gradients from the subsea plume to offshore surface and coastal waters in the northern Gulf of Mexico (nGoM). Numerous laboratory and field incubation experiments that aimed to evaluate the impact of the spill relied on single oil concentrations, and have not accounted for the effect of initial oil concentration on the variability of microbial and chemical data observed. Here, we investigated how crude oil concentration (0, 50, 100, 200, 400, and 800 ppm) affects the microbial community structure and hydrocarbon biodegradation rates. Coastal water from the nGoM was amended with different oil concentrations and incubated for 50 d at room temperature (24ºC). Hydrocarbon concentration and bacterial community were analyzed periodically by GC/MS and pyrosequencing, respectively. We observed a general trend on the change of overall bacterial community structure from 50 ppm to 800 ppm. Statistical analysis revealed that the bacterial community structures at 50 to 200 ppm were significantly different from those at 800 ppm. *Rhodobacterales*, *Altererythrobacter*, and *Neptuniibacter* increased in relative abundance with increasing oil concentration. On the other hand, *Parvibaculum* and the known oil-degrading *Alkanivorax*, remarkably increased up to >30% of total community at 50 to 200 ppm, but barely undetected at 400 and 800 ppm. At 28 d of incubation, >50% of total *n*-alkanes were degraded in 50-200 ppm, while <40% were consumed in 400 and 800 ppm. Similarly, >50% of total PAHs in the lower concentrations were degraded, but <30% in 400-800 ppm were metabolized. Calculation of degradation rate constant based on first order kinetics further revealed a decreasing rate with increasing oil concentration. This study demonstrated the impact of oil concentration on bacterial composition and hydrocarbon degradation rates in the nGoM and may help explain the data variability previously reported among different studies.

* Student Presenter

Multibeam Water Column Data Processing Techniques to Facilitate Bio-Acoustic Interpretation
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One component of the GoMRI CONCORDE project is focused on examining water column acoustic return data from a 400 kHz Reson 7125 multibeam sonar within the Mississippi bight in an effort to identify and map biomass throughout the region. The remotely sensed multibeam sonar acoustic data are traditionally considered relative measurements of a water column impedance contrast, which are difficult to correlate with biological and physical properties of the water column. To overcome this constraint, the data is being correlated with imagery from an In Situ Ichthyoplankton Imaging System (ISIIS) (with CTD, dissolved oxygen, PAR, and chlorophyll-a fluorescence) to help interpret the acoustic return data. There are many technical challenges associated with correlating the two datasets, as the multibeam sonar data are in three dimensions and they operate on different temporal and spatial scales. Overcoming issues with receiver sidelobe interference and developing a filtering algorithm to identify objects and areas of interest, which might normally be considered noise, is investigated.Multibeam sonar water column data is traditionally used by hydrographic surveyors to identify the minimum depths over anthropogenic seabed targets, like sunken vessels, when the bottom detection fails to observe the least depth. The development of these filtering algorithms will allow the data to be correlated to the reference imagery data from the ISIIS, and other sensor information, expanding the capabilities of the multibeam system. The processing techniques identified in the project will aid in applying this technology to biological and physical identification and takes advantage of the simultaneous data collections during the CONCORDE project.

Biological Toxicity of Extracts from Photochemically Degraded Water Accommodated Fractions
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To determine effects of photochemical weathering of petroleum, surrogate crude oil was exposed to solar radiation during the formation of Water Accommodated Fractions (WAF) in sterile seawater. Samples were incubated in either unfiltered sunlight, with ultraviolet radiation blocked (Photosynthetically Active Radiation [PAR] only), red and yellow filtered light and in darkness. WAFs were collected after one week. Acidic and basic soluble species produced in the WAFs were extracted using a liquid/liquid method. Of the acid extracts, those created during exposure to yellow light had the greatest toxicity. Basic species produced under exposure to red filtered light showed reduced bacterial growth indicating the longest wavelength of light is responsible for the formation of more toxic components. These results are consistent with those previously reported for surrogate and Macondo (MC252) oils.

Dynamics of Carboxylic Acids Produced in Weathered Deepwater Horizon Oil Samples and their Water Solubility
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As Deepwater Horizon oil weathered in the environment either through photooxidation or microbial degradation, oxygenated compounds were formed. These processes lead to the formation of an

* Student Presenter

oxygenated hydrocarbon (oxHC) fraction that dominates the composition of weathered oil. However, there is not much known about the composition and environmental fate of this fraction. Previous research suggested that carboxylic acids are one of the most abundant compound class in this oxHC fraction of the weathered oil. We investigated three different types of crude oil (including Macondo well surrogate oil, Alaska North Slope oil and heavy fuel oil) as well as weathered oil to determine differences in carboxylic acid concentrations in different types of oils. Weathered samples, in the form of sand patties, were collected from the Deepwater Horizon spill on the beaches of the northern Gulf of Mexico. Generally, we found that during weathering, smaller chain carboxylic acids were lost over time. At the same time, a suite of long-chain carboxylic acids appeared and are presumably formed during oil weathering. Furthermore, we prepared high and low energy water accommodated fractions (WAF) of a range of oils to investigate the concentration of carboxylic acid present in the water fraction. Overall, oil weathering and dissolution present a dynamic system in which these carboxylic acids are being formed, dissolved, and degraded. This study documents the concentration and leaching potential of carboxylic acids in weathered oil. Further research will investigate their potential toxicity or the bioavailability.

Incipient Motion of Sand and Oil Agglomerates

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Following the 2010 Deepwater Horizon oil spill, large mats of sand and oil formed along the northern Gulf of Mexico as weathered oil mixed with sediment in the surf zone. Wave action fragmented these mats into 1 to 10 cm diameter sand and oil agglomerates (SOAs), which are composed of 70%-95% sand by mass. SOAs were repeatedly observed on northern Gulf of Mexico beaches for years following the spill as they were unburied and transported on and along shore. The size, shape, and density of SOAs (i.e., larger, less spherical, and lighter than sand) increase uncertainties in the prediction of their motion and transport. To improve the understanding of SOA incipient motion, experiments were conducted in the Small-Oscillatory Flow Tunnel at the U.S. Naval Research Laboratory under a range of hydrodynamic forcing and bed configurations. During the experiment, spherical and ellipsoidal SOAs ranging in size from 0.5 to 10 cm were placed on a fixed flat bed, a fixed rippled bed, a movable sand bed. For experiments with the movable sand bed, the SOAs were initially placed proud for some trials and partially buried for other trials. SOA position was tracked with high-definition video and some of the larger SOAs were instrumented with an inertial measurement unit. Shear stress and horizontal pressure gradients, calculated from velocities measured by a Nortek Vectrino Profiler, were compared with observed mobility to assess formulations for incipient motion. The results indicate a deviation from the predicted critical shear stress that increases with size and diameter. For diameters less than 1 cm, incipient motion was consistent between spherical and ellipsoidal SOAs and agreed with predicted values. The shear stress required for incipient motion was lower than predicted for larger spherical SOAs, indicating an increased dependence on the horizontal pressure gradient. For ellipsoidal SOAs, the measured shear stress required was greater than predicted. These laboratory observations will improve the parameterizations of incipient motion, seafloor interaction, and transport of SOAs to assist future SOA clean-up efforts.

* Student Presenter

Seasonal Variability of Microbial Response to Crude Oil Water Accommodated Fractions
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The seasonal response of marine microbial communities to crude oil exposure was examined between September 2015 to September 2016. Water samples were collected from Pensacola Beach at two-week intervals and a standard oil exposure protocol was performed using a Water Accommodated Fraction (WAF) made from Gulf of Mexico Surrogate oil under photo-oxidizing conditions. WAF was added at six concentrations between 0 and 10% final vol/vol. Microbial growth was measured using 3H-leucine incorporation for bacterial production and 14C-bicarbonate fixation in photosynthesis vs irradiance curves for phytoplankton growth. The slope of inhibition from the dose response curve was used as a quantitative value for relative inhibition at each time point. Inhibition of bacterial growth demonstrated a clear pattern with maximal inhibition during warmer summer months with lower inhibition levels during colder winter samples. Inhibition of phytoplankton followed a similar pattern but inhibition increased earlier in the spring than it did for bacterial growth. There was a significant relationship between inhibition and water temperature. The relationship between other environmental parameters (nutrients, bacterial cell numbers, chl a, and microbial diversity) are currently being analyzed. Results further indicate that all oil spills are not created equally and that time of year may be a significant factor in determining the impact a spill may have on a local marine community.

Numerical investigation of chaotic behavior of breaking waves
Z. Wei, R. A. Dalrymple, C. Li, J. Katz
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During the course of a laboratory study on the dispersal of oil under breaking waves, Li & Katz observed the chaotic behavior of breaking waves, i.e., the shapes of the breakers vary between consecutive experimental runs, although the initial wave generation setups were the same. This phenomenon was later confirmed by Wei *et al*. when reproducing the experiment of Li & Katz by a numerical model; the non-breaking portion of waves was satisfactorily replicated by the numerical model, but not the shape of breakers. This study was motivated by the above observations, and we investigate the chaotic behavior of breaking waves by using a mesh-free Smoothed Particle Hydrodynamics model, GPUSPH. In an SPH simulation, the computational domain is discretized into a series of fixed size particles, and an initial perturbation was introduced in numerical simulations by placing the particles in different orders. For example, the particles can be distributed in the horizontal direction first in one simulation, and we distribute the particles in the vertical direction first in another simulation. By doing so, we are able to produce chaotic breaking waves, and we observe numerical predictions with a similar non-breaking wave profile but different shapes of breakers. To better understand the chaotic behavior of breaking waves, we further compare the evolution of breaking wave crests, and velocity and vorticity fields near the breaking wave crests, which provide some indications about the crest instabilities of breaking waves that were previously observed by Duncan's group in the laboratory and theoretically analyzed by Longuet-Higgins.

* Student Presenter

Comparison of Resilience in Naïve *Ruppia Maritima* (Florida) versus Pre-conditioned *Ruppia Maritima* (Louisiana) in Exposure to the Water Associated Fraction (WAF) of Crude Oil in Laboratory Mesocosms

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The Macondo oil spill was a significant environmental perturbation in the northern Gulf of Mexico, negatively impacting many coastal ecosystems. In this study, we compare the physiological responses and health of southwest Florida seagrass (*Ruppia maritima*) with its counterpart in the northern Gulf of Mexico (Chandeleur Islands, Louisiana) using mesocosm-based experiments. We are assuming that the southwest Florida seagrass beds are naïve to oil *versus* those from the Chandeleur Islands due to the lack of oil extraction activities along the southwest Florida coast coupled with the chronic low-level exposure from oil extraction activities in the northern Gulf of Mexico in addition to the acute, Deepwater Horizon event. We hypothesize that the southwest Florida seagrasses will therefore exhibit more evidence of negative impacts and reduced recovery capability versus the Chandeleur Islands seagrasses due to this naïvety. This project is a component of a larger effort addressing the following question: Are the Chandeleur Island environments less diverse due to chronic crude oil exposure, but also more resilient to acute events? Overall, these experiments will help address how environmental impacts (such as crude oil exposure) affect the health and resiliency of the seagrass species, *Ruppia maritime*.

Linking Chemical Composition to Toxicity of Fresh and Weathered Oil Samples Collected from the 2010 Gulf of Mexico Oil Spill

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Oil residues from the 2010 Deepwater Horizon oil spill are still found on beaches in the Gulf of Mexico, however few studies have looked at toxicity for such highly weathered oil. To fill this gap, crude and weathered oil samples were collected for chemical and toxic analysis using water-accommodated fractions (WAFs). The chemical composition of oil samples showed that toxic aromatic compounds were almost completely lost in weathered oil and that oxygenated compounds were responsible for predicted toxicity in six-year-old weathered samples. Toxicity tests using luminescent bacteria (*Vibrio fischeri*) showed that crude oil was acutely toxic, while weathered oil had no effect. Copepod (*Acartia tonsa*) assays showed greater mortality in full-strength crude and slick oil (5-30 days old) WAFs compared to highly weathered WAFs, which showed no effect on mortality. Sub-lethal concentrations of crude WAFs showed slight increases in respiration rates, while highly weathered WAFs showed no effect. Although oil from the Deepwater Horizon spill still exists in the environment, the chemical composition of weathered oil is much different from crude oil and no longer appears to be acutely toxic.

Measurements of Droplet Size Distribution Generated by Breaking Waves Acting on an Oil Slick

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The droplet size distributions generated by impact of breaking waves on oil slicks are of fundamental importance to predictions of the fate of oil spills. An extensive series of experiments examine the physical mechanism involved, and the time evolution of size distribution over several hours, starting from the initial breakup phase. Investigated parameters include the wave energy, oil viscosity and

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density, as well as oil-seawater interfacial tension. The experiments are performed in a transparent wave tank, with waves ranging from spilling to plunging breakers. The oil properties are varied by using crude, fish, and motor oils, with viscosities in the 9.4-306.5 cSt range. Interfacial tensions varying from 0.28 to 19mN/m are achieved by premixing the oil with Corexit 9500A at dispersant to oil ratios of 0.0, 1:25, 1:100, and 1:500. The size distributions are measured in-situ using high speed digital holography at resolutions of 11.1 and 1.1µm/pixel. Collected samples are also examined microscopically. Results show that decreasing the interfacial tension increases the generation of 2-10µm droplets by orders of magnitude and steepens the slope of the number size distribution. For DOR 1:25, the volumetric size distribution already peaks around 10µm. Being smaller than turbulence scales, these droplets are generated by micro-threading. A fraction of them remains suspended well over a day, and submicron droplets persist for longer periods. Droplets larger than 100µm are generated by turbulent shearing, hence their initial concentration increases with wave energy. Within this range, the size distribution slope steepens rather abruptly at a certain size, which depends on oil properties and time. The transition occurs for crude at a diameter smaller than that of more viscous oils. Due to buoyancy, the concentration of large droplets decreases with time, while smaller droplets remain suspended. Trends are consistent with those expected based on the droplet rise velocity.

Buried Crude Oil Alters the Microbial Nitrogen Cycle in Submerged Coastal Sands

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Large-scale mesocosm experiments were conducted in continuous flow advection chambers to examine the response of sedimentary microbial communities to weathered Macondo oil in beach sands. Incubations were conducted over a 3-month period and oxygen consumption rates as well as nutrient concentrations were monitored. Sediment was archived for a range of analyses including petroleum hydrocarbon chemistry, metagenomics, and potential rate measurements. The nitrification potential rate of sediment samples with and without prior oil exposure were measured in order to determine the impact of oil contamination on nitrification activity. Nitrification rates were measured in oiled and control sediments in triplicate, and in treatments with and without addition of allylthiourea (ATU) that inhibits the ammonia oxidation activity of ammonia-oxidizing bacteria but not ammonia-oxidizing archaea. No nitrification activity was observed in the replicated oil-exposed samples or in the samples that were treated with ATU. Activity was only observed in the control samples that were left untreated. Results indicate that ammonia-oxidizing bacteria, not ammonia-oxidizing archaea, played a key role in nitrification in submerged sands. Further, the lack of nitrification in oil-exposed sediments indicates that the nitrifying community was largely impacted by the oil treatment. Thus our study shows the potential impact of oil spills on the nitrogen cycle in coastal marine sediment; heterotrophic activity and its consumption of ammonia are reinforced, while nitrification activity is reduced.

Effects of Petroleum Hydrocarbon Exposure on Burrowing Activity and Oxidative Stress in Two Species of Fiddler Crabs from the Northern Gulf of Mexico

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Many macroinvertebrate species, including the Gulf marsh fiddler crab *Uca longisignalis* and the Gulf sand fiddler crab *Uca panacea*, were affected by the Deepwater Horizon oil spill in the Northern Gulf of

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Mexico. These decapod crustaceans act as ecological engineers as their burrowing activities enhance nutrient availability and oxygenation of the sediment. In addition, fiddler crabs are good bioindicators of coastal ecosystem health. The present study uses a mesocosm design to assess the effects of petroleum hydrocarbons on fiddler crabs. Mesocosms were filled with sediment and water, and placed in a greenhouse environment. For each species, individuals were exposed for 10 days to each of five concentrations of oil: 0, 8, 20, 40 or 55 mg/cm^2 for *U. longisignalis* and 0, 5, 15, 25 or 35 mg/cm^2 for *U. panacea*. Crude oil was mixed with 100 g of sediment and spread over the sediment surface in each mesocosm. Survival, burrow activity (expressed as changes in burrow diameters and burrowing frequency) and oxidative stress were measured at the end of the exposure. Oxidative stress was quantified for the hepatopancreas, using the TBARS assay. For *Uca longisignalis*, burrow diameters differed significantly among treatments ($p<0.001$); smaller diameters were observed in the presence of oil. TBARS assays indicated elevated levels of lipid peroxidation at higher concentrations of oil ($p<0.001$). For *Uca panacea*, experiments are still ongoing. It is expected that the two species may respond differently to the oil, as a consequence of their differences in body size and ecology. Future work will quantify concentrations of petroleum hydrocarbons in the gills and hepatopancreas, and assess histological changes in these tissues following oil exposure.

A Novel Approach for Screening Crude Oil Degrading Bacteria Consortia in Porous Media
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Studies have shown that many bacteria isolated from crude oil contaminated sites can use crude oil as their carbon source, making these microbes favorable crude oil degraders. Due to the wide range of isolated strains, there are a variety of strains to choose from to create an effective bacteria consortium. In order to produce the most effective consortium, various consortia's oil degrading abilities must be compared to one another. Common experimental methods that have been devised to make these comparisons require a large capital investment for supplies as well as demand a substantial amount of space and time. Our lab created a microscopic approach, which can speed up the screening process and decrease the amount of required material. This approach utilizes inexpensive, compact materials such as 35mm petri dishes and requires less oil and bacteria, ultimately needing fewer materials to grow and incubate the bacteria. This method offers a promising alternative to monitoring bacteria consortia in batch reactors. This can also enable us to visualize the entire progression of bacteria degrading a crude oil droplet. For the experiments, we selected 11 endophytes that were isolated from the root of crude oil contaminated *Spartina alterniflora*. Each individual strain's growth rates on both oil agar and normal agar were compared in order to determine if any of the strains had oil-degrading potential. We selected the strains that grew on both oil and normal agar as well as those that grew on only oil agar and combined them randomly to build various consortia, each with two or three single strains. By utilizing the newly devised microscopic approach, various consortia can be quickly and easily created and monitored. We successfully built and monitored a two-strain consortium, which possesses promising crude oil degrading ability. The scope of this novel visualization technique can be further extended to observe any changes in the oil degrading ability of the bacteria consortia resulting from adjusting the microbes' growth conditions such as adding surfactants, nitrogen, and phosphorus sources.

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Mineralogical (XRD) Signature of SWGoM Volcanic Ash Layers: Alternative Methods for Constraining the Ixtoc-I Event

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A series of sediment cores were collected from the vicinity of the 1979-1980 IXTOC-I oil spill site in the Southwestern Gulf of Mexico (SWGoM) in order to compare with the sedimentological record of the 2010 Deepwater Horizon (DWH) oil spill in the Northeastern Gulf of Mexico (NEGoM). In order to accomplish this, we need to first identify IXTOC-I sediments, which requires accurate age dating of the sediments. We currently utilize ^{210}Pb dating methods, however independent dating techniques are desirable to corroborate ^{210}Pb dates. This study proposes to use ash layers from known Chichonal (Chiapas, Mexico) volcanic eruptions as an independent geochronological tool. To accomplish this, we first need to determine a sedimentological signature of Chichonal ash layers, which is the focus of this study. Using short-lived radioisotope dating along with visual techniques, we have identified suspect volcanic ash layers in cores. Samples from these layers are currently being analyzed by x-ray diffraction (XRD) and processed employing the Reitveld method to determine their mineralogical content, which will help to identify the sedimentological signature of volcanic ash layers. Although this study has just recently begun, we have detected the presence of calcite, quartz and plagioclase minerals in suspected volcanic layers. Analyses will continue to confirm the mineralogy of the Chichonal ash signature.

Diversity of salt marsh soil microbial communities after oil exposure

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Though the effects of anthropogenic disturbances on coastal marsh plant communities have been extensively studied, root-associated soil microbiota responses to severe disturbance are not well understood. Over 1000 miles of shoreline across the northern Gulf of Mexico were oiled as a result of the 2010 Deepwater Horizon spill, with the Louisiana coast sustaining the heaviest oiling. In previous work, we found that oil exposure shifted the community composition of endophytes in Louisiana salt marshes. Other studies have similarly found that oil exposure affects salt marsh soil microbiota, but it is not clear whether exposure elicits parallel responses in root-associated microbiota. It is also not known how responses progress over time. We examined how the diversity of soil microbiota associated with Spartina alterniflora roots changed at a lightly oiled (Fourchon) and a heavily oiled (Bay Jimmy) salt marsh site in southern Louisiana, beginning approximately two years after the oil spill. We sampled three transects at the Fourchon site over 17 months and 22 plots at the Bay Jimmy site over 11 months. Using the Illumina HiSeq platform, we sequenced the V4 region of the 16S rDNA and the ITS1 rDNA to profile root-associated microbial communities in samples taken from the sites. We found the microbial communities of Fourchon and Bay Jimmy to be significantly different. At each site the community significantly varied with season as well. Bacterial communities showed compositional changes along oiling gradients at both sites. The differences between site and seasonal patterns at each site may be attributable to differences in oiling sustained at each site. Other factors, such as plant genotype, might be contributing to observed differences within and among our study sites. Future work will investigate relationships between root-associated soil microbiota, bacterial and fungal endophytes, plant genotype, and environmental conditions.

* Student Presenter

Effect of deposited DWH oil and phytoplankton on oxygen consumption and dissolved inorganic carbon production in Gulf of Mexico shallow shelf and shelf slope sediments

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Oil and phytoplankton particles settled to the seafloor in the shallow West Florida Shelf and the shelf slope after the Deepwater Horizon spill. The effects of the sedimentation of the fossil hydrocarbons and co-sedimentation of fossil and fresh carbon on benthic metabolism were unknown, precluding assessments of potential impact of the oil deposition on sediment biogeochemical reactions. This study investigated with a series of *in-situ* and laboratory chamber incubations these effects in the shallow shelf and deeper slope sediments of the northeastern Gulf of Mexico. *In-situ* benthic chambers were installed by divers at 5, 10, 15 and 20 m water depth near Pensacola Beach, Florida and spiked with oil particles, phytoplankton particles or both. Sensors in the chambers recorded oxygen consumption, and chamber water extractions produced data on the changes of dissolved inorganic carbon in the chamber water. Oil reduced sediment respiration, while the addition of algae led to an increase of sedimentary oxygen consumption and DIC production. The simultaneous addition of oil and algae resulted in oxygen consumption and DIC production rates exceeding those of the expected respiration based on the respiration of the individual additions. The deeper slope sediments responded similar to the shallow sediments but the reaction rates were lower despite the larger specific surface area of the slope sediments. The smaller rates can be attributed to the lower temperatures and reduced solute transport rates. The results of this study reveal the prompt response of the benthic system to the sedimentation of oil particles that suppressed benthic metabolism when no labile organic matter was present. Co-deposition of oil and phytoplankton reversed this effect, suggesting that the phytoplankton blooms observed after the oil spill may have had a key function for the decomposition of the oil that settled to the sea floor.

Impact of dispersant on hydrocarbon biodegradation in coastal waters

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During the Deepwater Horizon oil spill, a large amount of released oil contaminated beaches along the northern Gulf of Mexico. Oil contamination not only affects tourism, but also may adversely impact coastal ecosystems. To protect shorelines, an extensive amount of chemical dispersant was applied to reduce oil droplet size and enhance the bioavailability of discharged oil. This study investigates the effectiveness of dispersant application to stimulate biodegradation as well as the influence of dispersant on metabolically active microbial communities in coastal seawater. Dispersant and weathered oil concentrations were representative of concentrations and ratios expected during active response efforts. Preliminary results show that the application of dispersant decreased the half-life of most compound classes in 2 ppm weathered oil, even under relatively low mixing conditions in a 40-day-incubation. Alkanes up to C15 were completely removed in treatments with or without dispersant. For alkanes between C15 - C20, dispersant treatment significantly enhanced degradation. PAHs naphthalene and its homologs as well as phenanthrene approached complete removal, while the degradation of phenanthrene homologs decreased with an increase in alkyl groups. Elevated oxygen consumption and

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respiration also suggests application of dispersant facilitates biodegradation. Currently, experiments are being repeated under conditions of elevated mixing and microbial community analysis is underway.

Chlorophyll-a variations in the Gulf of Mexico in response to Deepwater Horizon oil spill

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Offshore oil spills directly deteriorate marine water quality, causing negative effects on the sustainability of the coastal environment. The chlorophyll-a concentration, which reflects the trophic condition, is one of the key indicators of marine water quality. However, the response of Chlorophyll-a to oil spills has not been thoroughly investigated. Traditional ship surveys and laboratory analysis are time-consuming and limited to small spatial coverage areas. In contrast, satellite remote sensing provides timely, large-scale observations, which can be used for monitoring both oil spill coverage and Chlorophyll-a concentration. In this study, the Moderate Resolution Imaging Spectroradiometer (MODIS) reflectance data from 2001 to 2015 (with a 500-meter spatial resolution and an 8-day temporal resolution) in the Gulf of Mexico were used for mapping oil spill coverage and for estimating Chlorophyll-a concentration. MODIS image classification was utilized to detect the area covered by the oil spill. Meanwhile, the Ocean Chlorophyll 3 MODIS (OC3M) algorithm was used to derive the Chlorophyll-a concentration product. During this process, the in-situ Chlorophyll-a concentration data for the northeastern Gulf of Mexico (NEGOM) (from 2010 to 2015) was adopted for calibrating and validating the OC3M algorithm. By comparing the remotely sensed Chlorophyll-a concentration before, during, and after the Deepwater Horizon (DWH) oil spill, analysis was carried out to understand the Chlorophyll-a response to the spill. The results show that the effect of the oil spill on Chlorophyll-a (and the duration of the effect) varies in time and space.

Copepods (Crustacea: Copepoda: Poecilostomatoida and Siphonostomatoida) associated with marine invertebrates in the Gulf of Mexico and Caribbean Sea

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The poecilostomatoid and siphonostomatoid copepods associated with marine invertebrates represent a third of the copepod species known-to-date. Nevertheless, those copepods are ignored in the recent biodiversity studies due to lack of research. One hundred and twenty six species of these copepods have been recorded for the Gulf of Mexico and Caribbean Sea, from which eighty-five are endemic (67%). These copepods are most commonly found within Cnidaria and Echinodermata, because these phyla are frequently targeted for studies in marine biology. An updated checklist containing information on the host, collection locality, and a complete bibliographical citation is presented. The first findings of *Macrochiron sargassi* (Family Macrochironidae) for the Gulf of Mexico is also presented. These findings highlight the need for future biodiversity research on copepods in this region, especially since less than 1% of the host species have been studied for these associations.

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Session 013: Multi-year Signatures of the DWH Oil Spill in Coastal Systems

Shoreline Mapping with High Spatial Resolution Radar and Geographic Processing
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A comprehensive mapping technology was developed utilizing standard image processing and available GIS procedures to automate shoreline identification and mapping precision from 2-m synthetic aperture radar (SAR) HH amplitude data. The development used four NASA Uninhabited Aerial Vehicle SAR (UAVSAR) data collections between summer 2009 and 2012 and a fall collection in 2012 of wetlands along the Mississippi River Delta that are beset by severe storms, toxic releases, and relative sea-level-rise. In comparison to shorelines interpreted from 0.3-m and 1-m orthophotography, the automated GIS 10-m alongshore sampling found SAR shoreline mapping accuracy to be ±2 m, well within the lower range of reported shoreline mapping accuracies for existing methods. The high comparability was obtained even though water levels differed between the SAR and photography image pairs and included all shorelines regardless of complexity. The high accuracy and repeatable performance of this SAR mapping technology was demonstrated in a separate study that showed Deepwater Horizon oiling intensified erosion of Mississippi River Delta shorelines.

Marsh Canopy Structure Changes and the Deepwater Horizon Oil Spill
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Marsh canopy structure was mapped yearly from2009 to 2012 in the Barataria Bay, Louisiana coastal region that was impacted by the 2010 Deepwater Horizon (DWH) oil spill. Based on the previously demonstrated capability of NASA's UAVSAR polarimetric synthetic aperture radar (PolSAR) image data to map Spartina alterniflora marsh canopy structure, structure maps combining the leaf area index (LAI) and leaf angle distribution (LAD, orientation) were constructed for yearly intervals that were directly relatable to the 2010 LAI-LAD classification. The yearly LAI-LAD and LAI difference maps were used to investigate causes for the previously revealed dramatic change in marsh structure from prespill (2009) to postspill (2010, spill cessation), and the occurrence of structure features that exhibited abnormal spatial and temporal patterns. Water level and salinity records showed that freshwater releases used to keep the oil offshore did not cause the rapid growth from 2009 to 2010 in marsh surrounding the inner Bay. Photointerpretation of optical image data determined that interior marsh patches exhibiting rapid change were caused by burns and burn recovery, and that the pattern of 2010 to 2011 LAI decreases in backshore marsh and extending along some tidal channels into the interior marsh were not associated with burns. Instead, the majority of 2010 to 2011 shoreline features aligned with vectors displaying the severity of 2010 shoreline oiling from the DWH spill. Although the association is not conclusive of a causal oil impact, the coexistent pattern is a significant discovery. PolSAR marsh structure mapping provided a unique perspective of marsh biophysical status that enhanced detection of change and monitoring of trends important to management effectiveness.

* Student Presenter

Characterization of the Sediment Archaeal Community in the Chandeleur Islands, Louisiana: Five Years after the Deepwater Horizon Oil Disaster

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Session 014: Circulation, Mixing, and Ecosystem Responses to River Discharge Patterns

Physical Dynamics on the Shelf/Slope around the MississippiRiver Delta during the Ol16 Experiment
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In March 2016 scientists from the Naval Research Laboratory, Harbor Branch Oceanographic Institute and the U. of North Carolina collected a suite of hydrographic, optical and biological datasets aboard the R/V Pelican in the Northern Gulf of Mexico during a 2 week cruise as part of the Optical Layers 2016 (OL16) experiment. Data were acquired on the shelf and slope east and west of the MS River delta in both coastal and offshore areas in waters ranging from 6-200 m. While the OL16 effort focused on testing methods to remotely detect and characterize optical layers using shipboard and satellite sensors, the focus of the present study is to describe the complex hydrodynamics occurring in the study area during the anomalous spring 2016 high-river discharge conditions through analysis of available hydrographic datasets. Observations of temperature, conductivity and velocity from both shipboard and moored instruments captured the variability on a wide range of spatial and temporal scales. Temperature and conductivity data were collected from 22 CTD (Conductivity-Temperature-Depth) casts, an offshore string mooring, a ship-board thermosalinograph, and from a towed undulating CTD instrument platform, while a ship-mounted ADCP (Acoustic Doppler Current Profiler) acquired velocity data. Ocean color and IR imagery provided larger-scale oceanographic context. In addition, the CONsortium for oil exposure pathways in Coastal River Dominated Ecosystems (CONCORDE) collected ADCP data concurrently from 5 bottom-mounted moorings. Early results show temperatures ranging from 15-23^{o}C with warmer waters generally concentrated offshore, and salinities ranging from 19-36, with pulses of fresh river plume waters interacting with saltier offshore waters. Two distinct thermohaline water mass relationships correspond to areas influenced by river inflow with mostly homogeneous temperatures, and to offshore saltier regions where temperatures monotonically decrease with depth below 40-60 m.

Observations of internal waves in the coastal waters of Alabama
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Internal waves, common to most shelf environments, are known to have an important role in the transport and mixing of material such as nutrients and dissolved oxygen and thus have the potential to impact the movement of subsurface oil and oil-derived materials. However, little is known about these waves and their relative importance on the inner shelf of coastal Alabama, particularly their potential for driving across-shelf fluxes of material as well as their capacity to enhance vertical mixing. Observations of hydrographic properties from CONCORDE consortium summer surveys as well as high frequency measurements of water column temperature, near-surface and bottom salinity, and water column horizontal velocities from a long-term mooring were used to examine the internal wave characteristic in this relatively wide, river-influenced shelf system. Significant internal wave activity was present in the time series data. Baroclinic currents at the diurnal frequency exhibited relatively strong

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mode 1 oscillations (i.e., ~20 cm/s, similar in magnitude to the low frequency currents) and were coupled with vertical oscillations in the temperature structure of ~3-4 m (~15-20 percent of water column). Being at the critical latitude (~30 degrees N), the coastal sea-breeze forcing is expected to be the dominant forcing mechanism, although other mechanism cannot be rule out at this point. While the role of internal waves on the movement of oil-derived material on the inner shelf is not yet clear, this is the first step towards assessing the importance of this mechanism along the coast of the Northern Gulf of Mexico, particularly with regard to the need for inclusion in predictive models of oil transport.

Satellite-derived Variability of the Mississippi River Plume
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The Mississippi River is an important source of freshwater input and terrigenous material to the Gulf of Mexico. We investigated the Mississippi River Plume (MRP) seasonality from 2002 to 2015, analyzing the distribution of terrigenous dissolved organic carbon (tDOC) in the Northern Gulf of Mexico (NGoM) as a proxy for the river plume. Specifically, we utilized daily observations of Remote Sensing Reflectance (Rrs) at multiple (443, 488, 547, 555, 667 and 678 nm) bands at 4 km resolution from Aqua Moderate Resolution Imaging Spectroradiometer (Aqua MODIS) to estimate the tDOC concentration from July 2002 to December 2015. Analysis showed that the seasonality is not homogenous in the entire region. East of the River mouth (85°-88°W), the MRP starts to moves offshore in March, reaching 29°N in July, before retracting to approximately up to 30°N in December. In the Central region (88°-90.8°W), the MRP widens from February to July, when plume waters can reach up to 28.5°N. Lastly, in the West region (90.8°-95°W), the MRP is widest March and June, and narrowest in January. Substantial interannual variability is also observed, with plume-influenced waters reaching 25.2°N in July 2009 and September 2015 in the Central region, and 25.4°N in July 2011 in the East region.

Semidiurnal Surface and Internal Tides in theGulf of Mexico in 4-km Global HYCOM Simulations
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University of Southern Mississippi, Hattiesburg, MS

Surface and internal tides can affect the dispersion of oil via tidal mixing fronts, residual currents, and internal wave breaking in the Gulf of Mexico. Semidiurnal surface and internal tides are investigated in realistically forced global HYCOM simulations at 4 km horizontal resolution. Harmonic analysis is applied to the surface tides generated by HYCOM to isolate the M2 tidal amplitudes and phases, which are plotted in cotidal maps. The HYCOM semidiurnal surface tides are compared to TPXO8 semidiurnal surface tides with a root mean square error calculation. The HYCOM simulations are analysed to identify generation sites, energy pathways, and dissipation sites of semidiurnal internal tides in the Gulf. The effect of background flow, such as the Loop Current, on the incoherence of internal tides in the Gulf is considered. Finally, the results are compared to available literature.

* Student Presenter

Spartina alterniflora Cuticle Accumulation of PAHs 6 Years Post-Spill
J. G. Kassenga, M. Decell, V. Elango, J. Pardue
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Concentrations of PAHs exceeding 80 mg/kg have been detected in extracts from the cuticle of *Spartina alterniflora* in plants with no other obvious indication of oiling. Cuticle concentrations primarily consist of 3-ring petrogenic PAHs (alkylated phenanthrenes and dibenzothiophenes) consistent with sediment PAH distributions at the same marsh locations. Cuticle PAH measurements of dominant vegetation like Spartina serve as an effective measure of long-term recovery of oil-impacted marshes. Data to be presented includes 2016 direct measurements from various fractions of Spartina leaf tissue in oil-impacted marshes in Port Fourchon and Bay Jimmy in upper Barataria Bay. These data will be compared with *Avicennia germinans* (black mangrove) data from the same site and data from appropriate control sites. Three PAH fractions will be described; (a) PAHs present in particles removed from the leaf surface using a 1 M EDTA solution at pH= 5; (b) PAHs present in the cuticle removed by extracting the leaf with dichloromethane immediately in the field and (c) PAHs incorporated into the leaf tissue removed by aggressive solvent extraction in the laboratory. Data from imaging of contaminated *Spartina* and *Avicennia* cuticles using two-photon confocal scanning laser microscopy will also be presented. The significance of this research is that this route of exposure on the plant surface has the potential to continue as the long-term recovery of marshes proceeds.

Accumulation of Petrogenic PAHs on Leaves of Black Mangrove (*Avicennia germinans*)
M. Decell*, J. Kassenga, V. Elango, J. Pardue
Louisiana State University, Baton Rouge, LA

Deposition of 3-ring petrogenic PAHs (alkylated phenanthrenes and dibenzothiophenes) on the exterior of *Spartina* leaves has been demonstrated in marshes impacted by the Macondo spill. Whether these deposition events result from contaminated tidal water or volatilization followed by deposition onto the leaf surface has not been conclusively established. Measurements of PAH deposition on the leaf surface of black mangrove (*Avicennia germinans*) can provide important evidence of the mechanism of deposition since these plants are rarely submerged by tidal water. In addition, these evergreen trees possess thicker cuticles with a higher capacity for PAH sorption than Spartina. Data to be presented includes direct measurements from various fractions of *Avicennia* leaf tissue in oil-impacted marshes in Port Fourchon and Bay Jimmy in upper Barataria Bay. These data will be compared with *Spartina* data from the same site and data from appropriate control sites. Three PAH fractions will be described; (a) PAHs present in particles removed from the leaf surface using a 1 M EDTA solution at pH= 5; (b) PAHs present in the cuticle removed by extracting the leaf with dichloromethane immediately in the field and (c) PAHs incorporated into the leaf tissue removed by aggressive solvent extraction in the laboratory. PAH leaf data was collected separately from mature leaves, new leaves from this growing season and leaves starting senescence. These age-sorted leaves will allow us to test the hypothesis that accumulation of PAH's in these leaves occurs predictably over time. The significance of this research is that if cuticle mangrove leaf measurements integrates recent PAH volatilization from oiled marshes, they may be effective long-term recovery measures for ecosystems with different oiling histories.

* Student Presenter

Contributions to Hypoxia Development in Mississippi Bight Waters as Revealed by Tracer Distributions during a 4-Year Time Series

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A transect across the Mississippi Sound (MS) and Bight (MB) from 2008-11 revealed hypoxia occurred in the MB during late spring and summer. Riverine sources to this region include the Mississippi River (MR), the Pearl River (PR) and St. Louis Bay (SLB). Two distinct freshwater signals in April 2008 and May 2011 were caused by the opening of the Bonnet Carré Spillway which redirects MR water through Lake Pontchartrain into the MS and MB. Oxygen isotope data ($\delta^{18}O$) showed that MB waters were regulated by mixing between MR water and seawater during hypoxic periods when strong stratification persisted. High Cs levels (5-99 nM) were observed in MS waters due to the release of Cs into SLB from a point source. Distributions of $\delta^{18}O$ and Cs in surface waters suggest that the influence of water from SLB was limited to the MS and not responsible for the development of MB hypoxia. Abnormally high dissolved Ba and nutrients were observed in both MS and MB surface and bottom waters in August 2009 (no hypoxia) and August 2011 (hypoxia), suggesting the presence of submarine groundwater discharge (SGD) in this region. During hypoxia, enriched bottom water Ba (89-360 nM) was also observed, as was high dissolved Mn (90-11,356 nM). Additionally, bottom hypoxic water was inhibited to exchange with surface oxygenated water due to strong stratification that enriched Ba and Mn accumulated at the bottom. In contrast, depleted V (17-30 nM) was observed in low oxygen water (1-29 µmol/kg) which was a result of reduced V removal. The Ba enrichment, in particular, is again suggestive of an SGD influence in the bottom waters. Overall, this comprehensive data set suggests that MR water, through stratification and possibly nutrient contributions, is a major contributor to hypoxia formation in the MB. Moreover, the trace metal data reveals SGD to be a non-negligible presence in MB waters.

Turbulence and Dispersion Associated with Near-surface Coherent Structures in Laboratory-scale Langmuir Circulation

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Near-surface turbulence and coherent structures associated with Langmuir circulation are an important part of the coastal ocean and play a critical role in dispersion and mixing across the surface mixed layer. To improve our understanding of the small-scale dynamics of near-surface turbulence related to Langmuir circulation, we simulate a large numerical wind-wave tank using a multi-phase model that explicitly resolves the air-sea interface. Traditionally, Langmuir circulation is parameterized through the addition of vortex force terms to the model equations. The multi-phase model presented here instead uses high spatial and temporal resolution across the air-sea interface to predict the underlying dynamics, including the Stokes drift and resulting Langmuir-type circulations. This is accomplished by implementing the model using the large-eddy simulation formulation within the open-source computational fluid dynamics code OpenFOAM. The numerical tank is designed to emulate the state-of-the-art SUSTAIN laboratory tank at the University of Miami, where extensive laboratory experiments studying Langmuir turbulence have previously been performed. The numerical simulations are set up to reproduce the experimental conditions during the laboratory experiments and can serve to complement the laboratory setting by providing full fields of velocity, as well as information on turbulence and particle dispersion. The simulations show a pattern of near-surface streaks and coherent structures consistent with the Langmuir regime and comparable to the laboratory observations. Near-surface

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streaks are also a well-known feature in boundary layer dynamics and their mechanism of creation is generally attributed to surface shear. The relationship between shear-driven boundary layer streaks and Langmuir-type coherent structures is investigated and the addition of vortex force “Craik-Leibovich” terms to the model equations is explored.

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Session 015: Monitoring and Modeling Responses to Oil Spill Injury and Restoration: Integrating Tools for Adaptive Management

Implementing Benthic Impacts of the DWH Blowout in an Atlantis Model

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An important component to modeling ecosystem level impacts of marine oil spills is incorporating potential benthic interactions. A significant portion of the oil released during the Deepwater Horizon blowout is estimated to have settled on the sea floor, and as a result benthic effects could be an integral constituent in modeling this event. To fully asses the ecosystem impacts of the oil spill in an Atlantis model, we examined benthic faunal abundances after the spill and developed forcing functions to test benthic interactions. First, dose-response relationships were established between total petroleum hydrocarbons (TPH) and the abundances of invertebrates in two categories: macrofauna and meiofauna. The abundances of both groups showed a significant parabolic response to the log of TPH. The subsequent decline in invertebrate abundance is attributed to toxic effects of oil, however there are several factors that could be driving the initial increase in abundance. We ran three different test scenarios in Atlantis to explore possible trophic interactions resulting in the initial increase. These scenarios include: direct forcing of primary productivity, direct forcing of an increase in detritus, and a predation pressure release. The results and possible implications of our test scenarios will be presented.

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Session 016: Fate and Transport of Oil In the Open Ocean: Water-Sediment Connectivity

Continuous-Flow Microfluidic Experiments for Long-Term Observations of Microbes at Oil-Water Interfaces
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Marine microbes are an important component of the remediation of oil spills by biodegradation of crude oil. Effective biodegradation of crude oil requires microbes to encounter the oil-water interface first where the processes, including near interface motility, cell adhesion and aggregate formation, are crucial for improvement in model development. Previous results have shown increases in microbe encounter rates at droplet surfaces in diffusion dominated regimes due to microbe motility. However, it remains unclear how fouling and particulate aggregates formed at oil water interfaces may affect encounter rates and residence times. We have developed a microfluidic bioassay including a microfluidic channel allowing for the generation of a single suspended pico-liter oil droplet and a recirculating chemostat permitting the continuous growth of bacterial culture and observation of interactions over a period of days. The temporal evolution of encounter rates, particle residence times, and the interfacial conditions can be determined using high-speed microscopy by tracking individual microbes and interface characteristics. Further analysis will include the effects of dispersants on microbial interactions at oil droplet surfaces.

An Updated Simulation of the 2010 Oil Spill
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Based on the observations of the oil spill fate, in water, coasts and sediments, a model that simulate the oil evolution and fate is implemented. It was developed using the Hybrid Coordinates Ocean Model (HYCOM), and an improved Lagrangian oil trajectory and evolution model which considers the effect of evaporation, dispersion, precipitation and dispersants. Results are compared with previous simulations.

Oil particle interactions: Theory, experiments, and numerical modeling
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When spilled oil droplets reach waters enriched with particles of sediments or organic matter, they tend to bind to these particles forming oil-particle-aggregates (OPAs), who have lower adhesion and subsequently smaller coalescence with each other. The OPA formation has been shown to be an important natural cleansing process in facilitating the transport of oil from one compartment in the environment to another. In this study, laboratory studies were conducted using the EPA baffled flask and different factors that could affect the OPA formation process, were considered. These included the mixing energy, interaction time, and the hydrophobicity of the particles. The resulting OPAs were analyzed by confocal laser scanning microscopy, to obtain the three-dimensional structures of OPA, which provided evidence of new theories of the oil-particle coagulation mechanisms in turbulent flows.

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The experimental data were then used to validate the newly developed OPA model, A-DROP, that requires as input oil and particle properties, and the mixing intensity. A-DROP was used to simulate the OPA formation in a typical nearshore environment, and modeling results indicated that the increase of particle concentration in the swash zone plays a major role in speeding up OPA formation. But the total oil amount trapped in OPAs did not seem to correlate with the concentrations. The developed A-DROP model could become an important tool for understanding the natural removal of oil and for developing oil spill countermeasures by means of oil-particle aggregation.

Potential Impact of Corexit on Marine Microgels

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Marine microgels play a critical role in the transformations between DOM (dissolved organic matter) and POM (particular organic matter) and in marine aggregation process. Corexit, a chemical dispersant, was extensively used during the 2010 Deepwater Horizon (DWH) oil spill in the Gulf of Mexico (GoM). The potential toxicity of Corexit on marine organisms has received intensive research interests and public concern. However, the impact of Corexit on marine microgels has not been investigated. Using dynamic light scattering (DLS), we accessed the influence of Corexit on marine microgel formation. Our preliminary results indicate that Corexit can effectively reduce microgel formation at 0.1 ppm and completely inhibit microgel formation at 1 ppm. In addition, Corexit can disperse pre-formed microgels prepared with marine DOM and various phytoplankton EPS (exopolymeric substance). The dispersion effect of Corexit on EPS microgels was found to be dependent on the chemical characteristics of EPS. Corexit can completely disperse EPS microgels from *Dunaliella tertiolecta* and *Thalassiosira pseudonana*, but only can partially disperse (70%) microgels from *Sagittula stellate* and *Amphora sp*. Our preliminary results here suggest that Corexit can impact marine microgels leading to potential disturbance of surface ocean carbon dynamics. These results go hand in glove with findings that Corexit may inhibit the formation of transparent exopolymer particles (TEP) and reduce the formation of diatom aggregates.

Investigating the Microbial Response to Oil and Dispersants in Surface Water Marine Environments

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On April 20th, 2010 the Deepwater Horizon drilling rig exploded in the northern Gulf of Mexico, resulting in the largest oil spill accident in the history of the U.S. petroleum industry. Over the following 87 days, an estimated approximately 750 million liters of crude oil was released with an estimated 60% reaching the sea surface. The application of chemical dispersants (e.g. Corexit) during the spill was intended to disperse more oil into the water column, thus increasing the total amount of oil available to hydrocarbon-degrading microorganisms. However, the usage of dispersants during the spill still remains controversial as their impact on microbial community composition, structure, and activity remains poorly resolved. We prepared coastal and pelagic surface water mesocosms to investigate the responses of natural microbial communities to the water accommodated fraction of oil with and without Corexit. Oil-amended mesocosms exhibited an increase in microbial diversity associated with the growth of several aliphatic- and aromatic-hydrocarbon degrading species over time. In contrast, the microbial communities in mesocosms containing Corexit had significantly reduced diversity and appeared to be enriched primarily with species which exclusively degrade saturated alkanes. However, fluorescent

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microscopic observation revealed the use of Corexit considerably increased the abundance and formation rate of bacterial micro-aggregates around oil droplets. Interestingly, the DWH *Colwellia* observed *in situ* and detected in deep water microcosms was not found to be abundant in the surface water experiments, indicating differential responses in deep waters versus surface waters. Taken together, these data improve our understanding of how microbial communities influence the degradation, dispersion, and transport of oil in marine environments and also enable us to further evaluate the effect of chemical dispersants on these processes.

Modulating the Fate of Oil in Near-shore Environments

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The fact that chemical dispersants are not allowed for use in near shore environments necessitates alternate strategies for oil remediation. Using natural mesocosm samples collected from near shore environments and doped with oil, we show using cryogenic electron microscopy, the role of fine sediments and particulates in stabilizing oil droplets through the formation of Pickering emulsions. Cryo electron microscopy is also used to understand the structure and morphology of exopolymers harvested in these environments. The growth rate of *Alcanivorax borkumensis* (AB) as a model oil biodegrading organism in these environments is also measured. In an extension of this work, we show that natural and engineered particulates containing adsorbed nutrients for bacterial growth can be used to adhere to the oil-water interface and promote bacterial colonization. These concepts apply both to oil in near shore environments on the sea surface, and to subsea ejection of oil where slurried particulates can stabilize oil droplets and enhance microbial growth. The concepts also constitute strategies to the minimal use of chemical dispersants.

Aldehyde and Ketone Photoproducts from Solar Irradiated Crude Oil-Seawater Systems Determined by MS/MS

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Oil is a vital energy resource and precursor for many materials, such as plastics, synthetic rubber, solvents, dyes, waxes, and lubricants. While it provides benefits to society, it can also be released into the environment during production and transport, leading to damage to life and the surrounding environment. Since spilled oil is often exposed to sunlight, it is necessary to understand the natural photochemical processes and photoproducts of crude oil. While several recent reports have enhanced our understanding of oil photochemistry, structures of oil photoproducts have not been well investigated and are poorly understood. More experimental results are needed to better understand the natural photochemical process and photoproducts. A wide array of photoproducts are generated during natural photochemistry of crude oil under solar irradiation. One class of photoproduct is carbonyl compounds. Herein, we report a thorough investigation of aldehyde and ketone photoproducts observed in the aqueous phase under oil exposed to simulated sunlight. Oil samples were spread over seawater in a jacketed beaker held at 27 °C and exposed to simulated sunlight. The aqueous phase was collected after irradiation and derivatized with 2,4-dinitrophenylhydrazine (DNPH), which selectively reacts with aldehydes and ketones. The derivatized carbonyl compounds were washed and enriched with a C18 extraction cartridge and were analyzed by HPLC, LC-MS, and LC-MS/MS. Numerous aldehyde

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and ketone photoproducts were observed in the aqueous phase under irradiation but were absent in dark controls. Based on the MS-MS fragmentation of the DNPH derivatives, these photoproducts were mainly classified into three types of carbonyl compounds: dicarbonyls, hydroxy &ndash carbonyls, and carbonyls with a carboxylic acid. These results will provide insight into the impact of photochemistry on the fate of oil in environmental systems and will have important implications for treatment of spilled oil.

New insights into the chemical weathering processes of crude oil after the Deepwater Horizon oil spill using ramped pyrolysis gas chromatography-mass spectrometry

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In response to the Deepwater Horizon oil spill, critical research has tracked the evolution of petroleum hydrocarbons with environmental weathering. There is a limitation, however, whereby analytical techniques cannot always identify the wide breadth of petroleum and petroleum-derived compounds. We explore the analytical capabilities of ramped pyrolysis - gas chromatography - mass spectrometry (Py-GC-MS) to evaluate environmental samples of petroleum hydrocarbons from the Deepwater Horizon oil spill. We show that bulk flow Py-GC-MS can quantify overall weathering degree, and that thermal slicing Py-GC-MS can quantify specific petroleum hydrocarbons in the “quantification zone”, as well as qualify changes of non-GC amenable petroleum hydrocarbons in the “cracking zone”. Our data also suggests an increase in thermochemical stability, oxygenated products and complexity of resin and asphaltene components with advanced weathering, particularly in oil sheen. Our further photooxidation experiments further confirmed these results. This analysis not only elucidates weathering trends with current samples, but also illustrates the analytical capacity of this method for future petroleum hydrocarbon investigations.

Where the oil from surface and subsurface plumes deposited during/after Deepwater Horizon oil spill?

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The Deepwater Horizon (DWH) oil spill released an estimated 4.9 million barrels (about 200 million gallons) of crude oil into the Gulf of Mexico between April 20, 2010 and July 15, 2010. Though Valentine et al. has linked the elevated oil components in some sediments with the subsurface plume, the sites with fallout from the ocean surface plume has not been identified. This piece of information is critical not only for a comprehensive scientific understanding of the ecosystem response and fate of spill-related pollutants, but also for litigation purposes and future spill response and restoration planning. In this study we focus on testing the hypothesis that marine snow from the surface plume were deposited on the sea floor over a broad area. To do so, we use publicly available data generated as part of the ongoing Natural Resource Damage Assessment (NRDA) process to assess the spatial distribution of petroleum hydrocarbons in the water column and deep-ocean sediments of the Gulf of Mexico. Sensitive hydrocarbon markers are used to differentiate hydrocarbons from surface plume, deep subsurface plume, and in-situ burning. Preliminary results suggest the overlapping but different falling sites of these plumes and the sedimentation process was controlled by various biological, chemical, and physical factors.

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Chemotactic response of bacteria to multiple chemical stimuli
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Chemotactic bacteria sense and respond to temporal and spatial gradients of chemical cues in their surroundings. We are investigating the impact of this phenomenon on the biodegradation of oil droplets in the marine environment. Chemical heterogeneity in this natural system produces numerous competing signals from various directions. Predicting the migration behavior of bacterial populations under such conditions is necessary for modeling the fate and transport of hydrocarbons from residual oil droplets. In this study we observed the response of *Escherichia coli* bacteria to a mixture of a chemoattractant (methylaspartate) and a chemorepellant (nickel ion) in various spatial configurations. The goal was to predict the overall response based on transport parameters that quantified the chemotactic response to individual chemicals. We used a combination of experimental assays and mathematical modeling. A microfluidic device designed to generate well-controlled chemical concentration profiles was used to evaluate the chemotactic transport properties for each chemoeffector separately. Then bacterial population profiles for various mixture configurations were compared to model predictions. We initially considered a modeling approach in which the macroscopic expressions for the chemotactic velocities were simply added together assuming a negative velocity for the chemorepellant. Because the chemosensory mechanism is well-documented for *E. coli*, we also considered a molecular-level modeling approach that incorporated several key steps in the pathway in order to deduce the mechanism by which bacteria process multiple signal inputs to generate an integrated overall response.

Chemotaxis by Methanotrophic Bacteria in the Presence of a Rising Swarm of Oil Droplets - Numerical Modeling of Subsurface Methane Bio-remediation
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In April 2010, high-pressure oil and gas escaped from BP's Deepwater Horizon exploratory well which was located 77 km offshore in the Gulf of Mexico. Methane was the most abundant hydrocarbon (HC) component (~33% by weight of the total spill) of the oil and natural gases released in the spill. A significant fraction of this methane was dissolved in the water column at a depth of 900-1100 m, thus facilitating its biodegradation by methanotrophic bacteria over a period of two months from mid-June to mid-August 2010. In this study, we consider the biodegradation of methane by modeling its uptake by methanotrophic bacteria - both motile and non-motile - in a swarm of oil droplets rising through the plume. The typical velocities and sizes of these droplets have been estimated to be in the range of of 0.05 - 0.14 m/s and 0.5 - 1 mm, respectively, resulting in a Reynolds number in the range of 1 - 10. The flow-field due to the rising oil droplets results in the dispersion of the dissolved HCs via diffusive and convective transport. This dispersion plays a vital role in the uptake of dissolved methane as it tends to enhance the heterogeneities in the plume, thus driving chemotactic motion of motile methanotrophic bacteria like Methylomonas. In addition to considering the chemotaxis-based uptake by motile bacteria, we also consider the uptake by non-motile bacteria and quantify the role of motility on the methane degradation. We also investigate the effects of droplet size and rise velocity on the bacterial distribution and the corresponding bio-remediation rates.

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Using Microfluidic Emulsions to Study Adhesion of Bacteria to Oil/Water Interfaces
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We characterize the effects of chemical dispersants on the ability of bacteria to move near and adhere to oil/water interfaces as a first step using microfluidics, optical microscopy, and image processing. To mimic the size of drops formed in an oil spill scenario, we exploit the Rayleigh-Plateau instability to make monodisperse oil-in-water emulsions using co-flow glass microfluidic devices. By varying the size of inner and outer microfluidic channel and the flow rates of the oil and water, we are able to generate oil droplets of diameter 35 - 200 μm. The oil droplets are stabilized using various surfactants, including dioctyl sulfosuccinate (DOSS), sodium dodecyl sulfate (SDS), and Corexit EC9500, some of which are used in oil spill response. Dispersant-stabilized oil drops are then introduced into aqueous media containing soil- or ocean-dwelling bacteria, including *Pseudomonas putida*. Here, we report preliminary experiments in which we investigate the motility of bacteria near oil/water interfaces using microscopy and cell-tracking methods, and relate adhesion of bacteria on oil/water interfaces to the hydrophobicity of the bacterial cells.

Mesoporous Silica Aerogel for Hydrocarbon Adsorption and Its Regeneration: Implications for Oil Spill Clean-up
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Silica aerogel is a promising adsorbent for oil spill clean-up. To make it an economic and environmental-friendly adsorbent, thermal regeneration of silica aerogels was investigated here. The adsorption capacities of silica aerogels were measured to be 12.4 ± 0.6, 11.2 ± 0.6, and 13.6 ± 0.5 g/g for toluene, petrol, and diesel, respectively. After hydrocarbon desorption at 80 °C, the adsorption capacities of regenerated silica aerogels decreased to 12.3 ± 0.5, 6.5 ± 0.2, and 2.3 ± 0.3 g/g for toluene, petrol, and diesel, respectively. To gain the mechanistic understanding, the physico-chemical property changes of silica aerogels after regeneration were detected using Fourier transform infrared (FTIR), small angle X-ray scattering (SAXS), and BET (Brunauer, Emmett and Teller) methods. The decreases in pore sizes of silica aerogels were observed after all hydrocarbon desorption, which caused the decreases in adsorption capacities of regenerated silica aerogels. In addition, incomplete desorption of diesel and its oxidation further decreased the adsorption capacity of regenerated silica aerogels. To improve diesel desorption, desorption experiments were also conducted at 200 °C. Under aerobic condition, severe diesel oxidation occurred during its desorption, which destroyed the mesopores of silica aerogels. Therefore, the adsorption capacity of regenerated silica aerogels for diesel decreased to 1.4 ± 0.2 g/g. To avoid diesel oxidation during thermal desorption, diesel desorption was also investigated under anaerobic condition at 200 °C. No diesel oxidation occurred during its desorption, and the pore size (13.2 ± 1.5 nm) and adsorption efficiency (10.0 ± 0.3 g/g) of regenerated silica aerogels only decreased slightly. This study provided new insights on the physico-chemical changes of silica aerogel during its regeneration. Also, novel regeneration approach under anaerobic condition was developed for practical applications.

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Exoenzymatic response of coastal and offshore surface ocean microbial communities to exposure to oil and an oil/dispersant mixture

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The responses of microbial communities to oil and the chemical dispersants used to remediate oil spills are central to our understanding of ecosystem response to oil spills. Analysis of exoenzymes provides insight into how the microbial communities respond to oil spill events by providing real-time rates of biogeochemically important reactions. To replicate the conditions of an oil spill, two mesocosm experiments were conducted using coastal water collected off the TX shelf in one and open ocean water from the NW Gulf of Mexico in the other. Triplicate 100 L mesocosm tanks with either no additions (control), added oil (WAF), added oil+dispersant (CEWAF) or diluted oil+dispersant (dCEWAF) were incubated for 3-4 days and sampled every 12 hours for alkaline phosphatase (AP), beta-glucosidase (BG), and leucine aminopeptidase (LAP) activities. Kinetics curves were measured for each enzyme and inhibition experiments were conducted using orthophosphate for AP, glucose for BG, and methionine for LAP. Enzyme activities were also measured in the presence and absence of the bactericidal compound sodium azide, across all the treatments in both mesocosm experiments. Interestingly, the highest activities were found in the CEWAF tanks while the lowest activities for all enzymes were observed in the control tanks. AP activity in both mesocosm experiments decreased over time or remained the same in all treatments except the CEWAF tanks, where it increased throughout the experiment. Likewise, BG activity decreased over time for all samples, though in the CEWAF tanks there was a spike in activity at 24 hours. LAP activity generally decreased over time in the open ocean mesocosm, except in the CEWAF tanks where it increased over time. In the coastal mesocosm, LAP activity increased over time in all treatments. Analysis of the kinetics experiments, inhibition experiments and sodium azide treatments will also be discussed and put into the context of the microbial response to oil spills.

Bacterial Chemotaxis to Aliphatic and Aromatic Hydrocarbons at High Hydrostatic Pressures

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The 2010 Deepwater Horizon (DWH) blowout occurred at about 1,100 m depth, corresponding to 11 megapascals of pressure. Flagellar motility is highly pressure-sensitive in mesophilic bacteria, yet some piezophilic (i.e. high pressure-adapted) bacteria retain functional flagellar motility at extremely high pressures. We hypothesize that the high hydrostatic pressures in the DWH oil plume will affect bacterial chemotaxis to hydrocarbons, which is likely to be advantageous for bioremediation at intermediate turbulence intensities. Here, chemotactic abilities of various hydrocarbon-degrading marine bacteria to select aliphatic and aromatic hydrocarbons are characterized as a function of pressure. Complex and defined media containing pentane, hexane, heptane, toluene, or naphthalene will be used to assess chemotaxis at a range of concentrations, temperatures, and pressures. Under high pressures, we will observe chemotaxis ring formations in three-dimensions within pressurizable bulbs. High pressure capillary assays will be used to generate quantitative data, and the results of these assays will be modeled by our collaborators. Transposon mutagenesis and subsequent gene knockouts will be used to identify and characterize hydrocarbon chemotaxis genes in select strains. These chemotaxis and motility mutants, along with motile and highly piezophilic bacteria, will serve as control strains for evaluating the effect of these systems on hydrocarbon utilization rates. Members from the following genera will be used in this study: *Alcanivorax*, *Alteromonas*, *Colwellia*, *Marinobacter*, *Oleispira*, *Pseudoalteromonas*,

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Shewanella, *Sulfitobacter*, and *Thalassolituus*. This study aims to shed more light on bacterial hydrocarbon chemotaxis at high pressures in order to better understand its role in hydrocarbon biodegradation as a function of depth in the ocean.

The Impacts of Pressure on the Motility of Hydrocarbon-Degrading Microorganisms

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Physical factors such as temperature and pressure can alter the motility of microorganisms, which in turn influences substrate acquisition and rates of biogeochemical cycles under many conditions. This study aims to address the hypothesis that hydrostatic pressures of the magnitude present in the DWH oil plume will dramatically affect the motility of many oil-degrading microbes towards various hydrocarbons. We are initiating this project by surveying pressure impacts on the growth and hydrocarbon utilization of approximately 2-3 dozen strains of hydrocarbon-degrading bacteria incubated in complex or defined media supplemented with 100 ppm of MC-252 oil, and various specific aliphatic and aromatic hydrocarbon species. Cell activity at high pressure will also be measured using the methionine analog HPG (L- homopropargylglycine), which can be used to fluorescently label newly synthesized proteins. Pressure effects on flagellar formation and swimming will be assessed in a number of assays. Flagella will be visualized by NanoOrange staining and fluorescence microscopy, and the motility of cells capable of growth at moderate to high pressure will be assessed following cultivation in low-percentage agar media in pressurizable plastic bulbs incubated in pressure vessels. The motility of cells and flagellar rotation will also be directly observed in a temperature-controlled high-pressure optical chamber coupled to an inverted microscope. Digital images will later be examined with tracking software to measure the fraction of motile cells, their swimming speed, the upper pressure limits for swimming, and the reversibility of the temperature and pressure effects. Differences in motility and/or flagellar rotation at high pressure will be incorporated into simulations performed by our collaborator Arezoo Ardekani. Utilizing these methods, a better understanding of pressure impacts on the motility of diverse hydrocarbon-degrading bacteria will be obtained.

Correlation of benthic sediment grain-size distributions to high-resolution multibeam sonar backscatter in the Mississippi Bight

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Multibeam acoustic backscatter intensity data can provide a proxy for the composition and distribution of surficial seabed sediments. The acoustic response of the seabed across a variety of grazing angles provides an indication of seabed scattering and, therefore, an estimate of general sediment grain-size distributions. These characteristics, along with multibeam bathymetry, can be used to derive a spatial overview of benthic habitats and aid in informing numerical models. As part of the GoMRI Consortium for oil spill exposure pathways in Coastal River-Dominated Ecosystems (CONCORDE) project, a high-resolution biogeochemical/lower trophic level model will be developed for further investigation of the river-dominated, coastal environment of the Mississippi Bight. One of the model inputs is distribution of bottom sediment type that factors into local sediment resuspension. Along with multibeam backscatter data collection, physical grab sampling and grain-size analysis of sediments at select locations along the CONCORDE observational corridors were performed in order to constrain the backscatter data and

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produce acoustically-derived sediment distribution maps. This involved a comparison of the relative backscatter intensity (dB) values and the average grain-size of the collected sediment samples to investigate any apparent patterns in the data. The sediment distribution corridor maps developed as part of this project will further our understanding of the benthic and demersal ecosystems within the Mississippi Bight. Future work on the dataset will involve the development of spatially varying drag coefficients as an additional input for the biogeochemical model.

Bacteria and Transport of Colloids at Fluid Interfaces

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Bacteria have long been considered a natural means of oil remediation, creating interest in the details of their interaction with oil-water interfaces. Using a model system of non-volatile and insoluble hexadecane, polystyrene microparticles and *Pseudomonas aeruginosa* PA14 *ΔpelA*, we demonstrate the increased transport of passive particles at the interface between oil and aqueous bacteria suspensions. Conventional particle tracking averages the displacements of the passive particles to determine microrheological material properties. This averaging masks interesting behavior; bacteria can move particles orders of magnitude farther and faster than the average, with trajectories with different signature behaviors that do not resemble random walks. We attribute these paths to direct adhesion of particles to bacteria cells, and discuss implications for increased transport of passive colloidal structures.

Deep Sea in a Can: Aerobic Methane Oxidation under High Pressure

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The Deepwater Horizon incident in 2010 released an unprecedented amount of petroleum hydrocarbons into the Gulf of Mexico. Methane was the main gaseous hydrocarbon released from the wellhead at 1500 meter depth [1]. In our laboratory, we enriched aerobic methanotrophic bacteria from surficial deep-sea sediment from the Gulf of Mexico. Particulate methane monooxygenase (*pmoA*) gene sequence analysis and fluorescence *in situ* hybridization revealed that the methanotroph belonged to the genus *Methylocaldum*. This genus cannot be detected by conventional 16s RNA gene and *pmoA* primers commonly used for detection of marine methanotrophs from environmental samples [2, 3]. The enriched methanotroph degraded methane at 10 bar 3 times faster than at 1 bar suggesting a metabolic response to increased methane concentration. With these properties, the enriched methanotroph, which had not been recognized so far, might have played an important role in methane biodegradation during the blowout.

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* Student Presenter

Fate of polycyclic aromatic sulfur-containing hydrocarbons after crude oil spills in shallow aquatic ecosystems

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Significant amounts of polycyclic aromatic sulfur-containing hydrocarbons (PASHs) were released into Gulf water during the Deepwater Horizon incident. If dissolution in deep water is ruled out then the ultimate dissipation fate of these PASHs is not clearly understood. Two dissipation processes, volatilization and degradation mediated by sunlight, have been suggested as mechanisms removing major components of spilled oil, and may be important for PASHs in shallow aquatic systems. DBT and its homologous, C1-DBT, C2-DBT and C4-DBT, were chosen as model compounds to investigate the impact of volatilization and degradation due to reaction with sunlit formed oxidant, hydroxyl radical, on estimates of their dissipation. The hydroxyl radical rate constant ($K_{\cdot OH}$) and Henry's law constant (H) of PASHs were determined in distilled water. The EPA Exposure Analysis Modeling System (EXAMS) was used to estimate the relative impacts of these two properties to overall chemical fate as a function of depth (0.1, 1 and 2 m). The analogue C1-DBT reacted fastest with $^{\cdot}OH$ relative to other PASHs. The C2-DBT and C4-DBT analogues had higher H compared to other homologues. Simulated dissipation of PASHs using EXAMS suggests that volatilization is a dominant fate pathway for the higher molecular weight and less polar C2-DBT and C4-DBT at all depths and DBT and C1-DBT at 0.1 m. However, model scenarios suggest hydroxyl radical degradation may significantly contribute to the degradation of more polar DBT and C1-DBT at 1 m and 2 m depths. These results suggest future areas for research of these compounds and may facilitate more accurate risk assessment and corresponding risk management decisions after catastrophic environmental disasters such as crude oil spills.

Effects of Crude Oil Weathering on Oil-Mineral Aggregation, and Implications for Marine Oil Spill Remediation

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When oil is released into the marine environment, it interacts with suspended sediments in the water column and forms oil-mineral aggregates (OMA), dispersing the oil into the water column or transporting it to the benthic zone. Enhancing natural OMA formation as an oil spill remediation technology has several benefits including cost effectiveness, reduction of oil contained in slicks, cleansing of oil contaminated beaches, and enhanced degradation rates of trapped oil. Many variables, including salinity, mixing energy, sediment type and oil type, have been previously examined in order to better understand their effect on OMA formation. However, there is a lack of understanding of how the weathering of a spilled oil will affect the OMA formation process over time. Oil weathers at an exponential rate in the environment, changing both its chemical and physical properties starting immediately after the release. A majority of currently published OMA studies were performed using fresh oil, or a single weathered stage of an oil, and as a result there is disagreement in existing literature about how OMA formation varies as oil weathers: whether it increases as a result of increased asphaltene content, or decreases as a result of increased viscosity. This study aims to understand this process by examining three oils with a range of original viscosities and asphaltene contents, each at a series of weathering stages. The percentage of oil that can be trapped in OMA both as fresh oil, and at each weathering stage, as well as the form in which it is trapped, is compared here. These findings will improve understanding of OMA formation, can aid in the production of mathematical models used to

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predict the formation of natural OMA formation following a spill, and can help provide guidelines for the application of fine sediment to a spill for remediation efforts.

Hydrocarbon Sources in Sedimentary Environments Impacted by Oil Spills at Depth: Chemical Signature of the Ixtoc-1 Spill

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In 1979, the exploratory oil well IXTOC-1 experienced a blowout resulting in the release of approximately 3 million barrels of oil. The goal of this study is to identify chemical signatures of Ixtoc-1 oil in marine sediment to better understand the long-term preservation of environmentally important chemical compounds associated with oil exploration related disasters. Sediment cores were collected at four sites in Campeche Bay in the southern Gulf of Mexico, subsampled in 2 and 5mm increments, and analyzed for biomarkers (hopanes, steranes, and diasteranes), and *n*-alkanes (C10-37). We measured biomarker and alkane ratios to differentiate inputs from recent oil exploration, buried Ixtoc oil, and marine and riverine sources. The four sediment cores were collected in diverse areas of Campeche Bay with different proximity to the coastline and present petroleum industry: IXNW-1600 is the deepest site (3214m water depth) with inputs primarily from marine sources; Ixtoc-1 (60m water depth) was recovered from an area of active and intense petroleum exploration known as “the exclusion zone”; IXW-250 (583m water depth) is located 80 km W from the IXTOC-1 wellhead and has indications of buried Ixtoc oil; LT-1 (16m water depth) is located 45 km from the mouth of the Laguna de Términos and has primarily riverine inputs. The upper 5mm of the Ixtoc-1 core shows alkane patterns typical of crude oil which we associate with recent oil exploration. We infer that IXW-250 has buried Ixtoc oil at 38mm core depth because at this depth the Ts/Tm (trisnorhopane 18a/trisnorhopane 17a) ratio is similar to a reference Ixtoc oil sample. LT-1 has carbon preference indices (CPIs) nearly five times greater than Ixtoc oil at 34mm indicative of buried riverine input. IXNW-1600 has distinct Ts/Tm ratios and CPI representing primarily marine inputs. Our results provide insight into the long-term preservation of chemicals deposited during the Ixtoc-1 spill and can improve the long term assessment of other oil spills such as the Deepwater Horizon spill.

A case study for demonstrating a novel protocol for identifying Deepwater Horizon Oil spill residues using combined physical and chemical characterization methods

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Deepwater horizon (DWH) oil spill residues were formed by nearshore processes, which are different from traditional oil spill residues that are formed by highly weathered remnant oil. This research proposes a novel approach to differentiate DWH oil spill residues from traditional oil spill residues. A field recovered DWH submerged oil mat (SOM) sample was analyzed as reference sample. Five DWH surface residual balls (SRBs) collected on Nov 11th 2015 along Alabama beaches were analyzed. Additionally, five traditional tar balls from Alabama, Mississippi, Louisiana, Texas and India, respectively, were physically tested and chemically analyzed. The physical properties of the SRB samples were characterized by six screening protocols in the field and their density and sand content were further measured in laboratory. Unlike the traditional tar ball samples that are black, shiny, rubbery and hard to tear apart, with little or no petroleum odor, DWH samples are brownish and dull, easy to break into fine particles with strong petroleum odor. The laboratory measurement shows that DWH samples have

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higher density (> 1.8 g/mL) and sand content of well over 75%, whereas non-DWH samples have lower density in the range of 0.8 to 1.3 and contain little or no sand. The significant differences in the physical properties of DWH SRBs and non-DWH SRBs indicate that physical characterization can be an efficient method to distinguish DWH SRBs from non-DWH SRBs. No single information can be conclusive, therefore, the chemical fingerprinting were also analyzed by GC Triple Quadrupole Mass Spectrometer to get unambiguous results. The curve plots of five groups of PAHs and petroleum biomarkers (hopanes and steranes) illustrate that all the DWH SRBs have similar distributions and they are consistent with DWH reference SOM sample, which confirms their same origin. The diagnostic ratios (DRs) of Ts/Tm and C29/C30 in DWH samples are around 0.93 and 0.37, respectively, which are totally different from those in non-DHW sample. The different shapes of hopanes radar plots also reveal the differences in DWH and non-DWH samples. The PAHs ratios plots are successfully applied to differentiate DWH SRBs from non DWH SRBs.

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Session 017: Genomics and Modeling of Biological Communities to Improve Predictions of Ecosystem Response to and Mitigation of Spilled Oil

DNA Damage in fish collected from Offshore and Nearshore locations in the Deepwater Horizon oil spill area during 2012 and 2013

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In 2012 and 2013 fish health surveys were conducted in nearshore and offshore locations in areas impacted by the Deepwater Horizon oil spill. During these surveys various fish health parameters were assessed, including general biometrics, immune function, reproductive endpoints and DNA integrity (damage). DNA damage is a non-specific general biomarker that has often been used in oil exposure studies as it will detect DNA damage via the multiple mechanisms that oil constituents may impact DNA i.e. direct strand breaks due to oxidative damage or the excision repair of DNA adducts. DNA damage was quantified using the COMET assay in various fish species and in multiple tissues, including the liver, spleen, gonad and gill. We present the findings from four separate research cruises in the vicinity of the Deepwater Horizon Incident; an offshore survey in 2012, a nearshore survey in 2012 and multi-year transect study in 2012 and 2013 investigating sites close to and further away from the Deepwater Horizon area.

De novo transcriptome assembly of the eastern oyster (*Crassostrea virginica*) exposed to hydrocarbons.

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The negative impact of an oil spill on marine invertebrates varies with location, the magnitude of the spill, the stage of life, habitat, sensitivity and the capacity of organisms to prevent or process contaminants. One way to asses the environmental impact of an oil spill is through the study of the effects of exposure to hydrocarbons on organisms that live throughout the water column and of the use of sessile organisms as indicators of the health of coastal ecosystems. In order to have a better understanding of the hydrocarbons effect on marine invertebrates, in the present study we exposed to the eastern oyster *C. virginica* to different concentrations of a mixture of light and super light hydrocarbons and evaluated the transcriptomic response with the Illumina platform. The experimental design consisted of four treatments (control, 50, 10 y 200 ug/L) and three replica, with n=30. The oysters were sampled in Laguna Morales (Tamaulipas) and the time of exposure to hydrocarbons was two weeks. A total of 33,469,374 readings from digestive gland were assembled using trinity 2.2.0, resulting 61,356 assemblies 'Genes'. Database Swissprot/Uniprot and PFAM-A were used for the annotation of proteins. At the end of this process were kept 86,409 transcripts. The resulting transcripts were comprised of a large set of stress response genes that included antioxidant enzymes, heat shock proteins and xenobiotic transporters. Another set of transcripts was composed of the cytochrome P450 family genes and oxidative stress such as superoxide dismutase (Cu-Zn), glutathione S-transferase and ferritin. Heat map obtained from the analysis of differential expression showed that oyster response to hydrocarbon exposure decreases after the 100 ug/L. Finally, biomarkers and metabolic pathways four in this work suggest its potential application in environmental conservation, although more studies are needed.

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Assessing the Impact of Phytoplankton Community Diversity on the Ecosystem Response to Oil Perturbation

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The Deepwater Horizon oil spill in April 2010 highlighted our lack of understanding about how phytoplankton respond to oil perturbation in the northern Gulf of Mexico (nGoM). Studies have demonstrated a key role of lower trophic-level community composition in the response to oil spills suggesting biodiversity can impact the resilience of the ecosystem. In this project, we are testing the hypothesis that increased functional, taxonomic, and genetic diversity in the phytoplankton community will enhance the resilience and recovery of the system to oil perturbation. As a first step, we wanted to isolate representative species of the major taxonomic phytoplankton groups found in the nGoM. Most of the regional cultures available in the national culture collections were isolated >30 years ago and taxonomically distinct, representative species co-occurring in the same region were not available. Using high-speed single cell sorting of water collected from the coast of Alabama, we established cultures of 8 different phytoplankton species. Microscopy or 18S sequencing identified 4 of these as the chlorophyte, *Tetraselmis*, the dinoflagellate *Prorocentrum spp*, and the two diatoms, *Skeletonema* and *Asterionellopsis*. Terminal restriction fragment length polymorphism of 16S and 18S rDNA confirmed them to be unialgal with low bacterial diversity. We are conducting oiling and dispersant exposure experiments in the lab on these species, as well as on the cryptophyte, *Hemiselmis andersenii* (CCMP439), also isolated from the nGoM. Measurements of cell abundance, photosynthetic rates, carbon fixation, and transparent exopolymer production are used to assess the impact of oil and dispersant on cellular physiology in single culture experiments. Using mixed populations of varying levels of diversity, we aim to understand how oiling impacts individual species and whether increased diversity leads to a more resilient community.

New methods for the identification of benthic infauna communities using next generation sequencing

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Identification of benthic meio- and macrofauna samples is labor intensive, time consuming, and costly. We are attempting to develop a quicker and cheaper way, using genetic sequences to characterize benthic communities. For this purpose, we are developing a reference library of whole genomes for widely distributed infauna species of the Gulf of Mexico. We are testing the effectiveness of the reference genome library by comparing it to 18S nuclear small subunit rRNA and whole metagenome shotgun sequences of sediment cores from the Gulf of Mexico. A major challenge we encountered in the development of the reference genome library is to find a preservation method, which allows for both morphological identification and DNA sequencing. Instant freezing of infauna specimens is best for sequencing efforts. However, the morphology of soft bodied animals, such as polychaetes, nemerteans, or certain mollusks, is compromised by the freezing, making their identification impossible. In contrast, formalin preserves the morphology of infauna organisms exceptionally well and has therefore been routinely used for sample preservation during ecological surveys. However, formalin is known to break DNA strands, which hinders sequencing efforts. Nevertheless, we are currently trying to sequence

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genomes of a diverse array of macrofauna species that were fixed in formalin during the Deepwater Horizon Natural Research Damage Assessment (NRDA) surveys. Recovery of DNA sequences from these samples would be an enormous success because a vast number of samples and a diverse assortment of species from the NRDA surveys, or any other sample collection, would be available for our genome reference library.

Biotransformation of soluble oil and gas compounds in natural seawater at low temperature

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During the DWH oil spill it was suggested that gas compounds, particularly propane, promoted rapid hydrocarbon biodegradation in the deep water plume, and stimulated bacterial populations for biodegradation of other hydrocarbon (Valentine *et al*., 2010). In the current study we performed a biodegradation study of water-soluble fractions (WSFs) of a crude paraffinic oil (Statfjord) and gas compounds (methane, ethane and propane) dissolved in natural seawater (SW) from a Norwegian fjord. WSFs were prepared by slow stirring of oil in natural seawater (no vortex) at an oil:SW ratio of 1:10,000 at 5°C for 3 days. The WSF was distributed on sterilized flasks with butyl rubber septa. Gas compounds were mixed in ratios of methane/ethane/propane of 8/1/1 in gas-tight bags, and gases bubbled into flasks with WSFs, or with SW only (triplicate samples). Sterilized controls were included. Flasks with WSFs and gas, gas compounds without WSFs, and WSFs without gas, were incubated at 5°C for up to 64 days. Flask were sacrificed after weekly or bi-weekly for analyses of gas compounds (GC-FID) and 36 targeted volatiles oil compounds (alkanes and monoaromatics; GC-MS). Biotransformation of volatile oil compounds started after 7-14 days of incubation, both in SW with and without gas compounds, and with comparable depletion in the two systems. The presence of gas compounds did therefore not seem to affect biodegradation of volatile oil compounds. Methane depletion also started after 7-14 days of incubation, while no depletion of ethane or propane was measured at this time. Initial methane depletion was only observed in SW without WSF. Biodegradation rates from these experiments will be used as input data for gas and oil compound groups in the fate and exposure model OSCAR.

Diversity of zooplankton and ichthyoplankton in the Gulf of México: A taxonomic and metagenomic approach

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The Gulf of Mexico exhibits seasonal variability that influences the dynamics of the zooplankton assemblage. Zooplankton and Ichthyoplankton are important sources of energy for organisms of higher trophic levels and can be indicators of the overall health of marine ecosystems. Recent events in the Gulf of Mexico such as oil spills make it a priority to assess accurately the current plankton composition and therefore evaluate possible impacts of such events. Next generation sequencing offers a suite of tools, such as metagenomic analysis, that have become accessible to do fine scale diagnosis and to understand plankton community composition. We report preliminary results on the metagenomic and taxonomic analysis of plankton communities in the Southern region of the Gulf of Mexico. For this study DNA was extracted from 24 plankton samples collected during a September 2015 cruise in the Gulf of Mexico. For each sample region V9 of the gene 18s was amplified to generate amplicons; sequencing of this amplicons was done using MiSeq to obtained MOTUs from the zooplankton community sampled

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across the 24 samples. Our goals include fine scale diagnosis and the influences of environmental variability on the distribution and diversity of Zooplankton and Ichthyoplankton communities in the Gulf of Mexico. With the help of morphology based taxonomy and molecular biology we intend to contribute to both the taxonomic knowledge and understanding how the plankton communities are responding to oil spills.

Immediate and Delayed Changes to Gene Expression in *Sciaenops ocellatus* and *Oncorhynchus kisutch* after Sublethal Exposure to Oil and Dispersant

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Both red drum, *Sciaenops ocellatus*, and coho salmon, *Oncorhynchus kisutch*, reside in environments at risk of exposure to crude oil and dispersants; indeed, effects of exposure on fish health and impacts to sustainability of these commercially important fish are still uncertain. Laboratory experiments with aquaculture-reared stocks examined immediate and delayed sublethal effects of chemically enhanced water accommodated fractions (CEWAFs) on these geographically diverse species. Juvenile red drum were exposed for four days to 1ppm (TPH) CEWAF of South Louisiana crude oil and Corexit 9500 and allowed to recover in clean seawater for six days. Two fish per tank were sacrificed daily. Serum and tissues were collected through day four and every-other-day through Day 10. Remaining fish were tagged and sampled three months later. Juvenile salmon were exposed for 12 hours to 1 ppm (TPH) CEWAF, and allowed to recover in clean seawater for four days before sacrifice and sampling of serum and tissues. Again, remaining fish were tagged and sampled three months later.To further understand the effects of CEWAF on the immune response of exposed individuals and the post-exposure sustainability of these two fish species, several cytokines (interleukin 1 beta, a mediator of inflammatory response; interleukin-8, a mediator of immune response; and tumor necrosis factor alpha, a key in immune cell regulation) were analyzed for gene expression and circulating protein concentrations. Whereas some biomarkers do not measure vital biological functions, depressed immune function can impact life histories, fitness of individuals and sustainability of wild stocks. Thus, the use of immune system biomarkers as endpoints has great value to conservationists and managers. Our studies not only demonstrate clear responses in immune function of exposed fish, but also allow for better-informed conservation decisions that can enhance stock sustainability for multiple stakeholders.

Differential Gene Expression in the Hepatic Tissue of CEWAF Exposed Red Drum (*Sciaenops ocellatus*) Using RNA-seq

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RNA sequencing (RNA-seq) technology has become a useful tool for investigating biological processes of fish effected by exposure to oil and dispersant. This technology gives a snap shot of all the gene transcripts that are differentially expressed in a tissue at a given moment of time. One key advantage of this type of gene expression analysis is that no genome information is needed, making it ideal for non-model wild species, such as red drum. For these reasons, this technology was utilized to explore the molecular pathways that are most effected in juvenile red drum that were exposed to a mixture of Louisiana crude oil and Corexit 9500 dispersant as a chemically enhanced water accommodated fraction (CEWAF). This was part of an uptake and depuration study that was conducted in which juvenile red drum were exposed to CEWAF (1ppm) for a period of four days and allowed six days of recovery in

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seawater. Day three of CEWAF exposure was chosen for sampling the livers for RNA-seq analysis. Liver samples were collected from red drum controls and CEWAF exposures. RNA was extracted from the livers and sequenced using the Illumina HiSeq2500 platform and bioinformatics by Omega Bioservices (Norcross, GA). Differential gene expression in the liver of controls and CEWAF exposed red drum was carried out using the DESeq2 package in which count data from the RNA-seq is assigned to each gene. This analysis generated over a 100,000 gene transcripts of which several hundred were significantly differentially expressed in the livers of CEWAF exposed red drum compared to the controls. These gene transcripts were then annotated using Blast2GO and the biological processes significantly impacted by CEWAF exposure will be presented.

Transcriptomics Reveal Responses of Deep-Water Microbial Communities to Oil and Dispersant Exposure.

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Chemical dispersants are used commonly in response to oil spills. However, the impacts of dispersants on microbial community composition and activity are poorly understood. We simulated the deep water conditions that prevailed following the 2010 Deepwater Horizon oil spill and evaluated the response of the microbial community to elevated levels of oil, chemical dispersants and dispersed oil using metatranscriptomics. Clustering factors were compared across levels of a hierarchical annotation system to increase the power of prediction and contrast in our datasets. We found significant dispersant-driven changes in terms of diversity and abundance of microbial composition and activity, shifting the dynamics from one dominated by oil biodegradation in oil-only treatments to those dominated by dispersant biodegradation in dispersant-amended treatments. These results have important implications for understanding the impacts of chemical dispersants on the ability of microbial communities to efficiently degrade oil in the environment.

DNA Methyltransferase Gene Expression in Larval Sheepshead Minnows (*Cyprinodon variegatus*) Following Oil Exposure

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Exposure to oil can alter the growth and development of larval fish, which may have detrimental effects on populations and community-level impacts. Previous studies investigating mechanisms underlying oil-induced developmental abnormalities have focused on changes in gene expression. However, the extent to which oil-induced transcriptional changes are mediated via epigenetic mechanisms is unclear. Epigenetic marks, particularly DNA methylation, can cause transcriptional alterations that endure throughout an organism's life and possibly be transmitted to offspring via transgenerational epimutations. To investigate the role of epigenetics in oil-induced gene expression, sheepshead minnows (*Cyprinodon variegatus*) at 0, 4, and 8 days post-fertilization (dpf) were exposed to various concentrations of high-energy water accommodated fraction (HEWAF) for 48 hours. Transcript abundance for the DNA methylation enzymes DNMT1a, DNMT3a, and DNMT3b was then measured via qPCR. Our data demonstrate that oil exposure alters expression of transcripts related to DNA methylation, and further suggests that epigenetic mechanisms may mediate some oil-induced transcriptional changes. These data serve to increase our understanding of the mechanisms governing

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oil-induced gene expression alterations, and provide evidence that the deleterious effects of exposure to oil in critical developmental stages may have long-term consequences.

Alterations to the Sheepshead Minnow (*Cyprinodon variegatus*) Transcriptome after Corexit and Oil Exposure

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Approximately 1.84 million gallons of the oil dispersant Corexit were used during the BP Deepwater Horizon (DWH) oil spill. While Corexit is understood to be toxic to marine life, the mechanisms of toxicity for Corexit and Corexit-oil mixtures remain largely undefined. In particular, there is little information regarding transcriptome-level responses of aquatic organisms to Corexit exposure. To investigate the effects of dispersant and dispersant-oil mixtures on teleost transcriptomes, we exposed sheepshead minnows (*Cyprinodon variegatus*) to Corexit and oil mixtures and measured resulting changes in gene expression. Adult sheepshead minnows were exposed to sublethal concentrations of high-energy water accommodated fraction (HEWAF), chemically enhanced accommodated fraction (CEWAF) or Corexit alone for 7 or 14 days. Liver tissue was harvested and used for microarray analysis of gene expression. Differentially expressed genes were identified and pathway analysis used to predict biological outcomes of exposure. Our pathway analysis offers insight into the comprehensive effects of exposure on individuals, which further enables predictions regarding population level impacts. In particular, because sheepshead minnows naturally occur in estuarine habitats oiled during the DWH event, this study provides information relevant to the community impacts of DWH contamination that may be important to development of management strategies to mitigate the effects of future spills.

Enrichment of Marine Microbial Mats associated with Salt March Plants Exposed to Oil Amendments

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The 2010 Deepwater Horizon (DWH) oil spill highlighted the fragility of coastal marshes and barrier island marshes as moderate to heavy oiling occurred in parts of Louisiana, Alabama, Mississippi and parts of the Florida coast. The resulting losses of marsh wetlands pose serious risks to long-term coastal resiliency and coastal ecosystem services. To investigate the interactions of microbial mats associated with above-ground marsh plant biomass, large-scale open-air, flowing seawater mesocosms were designed and operated for a one year period. Replicates of individual and mixtures of marsh plants (mono-phyletic and polyphyletic species of Spartina and Avicennia) were grown in flowing seawater mesocosms with and without oil amendment applied to standing marsh plants at an approximate concentration of 4,000 mg/kg. Samples of microbial mats from oiled and non-oiled mesocosms were collected after one year of incubation and subjected to molecular, and traditional microbiological, and microscopic characterizations. Several of the mat samples were shown to have denitrifying capabilities. In this study, microbial mat communities from oiled and non-oiled samples, characterizations by molecular methods including Illumina sequencing as well as cultivation-based techniques, will be compared and contrasted to below-ground plant associated microbial communities from the same plant species type.

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Anglerfish Bacterial Symbionts and Seawater from the Northern Gulf of Mexico

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Female anglerfishes belonging to 9 out of 11 families (suborder Ceratioidei) develop a lure ("esca") containing bioluminescent bacterial symbionts. However, the source of symbionts remains unclear as previous work indicates the larval fish do not possess these bacterial symbionts in the immature escal organ, suggesting no vertical transmission. As part of the DEEPEND project (www.Deependconsortium.org), the objective of this study is to characterize the escal microbiomes of several deep-sea anglerfish species and to determine whether symbionts may be acquired horizontally from the water column. Because no active large oil spill existed during DEEPEND collections, these results reflect a GOM baseline of symbiont presence in the water and possible horizontal uptake to hosts after concomitant profiling of the pelagic habitat. Anglerfish were collected on four biannual cruises (DP01-DP04) in May and August of 2015 and 2016. Seawater samples were simultaneously collected via CTD-mounted Niskin bottles from a total of 38 sites. Escal specimens represented 24 mature individuals comprising a total of 6 anglerfish species: *Cryptopsaras couesii*, *Melanocetus johnsonii*, *Dolopichthys* sp., *Ceratias uranoscopus*, *Melanocetus murrayi*, and *Centrophryne spinulosa*. Larval anglerfish from the Oneirodidae, Linophrynidae, and Gigantactinidae families were also collected. High throughput 16S rRNA V4 sequencing revealed *Vibrionaceae*-like OTUs dominating the escal microbial community (up to 95.1% of relative abundance). Preliminary analyses from 2015 DP01 and DP02 cruises indicate lesser abundances of the *Vibrionaceae* symbiont on fish exteriors (skin, gills). A different symbiont was identified in both the *M. johnsonii* and *Dolopichthys* sp. escal specimens. Both symbiont types were identified within the seawater from nine DP02 sampling sites (*C. couesii* symbiont being most abundant), while neither was detected in cruise DP01. Ongoing analysis focuses on incorporating more specimens collected in 2016 as well confirming the seawater findings.

Microbial Community Response to the Deepwater Horizon oil spill: Metagenomic Insights into Northern Gulf of Mexico Saltmarsh Ecosystems

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Oil spills such as the recent Deepwater Horizon (DWH) disaster can significantly impact biochemical and biological processes in coastal sediment imparting short-term and long-term effects on ecosystem functions. Denitrification, a biogeochemical process, is a vital ecosystem service providing considerable ecological and economic value in coastal habitats, particularly in salt marsh ecosystems. Denitrification, the conversion of nitrate (NO_3^-) to dinitrogen gas (N_2) or intermediates such as nitrous oxide (N_2O) is microbially mediated. Studies focused on the long-term impact of heavy oiling on microbial populations carrying out denitrification in northern Gulf of Mexico marsh ecosystems are surprisingly limited. In the current study, we used a combined approach including field-based analyses of sediments collected from the Chandeleur Islands (Louisiana), a site heavily impacted by the DWH oil spill, along with oil amended mesocosm experiments to assess N cycling microorganisms. The specific objectives of this study were to: i) assess temporal effects of denitrification with marsh sediment samples spanning two seasons (July-November 2015, February 2016), ii) assess mesocosm samples to determine the impact of plant diversity and oiling on denitrifying microorganisms. To gain a greater insight into microbial community biodiversity, high throughput next generation deep-sequencing methods were utilized. Analysis of ~1.3Tb of sequences derived from 30 different vegetated and subtidal marsh sediment samples will be

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discussed. The genetic diversity and composition of the microbial community within field and mesocosm samples will also be discussed. The combination of molecular ecology methods to assess biodiversity coupled with biogeochemical measurements provides greater insights into marsh microbial interactions and N cycling as a result of the 2010 DWH spill, a major disturbance that negatively impacted northern Gulf of Mexico coastal saltmarshes.

Deep Sea in a Can: Finding Culprits - Bacterial Community Fingerprints under Pressure
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The bacterial community in the water column responded to the vast amount of hydrocarbons spilled into the deep sea environment during the Deepwater Horizon blow out in 2010. Successional changes of the bacterial composition following the weathering of crude oil components are well documented. So far only few *ex situ* experiments on deep-sea samples consider elevated hydrostatic pressure like it is present in the deep sea. The motivation is to close the knowledge gap about the importance of elevated pressure as a factor of influence on biodegradation and community structure. To address this topic we incubated top layers of sediment from the Gulf of Mexico at ambient and elevated hydrostatic pressures mimicking the conditions at the surrounding of the DWH well. Crude oil degradation was investigated by on-line oxygen measurement as a proxy for metabolic activity. Bacterial community composition changes are evaluated with fingerprinting and sequencing methods. This work is aiming to contribute to the understanding of the complex microbial ecology at the deep sea and its responses to oil spills.

The effects of Oil and Corexit on the interaction between bacteria and phytoplankton in Mesocosm experiments
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Marine phytoplankton account for 50% of global primary production and thus play an important role as the base of the food web in aquatic ecosystems. Phytoplankton communities interact with associated bacterial communities to recycle nutrients and carbon metabolites as part of the biological/microbial pumps. These interdependent communities can play an important role in the bioremediation of oil spills by breaking down petroleum hydrocarbons. The exopolymeric substances excreted by phytoplankton can create conditions that promote the recruitment and growth of diverse bacterial communities. Genetic and transcriptomic analysis can reveal how phytoplankton and bacterial communities interact in response to oil spills to degrade hydrocarbons. To also investigate the changing relationship between phytoplankton and bacterial communities, we simulated an oil spill in both open ocean and coastal water environments in experimental mesocosms. Twelve 130 L mesocosms with four different treatments were prepared: water accommodated fraction of oil (WAF), chemically enhanced water accommodated fraction (CE-WAF), diluted chemically enhanced water accommodated fraction (dCE-WAF), and a control (no oil or dispersant added). These were allowed to incubate for 4-5 days in either coastal or open ocean waters. In each experiment, we extracted DNA from water samples sampled every 12 hours and prepared both 16S and 18S rRNA gene libraries. Here we present a description of the composition and structure of phytoplankton and bacterial communities within the mesocosm experiments over time. This experiment will demonstrate the importance of the microbial communities,

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and highlight the potential of these microscopic primary producers and bacterial communities for the bioremediation of oil spills.

The Effect of Natural Seep Exposure on the Microbial Community and Metabolome of the Deepwater Coral *Callogorgia delta*

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Coldwater corals create structural habitat that support a diverse faunal community that includes commercially important fish. Coldwater coral-based communities occur throughout the Northern Gulf of Mexico and those near the site of the Deepwater Horizon blowout were acutely impacted by the spill. Further, some species of coral occur near active cold seeps and thus may be naturally exposed to seeping oil and gas. Studying the effect of natural seep exposure on corals may reveal specific adaptations of corals to oil exposure. One coral in particular, *Callogorgia delta*, is a good candidate species for study since it is found at higher densities near cold seeps and thus has a greater potential for exposure. Colonies of C. delta were sampled from areas both near and away from visual signs of active seepage from each of three sites in the Northern Gulf of Mexico. Tissue carbon and nitrogen stable isotopic compositions of these samples were analyzed and show depletions in ^{13}C and ^{15}N for colonies growing near signs of active seepage, indicating incorporation of seep-derived organics. A metabolomics analysis of these samples that targeted lipids identified metabolites that are higher in abundance near seeps that are associated with signaling pathways and membrane structure. Since coral health and function are affected by their associated microbial community and the microbial community of cold seep sediment is distinct from its surroundings, the microbiomes of these corals were analyzed using 16S rRNA sequencing, a culture-independent technique. Sediment and water samples were also collected to identify coral-specific microbes. The microbiome and metabolome data will be integrated to identify any metabolites that may play an important role in shaping the microbial community or are produced by it.

* Student Presenter

Session 018: Oil Spill Modeling: Source to Sink

Direct numerical simulations of primary atomization physics in turbulent oil plumes
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The distribution of oil droplet sizes within two-phase, oil and seawater, plumes plays a primary, dynamic role in the bouyant evolution of the plume and directly affects the dispersive properties of the effluent. As such, accurate phenomenological models for droplet size distributions, and proper parameterization of such models, are important components in any deep-spill prediction system. While there exists a considerable body of literature on the atomization of liquid-gas jets, the dynamics of liquid-liquid jets, especially at the extremely large Reynolds numbers encountered in deep water blowouts, remains relatively underexplored. Here we employ a multi-grid, adaptive-mesh, volume of fluid solver to study the parameter dependence of primary atomization of oil-in-water jets. By restricting attention to moderate, but fully turbulent, pipe Reynolds numbers, the model provides a quasi-DNS of the near-field interfacial dynamics at the relatively small density ratios, moderate viscosity ratios, and large Weber numbers typical of oil in water jets.

Numerical simulation of turbulent *live* oil and gas plumes in stratified environments
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Inspired by deepwater blowouts, turbulence resolving numerical simulations have been used to studyhybrid plumes where the buoyancy flux at the inlet is set by a combination of sources including thermal effects and the presence of a lighter secondary phase. When considered, the oil was thought to be a buoyant, non-slipping, perfectly miscible material. Therefore, in a linearly stratified environment the oil raised until reaching the neutrally buoyant height where it accumulated forming a lateral intrusion. However, estimations for the Deepwater Horizon accident claim that only 30-40% of the total oil remained subsurface. To improve the model capabilities in predicting the dynamics of the plume, a better description ofthe physicochemical processes is necessary. First, we consider the effects associated to the slipping nature of the oil droplets under the *mixture model* approach for the liquid phase. The smaller values of the escape velocity incomparison to the gas bubbles lead to significant differences in the overall dispersion of both pollutants. Second, we include the *live* oil effects associated to the continuous degassing of theoil plume as the ambient pressure drops along the water column. In comparison to an injection of segregated phases (degassed or *dead* oil and gas) the injection of a *live* fraction notably changes the spatial distribution of the phases including the oil expression at the surface.

* Student Presenter

A review of biodegradation models for oil in the open water

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The biodegradation of low solubility hydrocarbons in water is very complex and involves numerous biochemical pathways that are dependent on both the oil and water properties. The modeling of oil biodegradation from basic principles is not possible within current experimental and numerical capabilities. Therefore, oil biodegradation modeling has relied on semi-empirical approaches that capture the salient features of the processes with a focus on matching observations and on prediction. To this end, the modeling of oil has followed two main approaches: 1) A purely empirical approach, fitting simple models, such as first-order models, to experimental data, and 2) An approach that relies on capturing major biodegradation pathways, such as colonization of the low solubility oil components by microorganisms, dissolution by biosurfactants, and kinetics that depend in a nonlinear way on environmental variables (e.g., Monod kinetics). The first approach is widely used and seems to reproduce large-scale observations, and is commonly used by operational models. The second approach may be more promising for prediction and exploration of various remediation scenarios, but suffers from the lack of observational and experimental data. The paper summarizes three main areas where biodegradation modeling has been well established: 1) The biodegradation of dissolved hydrocarbons (e.g., BTEX) in open water and within sediment, 2) The biodegradation of low-solubility hydrocarbons within sediments, and 3) The biodegradation of organic matter in open water (e.g., wastewater influent). The biodegradation of low solubility hydrocarbons are then found to contain elements of modeling from each of these areas. A numerical sensitivity study is then conducted to explore the impact of these models on the fate of oil released from a Deepwater Horizon type spill. The paper concludes by discussing how models of oil biodegradation in open water can incorporate the latest advances in genomics, and makes recommendations on the experiments that need to be conducted to advance the modeling.

Connectivity in the Gulf of Mexico

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Markov-chain models of the dynamics in the Gulf of Mexico (GoM) are constructed using trajectories from the integration of various representations of surface-ocean velocities and a recent Maxey--Riley model for the motion of floating objects fed with these velocities and reanalyzed winds. Dynamical geographies are then built from the almost invariant sets and basins of attraction resulting from level-set thresholding eigenvectors of the associated transition matrices. These subdivisions separate weakly dynamically interacting flow regions and provide crucial information for pattern predictions of oil spill and marine debris. Furthermore, we assess the importance of inertial effects (i.e., of objects' finite-size and buoyancy) through comparisons with a dynamical geography inferred using satellite-tracked drifter trajectories and discuss implications for connectivity. Joint work with F. J. Beron-Vera and M. J. Olascoaga.

* Student Presenter

A Review of Biodegradation Models for Oil: Model Parametrizations and a Sensitivity Study
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Biodegradation is an important process governing the ultimate fate of spilled oil, and occurs for dissolved hydrocarbons, oil droplets, surface slicks, and oil trapped within the sediments, either along coastlines or the seafloor. Degradation depends on ambient conditions, the quantity and type of oil, the conditions under which it is released, and whether or not the oil has been treated with chemical dispersants. Most operational oil spill models include biodegradation, but their formulations differ, and they base their rates on different data. Our paper summarizes how the major operational oil spill models treat biodegradation, focusing on degradation of dissolve oil and droplets, and reviews available laboratory and field data concerning rates. We then present a sensitivity study where different model formulations, with a range of published rate constants, are used to simulate the degradation of oil released in a Deepwater Horizon type spill. Simulations are made with a Lagrangian tracking model (LTRANS; North *et al*., 2015) with realistic but idealized ambient conditions (ambient velocity, turbulent diffusivity, temperature) and discharge conditions (oil and gas flow rates, release depth, treatment with chemical dispersants, etc.) culled from a previous model inter-comparison study (Socolofsky, *et al*., 2015).

MFOIL - the MIT/FSU Oil Model
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We introduce a recently developed deep oil spill prediction tool consisting of a near-field three dimensional multiphase near-field plume model embedded in a general circulation model. The inoculent consists of oil and gas components that are fully active throughout the computational domain. The general circulation model accepts boundary data from larger scale to global models and provides detailed and dynamically consistent ocean fields. The model is two way interactive and incorporates a number of recent structural advancements designed to maximize throughput. An application to a Deep Water Horizon like deep oil release is presented and compared to observations.

Assessing Oil Spill Contact Probabilities in the Gulf of Mexico
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The Bureau of Ocean Energy Management (BOEM), an agency of the U.S. Department of the Interior, maintains a leasing program for commercial oil and gas development on the Outer Continental Shelf in U.S. territorial waters. The BOEM performs an oil-spill risk analysis (OSRA) using, in part, a statistical model of hypothetical oil-spill trajectories. The OSRA Model is driven by analyzed sea surface winds and model-generated ocean surface currents. Instead of focusing on individual oil-spill events, the OSRA examines oil-spill risks over long periods of time, ranging from 5 years to decades. In the latest OSRA analysis, the OSRA Model calculated 40 millions of oil-spill trajectories over extended areas of the U. S. continental shelf and tabulates the frequencies with which the simulated oil-spills contact the geographic boundaries of designated natural resources within a specified number of days after the

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simulated spill events. The modeled ocean currents and wind fields used in the OSRA analysis are from 1993 to 2014 for 22 years. The contact probabilities of oil spills in the GOM are analyzed in detail. The OSRA model is also applied to analyze the contact probabilities of the Ixtoc Oil Spill, which happened on June 3, 1979 in the Bay of Campeche of the Gulf of Mexico and lasted for 10 months. The Ixtoc 1 Oil Well suffered a blowout, resulting in one of the largest oil spills in history and 3 million barrels of oil spilled. The OSRA model is applied to simulate particle trajectories released at the Ixtoc location using historical current and wind fields between 1993 and 2014. Detailed analysis is conducted to understand the environmental risks of the Ixtoc Oil Spill.

Hindcasting and forecasting the dynamics of deep hydrocarbon plumes: Results from a data-assimilative model

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An ability to predict the movement and monitor the decay of hydrocarbon plumes in the water column is important in the event of a deep-water oil spill like the 2010 Deepwater Horizon (DWH) disaster. We are developing a data-assimilative model for the Gulf of Mexico that is able to simulate the distribution, transport and decay of deep-water hydrocarbon plumes. By combining the model with real-time observations from satellites and autonomous platforms, predictions of plume movement and optimal hindcasts of plume distribution can be produced. We will demonstrate some of the capabilities and applications of this model using observations from the DWH spill, which released a significant fraction of hydrocarbons in neutrally buoyant deep-water plumes. The model is based on the Regional Ocean Modeling System (ROMS) and includes tracers for hydrocarbon fractions and dissolved oxygen. Assimilation of observations makes use of the Deterministic Ensemble Kalman Filter (DEnKF), an ensemble technique that has proven to be robust, flexible and comparatively efficient. Ultimately the model will be part of an integrated observation-prediction capability that combines data-streams from satellites and physical-biochemical measurements from profiling floats with a data-assimilative physical-biogeochemical model.

A Comprehensive System for Simulating Oil Spill Trajectory and Behaviour in Subsurface and Surface Water Environments

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Accidentally release of pollutants such as offshore oil spills can cause significantly negative impacts on the environment and socio-economy, and constitutes a direct hazard to marine life and human health. Particularly, deepwater blowout released spills are more challenging to study because the trajectory and behaviour of oil are difficult to be comprehensively simulated. Currently, there are numerous models developed for simulating oil spilled from sea surface. Comparatively, the models aiming at deepwater blowout are limited. In addition, insufficient information on oil droplet size distribution with/without effects from dispersant application further limits the reliability of models for oil spills in either surface or subsurface water. To fill the gaps, this study is aiming at developing a comprehensive simulation system for trajectory and behaviour of oil spills from deepwater blowout. Such a system is an advance of the 3D Water modelling system (MOHID) from its jet model and three-dimensional oil spill model. Since the jet model in MOHID is only target wastewater, an advanced jet model for oil spills is developed based on

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algorithms from Texas A&M Oilspill Calculator (TAMOC). The TAMOC is a new modeling suite for simulating the trajectory and behaviour of oil and gas released from subsea accidents, which is capable of simulating the spills in weak cross-flow (plume is mainly affected by buoyancy and dissolution) and strong cross-flow (plume is additionally governed by subsurface current) conditions. It has advantage in its double plume integral model, which consists of an inner plume of entrained water, oil and gas and an outer plume of water and fine oil droplets exchanging with both the ambient environment and the inner plume. Furthermore, a Reynolds number scaling approach is introduced into the jet model to predict the oil droplet size with and without chemical dispersant application. The three-dimensional oil spill model is advanced by a new biodegradation approach based on the coupled pseudo-components and first-order biodegradation algorithms and a dispersion approach based on the modified weber number. By providing comprehensive simulation for oil spills, the developed system should provide significant support to the response to offshore oil spill, especially from deepwater blowout.

Measurement and Modeling of Oil Slick Transport

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Transport characteristics of oil slicks are reported from a controlled release experiment conducted in the North Sea in June 2015, during which mineral oil emulsions of different volumetric oil fractions and a look-alike biogenic oil were released and allowed to develop naturally. The experiment used the Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) to track slick location, size, and shape for 8 h following release. Wind conditions during the exercise were at the high end of the range considered suitable for radar-based slick detection, but the slicks were easily detectable in all images acquired by the low noise, L-band imaging radar. The measurements are used to constrain the entrainment length and representative droplet radii for oil elements in simulations generated using the OpenOil advanced oil drift model. Simultaneously released drifters provide near-surface current estimates for the single biogenic release and one emulsion release, and are used to test model sensitivity to upper ocean currents and mixing. Results of the modeling reveal a distinct difference between the transport of the biogenic oil and the mineral oil emulsion, in particular in the vertical direction, with faster and deeper entrainment of significantly smaller droplets of the biogenic oil. The difference in depth profiles for the two types of oils is substantial, with most of the biogenic oil residing below depths of 10 m, compared to the majority of the emulsion remaining above 10 m depth. This difference was key to fitting the observed evolution of the two different types of slicks.

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Session 019: Policy-Relevant Implications of Science Emerging from the Deepwater Horizon Disaster

Influencing Federal Oil Pollution Research Efforts: Overview of the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) Oil Pollution and Technology Plan (OPRTP)

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Federal oil pollution research efforts began to take shape in the late 1960s following the Torrey Canyon oil spill off the coast of England. At that time, the U.S. had neither the technical nor operational capacity to deal with a large oil spill in the marine environment. The federal government developed the first National Contingency Plan to address oil spills and began extensive oil pollution research over the next 20 years. Coordination of the federal research efforts was informal and on an ad hoc basis. The challenges posed by the response to the Exxon Valdez oil spill in 1989 revealed the need for federal agencies to better coordinate their research. This resulted in the Title VII of the Oil Pollution Act which established the ICCOPR and the first requirement for a comprehensive and coordinated Oil Pollution Research and Technology Plan (OPRTP). ICCOPR published its first version of the OPRTP in 1992 and published a revised version in 1997. These two versions provided an initial baseline assessment and analysis of: agency roles and responsibilities; status of knowledge of oil pollution prevention, response, and mitigation technologies; priority research and development needs; and an estimate of resources and time needed to implement the program. The purpose of the FY 2015-2021 version of the OPRTP, and subsequent revisions, is to provide current assessments of the oil pollution research needs and priorities. ICCOPR intends to update this OPRTP every six years to reflect advancements in oil pollution technology and changing research needs. Through the development of the 2015 OPRTP, using a gap analysis, 570 unique research needs were identified. A Categorization Framework was subsequently developed establishing 25 Standing Research Areas within 4 over arching research classes (prevention, preparedness, response and mitigation). Through a rigorous process, ICCOPR identified the top priorities in each SRA or SRA Subcategory. These 150 priority research priorities are delineated in the plan, and are used to influence Federal oil pollution research efforts. The 2015 OPRTP provides a basis for coordinating research to address oil pollution issues in the U.S. It is primarily directed at federal agencies with responsibilities for conducting or funding oil pollution research, but can serve as a research planning guide for industry, academia, state governments, research institutions, and other nations.

Crude Responses: A Comparative Analysis of the 2015 Santa Barbara and 2010 BP Gulf Oil Spills & Implications for Coastal Cities

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May 2015, a section of an oil pipeline ruptured near coast of Refugio, CA. There were reports that 105,000gal of crude oil spilled; 21,000 spilled into the Pacific Ocean. A nine mile oil slick was created in the Pacific and nearby beaches were contaminated. The ocean current and waves caused the oil to move south along the coastline. The purpose of this study is to make a comparative assessment of the SB Oil Spill vs. BP Oil Spill while the response was taking place. Both oil spills claimed marine animal lives. There are concerns as to the amount of damage these spills are causing to the ecosystem and if other pipeline ruptures will occur. There are 7,000 miles of oil pipelines. Plains All American Pipeline has been cited and fined for decades for poor upkeep of these pipelines. The state inspectors who regulate

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the pipelines rely on the documents from the companies. There are questions of the use of chemical dispersants, toxic chemical additives in the pipeline oil, tougher rules, and better prevention technology. Also, there is a concern about how the affected communities recover from these spills. Data was collected as follows: Statements were collected from Plains All American, Contractors, First Responders, and the US Coast Guard. California public documents were reviewed. Similar data were compared from the 2010 BP Spill. GIS Mapping and the tracking of the movement of the oil were done in CA. The fingerprint analysis records were accessed to differentiate the oil from the pipeline vs. the oil from natural seeps in CA. There were comparesons of oil spill responses, contingency plans, and policies. Five years after the BP Spill, many questions remain concerning whether or not any lessons were learned from a disaster planning standpoint. In CA the footprint Shrunk from 70 miles of coastline to less than 1 mile in 88 days. Plains Company responded to spill in an efficient manner. The immediate overwhelming force was successful in CA. Evidence shows that the events were caused by lack of inspection regime by the Companies, lack of enforcement regime by authorities, or both- CA and LA. Booms are still being used which does little to stop oil from rolling in on the beach. The response for deep water in LAvs.CA superficial. Future considerations -new policies for both CA and the Gulf states and continue monitoring the conditions.

Oil Spill Governance in China after the 2010 Gulf of Mexico Oil Spill

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The Gulf of Mexico Oil Spill of 2010 was an ecological disaster. The remarkable performances of US government agencies, community groups, and the public in response to the event have had a profound influence on the international community in dealing with marine oil pollution incidents. A similar underwater spill occurred in China's Bohai Sea in 2011. The Penglai 19-3 Oil Spill also caused huge damages to the ecological environment in the region, and is now known as China's Gulf Oil Spill among Chinese scholars. After the accident, the Chinese government and the public noticed the wide range of differences between China and the United States in terms of governance of such incidents. Chinese scholars conducted comparative analyses and made a number of recommendations to management agencies. Five years have passed, the impacts of the Gulf of Mexico Oil Spill on China's marine pollution management practice are evident. This poster will present a summary of these impacts from multiple aspects including legal framework, policy development, and public participation. In addition, we will report findings of a comparative analysis of recent developments in oil spill governance in China and the United States.

Characterizing Dioctyl Sodium Sulfosuccinate as an Obesogen i*n vivo*

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Childhood, adolescent and adult obesity rate in the United States and worldwide have been increasing since the 1970s and have reached epidemic proportions. While genetic predisposition, diet and exercise are known factors in obesity development, recent studies have focused on elucidating environmental exposure associated with obesity. Our specific focus is on exposures to endocrine/metabolic disrupting chemicals known as obesogens, which can increase stem cell to fat cell differentiation, and have other

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metabolic effects that collectively promote obesity development. Recently, our lab identified dioctyl sodium sulfosuccinate (DOSS) as a PPARg agonist and a probable obesogen and wanted to further validate its obesogenic potential *in vivo*. DOSS is a commonly used non-ionic surfactant, present in Corexit variety of consumable and personal care products as an emulsifying agent. The work described here was done to determine if DOSS is a bona fide obesogen in vivo, using dosing and exposure routes common to human scenarios. Pregnant women often become constipated at midgestation and are prescribed as the standard of care stool softeners that are essentially DOSS (500mg/day) through nursing. To parallel this scenario, pregnant female mice were orally dosed with either 30ug/mL DOSS in carboy methyl cellulose (0.5% CMC) vehicle or vehicle control alone their drinking water from midgestation (day E11.5) through weaning. F1 offspring were then given untreated water until they were 16 weeks old and end point analysis for obesity markers was performed including glucose tolerance, plasma cytokine and adipokine levels, DEXA scans for fat percentage and bone density, tissue gene expression, and bone marrow mesenchymal stem cell differentiation potential. Data and describing differences between treated and untreated animals as well as male and female animals will be reported and discussed.

* Student Presenter

Session 020: Discoveries from DWH to Inform Future Oil Spill Response Decision Making and Engage Stakeholders

DEEPEND: Diving into Education at All Depths

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Effective education and outreach capacity is essential for science communication to students, resource managers, stakeholders, and the public at large. The DEEPEND Consortium has developed a multi-sectoral education/outreach program to affect this communication. The Consortium has an integrated approach to convey the foundational concepts of DEEPEND projects (community ecology, from microbes to large fishes; animal mapping with acoustics; food web studies; monitoring of important oceanic fisheries (e.g., tuna); genetic studies to understand diversity; contaminant studies, using advanced biochemistry; and advanced oceanographic studies to understand open ocean habitats). An educational partnership with WhaleTimes, Inc. has focused on K-6 education through “virtual missions” with the DEEPEND team, reaching over 10,000 students to date. Deep-sea teacher workshops are the focus of Grade 8-12 educators, which includes “Teacher-at-sea” experience on every DEEPEND research cruise. An animated DEEPEND mascot, *Squirt the Squid*, delivers educational messages to children and adults of all ages. Management, stakeholder, and public outreach components include: presentations at scientific and management meetings (e.g., SeaGrant, Ocean Sciences); public engagement at special events (e.g., fishing tournaments, charity events); media engagement with reporters (magazine, newspapers, and radio), highlight stories with editors (e.g., *Sport Fishing* Magazine) and federal entities (e.g., Smithsonian Institution *Ocean Portal*); documentary participation (e.g., BBC *Oceans*, GoMRI documentaries); DEEPEND educational displays at zoos and aquaria (e.g., San Antonio Zoo, Oregon Coast Aquarium); online products in the form of project synopses and education modules; and printed materials, which are distributed freely.

The Importance of Oxidative Transformation Mechanisms in Future Oil Spills

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The release of petrogenic carbon into the environment starts the clock on oxidative transformation processes that affect fate, transport, and toxicity of the oil plume. The species initialed spilled ≠ what is floating on the surface ≠ what washes ashore. These important oxidative transformation products are unaccounted for by conventional analyses. Simply, a large fraction of the unaltered oil that was initially accessible by conventional methods is chemically transformed into species that preclude analysis via conventional techniques; these species are noteworthy, as they influence toxicity, solubility, emulsion/mousse formation, aggregation, and ultimately, bioavailability. Thus, the petrogenic transformation products and their potential to form undesirable future contaminants remain unknown. However, analytical methods developed over the past 5-10 years for this spill as well as heavy oil analysis have exposed tens-of-thousands of previously unidentified Macondo well oil (MWO) transformation products. Molecular-level analysis of field samples from the Deepwater Horizon event by

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Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR MS) has exposed their temporal evolution, importance in mousse / stable emulsion formation, and role in sand patties / tar balls collected in coastal ecosystems. Our latest results reveal that the photo-oxidized, water-soluble products are more toxic than the unaltered oil. Here we summarize the importance of the chemical "dark matter" of oil spills: the species for which bulk properties are known, but the exact chemical composition via conventional analytical methods, remains unknown. We highlight the contributions of ultra-high resolution mass spectrometry in the understanding of this once, chemical "dark matter" and summarize how these findings might be useful in future oil spills. Work supported by NSF Division of Materials Research through DMR-11-57490, The Gulf of Mexico Research Initiative, Future Fuels Institute, and the State of Florida.

Mini AUVs: Engaging Hands-on Activities for STEM and Marine Education or Outreach
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SeaGlide (www.seagide.net), is a build-your-own miniature underwater autonomous vehicle that has been utilized in primarily high school classrooms, in STEM and other educational curricula. Because the LADC-GEMM research project deploys ocean gliders equipped with passive acoustic recording systems as part of an effort to assess impacts on cetaceans of the Deepwater Horizon (DWH) oil spill, LADC-GEMM adapted SeaGlide for a science-related educational product aimed at teachers and students in K-12 classrooms or after-school programs. Developing appealing instructional programs for this audience - decision makers and stakeholders of the future - presents challenges quite different from other user groups. They must be highly engaging to capture the attention students and instructors. They must present, particularly at earlier grades, material in a manner simple enough to be comprehensible by students. New curriculum must often be aligned to specific curriculum standards and, as with materials, must be packaged so as to require very little preparation time by instructors. The 2016 LADC-GEMM teacher's SeaGlide workshop is as an example of comprehensible DIY technology and how it can provide a multi-disciplinary approach to STEM concepts: mechanical and electrical engineering, Arduino-based programming, physics, acoustics, and oceanographic principles. STEM education is a key component for bridging research to future stakeholders who will be responsible for oil spill response decision and other marine policies.

Getting the Science out of the Lab: From Fact Sheets to Multimedia Blogging
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One of the outreach goals of the Alabama Center of Ecological Resilience (ACER) consortium is to communicate its research with the general public, an important group of local stakeholders. While the ACER education and outreach team has done this using traditional fact sheets, we have also utilized the ACER website and social media platforms to share an educational (sensu lato) blog on the current research activities of our 7 research teams. Blog stories are organized in three categories: *Word Wednesday*, *Tool Talk* and *Habitat Focus*. *Word Wednesday* introduces and explains key terms and jargon, *Tool Talk* describes some of the methods and equipment used in ACER research and *Habitat Focus* shows and describes the coastal habitats that are the focus of ACER research. The blog incorporates various forms of multimedia (e.g. pictures and videos) to engage audiences of all ages and backgrounds. These blogs have also been integrated into lesson plans being shared with formal

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educators in the region and are a resource for other informal and formal K-12 educators. Website analytics show that blog readership is growing. Data also allow an approximate comparison to fact sheet use.

The role of eastern oyster genetic diversity in response to oil spills and associated clean-up activities

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In the Gulf of Mexico, eastern oyster (*Crassostrea virginica*) larvae settle gregariously, leading to the formation of structurally complex reefs that provide numerous ecological and economic benefits to near shore ecosystems and communities. Oyster reefs thrive in mesohaline estuarine areas, both subtidal and along vegetated shorelines. During the Deepwater Horizon Oil Spill, various tactics were used to prevent oil contamination of oyster reefs in the northern Gulf of Mexico. Louisiana opened fresh water diversion structures that lowered salinity, Alabama filled a breach along a barrier island that elevated salinity, and response crews applied dispersant to the oil. The potential ecological effects of these response activities have been debated, along with the role of population diversity in resilience to disturbances. We used a mesocosm experiment to examine how genetic diversity of oysters plays a role in the response and resilience to the combined effects of low salinity, oil, and dispersed oil. We spawned and reared oysters from 5 different parental pairs and then tested all 5 monocultures, as well as various mixes or polycultures, resulting in 11 different genetic groups. Each genetic group was subjected to 6 different water treatments: low salinity sea water, mesohaline sea water, low salinity oiled sea water, mesohaline oiled sea water, low salinity dispersed oiled sea water, and mesohaline dispersed oiled sea water. Response metrics were growth, condition indices, and mortality. The results of this experiment may be used to understand how the genetic diversity of oyster populations may help mitigate the effects of disturbance and response activities. The information gained from this experiment can be applied to future response activities as well as commercial oyster farmers who want to minimize economic losses, and can also help with informed planning and preparedness.

Microfluidic Device, Toxicity of Crude Oil and Nanoparticles on *Caenorhabditis elegans* to Engage Underrepresented Minorities in Oil Spill Research

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The Deepwater Horizon oil spill of 2010 caused release of crude oil into the Gulf of Mexico and coastal soil. As a consequence, oil particulates and oil flocculants have been observed. Residents affected by the oil spill included underrepresented African American of New Orleans and the local Gulf coast. Facilitating these stakeholders in oil spill related research has the potential to bridge the gap between stakeholders and research. Recently, polymers of synthetic or biological origin were tested as flocculants and to remove oil from water. Some of it are in the size range of nanoparticles. Furthermore, nanoparticles were tested to remediate crude oil spills. Some nanoparticles have been reported to have toxic effects on living organisms. The nematode worm *Caenorhabditis elegans* lives in the soil and is an established animal model to study toxicity of agents. It was also used to study effects of oil dispersants. Thus, it was hypothesized that toxic effects of crude oil and nanoparticles could be studied using *C. elegans*. In order to test the hypothesis *C. elegans* was grown on agar with or without exposure to crude oil, water or different types of nanoparticles. Average size and number of worms was assessed using

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photomicrographs and morphometric analysis with ImageJ software. The uptake of nanoparticles was analyzed using fluorescent nanoparticles and photomicrographs. Worms showed a smaller size when exposed to amino carboxylate or silver nanoparticles. Fluorescent nanoparticles were found inside the worm. Microfluidic devices were designed for closer observation and better defined micro-environments. In conclusion, nanoparticles appeared to have some negative effects on the worm and it could be used to study effects of nanoparticles. High school and undergraduate students of underrepresented minorities became stakeholders conducting oil spill research affecting their community. The research was funded by NSF RAPID, NASA CAN & LEQSF-EPS SURE, NASA EPSCoR & LaSPACE.

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Session 021: Marine Oil Pollution Monitoring Methods: New and Emerging Techniques for Obtaining and Analysing *in-situ* Observations and Laboratory Data

Remote-sensingInstrument for Detection and Localization of Micro-scale Scattering Centers
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Identifying and quantifying physical, geological, and biological processes within coastal and oceanic waters requires techniques for real-time characterization of particle fields as synoptically and persistently as possible. Suspended sediments, microbial populations, algal assemblages, zooplankton, and anthropogenic pollution, such as oil droplets, are all embodied in coastal and oceanic particle fields. The Fine-Structure Under-water Imaging LiDAR (FSUIL) instrument was developed for long-range, high-resolution environmental sensing applications. The instrument provides high resolution inherent optical property characterization within the water column, and has recently been demonstrated during series of field and controlled environment exercises. The scanned LIDAR approach provides critical information on particle populations at a high vertical and temporal resolution over a scale of centimeters to tens of meters. The data is rendered to produce high-resolution 3D scattering maps describing the highly dynamic microstructures within the water column. The FSUIL instrument exploits several state-of-the-art technologies originally developed for aerospace and medical industry applications to improve the detection range and resolution. The main objective of this study was to conduct a series of early-concept controlled laboratory experiments to assess the feasibility of a FSUIL technology to remotely and non-intrusively detect isolated clouds of spherical particles within an underwater environment where non-spherical particles dominate. The experiments were conducted at an extended range underwater imaging facility at the Ocean Visibility and Optics Laboratory at Harbor Branch Oceanographic Institute. The results demonstrated that the polarization-sensitive time-resolved backscattering signal is an effective method to enhance the contrast between the target microstructure and the surrounding medium.

A Method for *in-situ* Measurement of Individual Oil Droplet Interfacial Tension
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Knowledge of the interfacial tension between oil and water is critical for understanding the mechanisms for droplet breakup and formation, especially where chemical dispersants are applied for reducing droplet size. Typically, the interfacial tension between oil droplets and water is measured ex-situ, via extraction of oil from an experiment and subsequent measurement in the laboratory. However, these measurements are limited to characterising a 'bulk' interfacial tension for the sample, and can be prone to errors resulting from the extraction of oil from an experiment. Recent advances in the use of *in-situ* imaging techniques for measuring the size distribution of oil droplets have opened up new possibilities for additional information to be extracted from the images recorded. Here we present a method to estimate the interfacial tension of individual oil droplets rising freely in water. The technique is based on the relationship between droplet deformation, interfacial tension and droplet size. Experimental releases of oil droplets in the SINTEF Tower Basin are used to simulate a subsea blowout with and without subsea injection of dispersants. The SINTEF SilCam particle imaging system is used to measure the resulting size distributions of the oil droplets formed, and the presented method for estimating the interfacial tension is applied to these measurements to yield interfacial tensions for each droplet. The

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distribution of interfacial tensions within the plume is explored. Results indicate significantly lower interfacial tensions for smaller droplets in comparison to larger droplets within the same, chemically-treated plume.

Evaluation of Benchtop and *in-situ* Fluorometers using Water Accommodated Fractions Prepared with Fresh and Weathered Deepwater Horizon Oils

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The April 2010 blowout of the Deepwater Horizon (DWH) released millions of barrels of crude oil about 65 kilometers off the coast of Louisiana. As part of the subsequent Natural Resource Damage Assessment (NRDA), we implemented a laboratory testing program to evaluate the toxicity of DWH oil and oil/dispersant mixtures to aquatic organisms of the Gulf of Mexico. Due to the variety of exposures that likely occurred during and after the spill, the testing program included four DWH oils, which encompassed a range of oil weathering states, and three different oil-in-water mixing methods, for a total of 12 different water-accommodated fractions (WAFs). To better understand exposure chemistry across the toxicity testing program, we characterized the chemistry (both dissolved and particulate fractions) as well as the droplet size of these 12 WAF preparations at different dilutions and across time. In addition to the traditional gas chromatograph (GC) chemical measurements, we also measured fluorescence with both a benchtop fluorometer and a Turner Designs Cyclops 7 *in-situ* fluorometer. In this presentation, we will discuss our evaluation of the accuracy and sensitivity of both fluorometers for each of the different oil types and mixing methods. In addition, we will describe how changes to the dissolved and particulate phases, the associated droplet sizes, and the presence of dispersant influence fluorescence measurements. Ultimately, this work provides additional insight into oil-in-water detection and quantification using fluorescence spectroscopy.

Fate and transport of particulates below the sea surface: Testing a new method for the quantification of exopolymeric substances

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Many marine microorganisms respond to oil with the release of exopolymeric substances (EPS) which can disperse oil or promote the formation of sinking marine oil snow (MOS). Microbial EPS are thus central in determining the fate of spilled oil in the ocean. One class of particulate EPS are comprised of acidic polysaccharides forming transparent exopolymer particles (TEP) that often act as glue for marine snow. Another type of EPS is classified as Coomassie stainable particles (CSP) of proteinaceous origin. TEP and CSP were analyzed in the water column at three sites in the northern Gulf of Mexico that are influenced by natural and anthropogenic oil seeps. We used the well-established spectrophotometrical methods as well as a recently published method that allows direct observations of TEP and CSP in whole water samples using a portable flow-through microscope (FlowCAM). If applicable, the FlowCAM method provides an onboard tool to analyze concentration and particle properties of EPS (size, volume etc.) shortly after sampling. Information on levels of particulate EPS in the water column provides insights into microbial metabolism as well as the potential for MOS formation in the presence of oil.

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Developmental Cardiotoxicity in Red Drum is Not Influenced by WAF Preparation Method

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The 2010 Deepwater Horizon (DWH) incident produced oiling scenarios that were different than previous large spills such as the 1989 Exxon Valdez oil spill. DWH was characterized by the mechanical and chemical dispersion of oil into small droplets under high pressure at the sea floor. In addition, slicks of various thicknesses occurred over thousands of square miles resulting in highly weathered material becoming stranded in nearshore bays and marshes characterized by lower surface wave energy. In contrast, the surface slick produced by the Exxon Valdez spill was subjected to high wave energy from storms, followed by the shoreline deposition of mousse on cobble beaches. To address the DWH conditions, we developed a simple, easily standardized and reproducible method to mechanically disperse crude oils into seawater using a commercial blender, generating high-energy water accommodated fractions (HEWAFs). Using red drum (*Sciaenops ocellatus*), a nearshore species of the Gulf of Mexico that produces pelagic embryos and yolk sac larvae, we compared the HEWAF method to low-energy WAFs prepared by the standardized methods that avoid mechanical dispersion of droplets into the water column (e.g., the CROSERF method). Using a variety of functional and morphological endpoints for developmental cardiotoxicity, we show the impacts of oil exposure are practically identical for both high- and low-energy methods. In comparison to other Gulf species (e.g., tunas, mahi), red drum embryos are intermediate in sensitivity, showing both relatively severe impacts on heart function and development, as well as secondary abnormal morphology phenotypes. In conjunction with data obtained from other marine and freshwater fish species, and other geologically distinct crude oils, we demonstrate that teleost embryos display a highly consistent and conserved cardiotoxic response to crude oil, irrespective of how the oil enters the aquatic environment.

Aerosol Emission from Crude Oil and Crude Oil-Dispersant Contaminated Seawaters due to Bubble Bursting

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Bubble bursting observed in oceanic whitecaps is a well-known mechanism of marine aerosol generation from seawater surfaces. During an oil spill, aerosols ejected due to such bubble bursting may contain toxic constituents (e.g., benzene, toluene) posing health concerns when inhaled. Use of chemical dispersants as a treatment strategy for oil spills significantly reduces the oil-water interfacial tension, thereby altering the size distribution of the aerosolized particles and potentially facilitating further particulate respiratory penetration. The purpose of this study was to measure the effect of dispersants on aerosolization of an oil slick by bubble bursting. Bubbles were generated by injecting a bubble cloud with controlled size distribution into a vertical seawater column (0.6 m diameter, 1.8 m high). The bubble plume rises to a surface contaminated with an oil-slick with controlled thickness and properties, and the bubbles subsequently burst. The resulting concentration of aerosolized droplets between 0.5 to 20 µm in size was monitored by an aerodynamic particle sizer, whereas a scanning mobility particle sizer measured droplet concentrations in the 10 to 370 nm range. The interface and bubble plume characteristics were monitored with high speed imaging. Measurements were performed at the same air injection rate for varying bubble diameters (150, 600 and 1000 µm), interfacial tensions (crude oil, and crude oil premixed with the dispersant Corexit 9500A (Nalco) at dispersant-to-oil ratio (DOR) of

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1:100 and 1:25) and oil-layer thicknesses (0.1 and 0.5 mm). Results show that the crude oil slick produces the lowest concentration of aerosolized droplets over the entire particle size range (10 nm to 20 µm). For all bubble sizes injected, the number concentration of nano-sized (10 to 370 nm) droplets increases by an order of magnitude above a DOR 1:25 oil slick while the micron scale droplet concentration did not change appreciably.

Acoustic Measurements of Slick Thickness, Oil Droplet Size, and Dispersant Effectiveness in the Presence of Gas

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Understanding the physical characteristics of oil is important when remediating surface spills and subsurface releases. Specifically, knowing the location and thickness of slicks on the surface is important for directing remediation efforts and knowing the oil droplet size distribution is critical for determining the fate and transport of the oil in the water column as well as for determining the efficacy of dispersant applications. We have been developing acoustic methods to measure these oil properties and have advanced them through various technology levels. We delivered an ROV to measure slick thickness from less than a mm to many centimeters thick at Ohmsett. We are working on measuring oil droplet size distribution and gas bubble size distribution using acoustic scattering methods for surface and subsurface releases of oil, oil and gas, and subsurface dispersant injection (SSDI) with oil and SSDI with oil and gas. Acoustics are desirable because they penetrate far into the water column and plume and work in very high concentrations of oil and do get fouled by oil even if a thick film of oil forms on the sensor (~several mm). Our results show the ability to measure mean droplet size for surface release of oil and dispersant applications and to measure dispersant effectiveness for SSDI into plumes of oil and plumes of oil and methane. The data was collected in lab settings as well as at Ohmsett and SINTEF for several oils and dispersant to oil ratios (DOR). We are working on extending these measurements and theories to determine the oil droplet size distribution and to characterize other remediation methods. We are deploying these high fidelity acoustic measurements on free swimming ROV and glider platforms and beginning the integration of the acoustic measurements of slick thickness, oil droplet size, and dispersant effectiveness to deployable platforms. *This study was funded by the Bureau of Safety and Environmental Enforcement (BSEE), U.S. Department of the Interior, Washington, D.C.*

Incidence of Foraminifera Deformity as an Indication of Chronic Hydrocarbon Contamination of Parts of the Iranian Coastline of the Persian Gulf

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Hydrocarbon contamination is an important issue of concern in the Persian Gulf, where the whole body of water is heavily influenced by oil and gas developments on both northern and southern coastlines. As the number and volume of developments in this important body of water continue to rise, coastal ecosystems are increasingly threatened by this type of heavy contamination impacts. In the past few decades, the Persian Gulf has become a habitat for a new sedimentary process: sediment cementation by oil that is chronically spilled from offshore operations, the freighters and tankers that carry the oil out

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of the Persian Gulf, oil leakage from land pipelines, as well as catastrophic oil spills that occurred during the Persian Gulf War. Oil spills are not only annoying and unsightly, but many of the compounds can be extremely toxic. Monitoring and evaluation of oil spills should be a regular part of managing the coastlines. One of the best and cheapest monitoring schemes available is using bio-indicators. Benthic foraminifera communities can be used as bio-indicators of coastal oil contamination as contact with hydrocarbons can induce growth deformities in their shapes. These indicators are of short lifespans with quick response to environmental condition fluctuations and can easily be found in carbonate sediments in most of the parts along the study coastline. This study aims to provide a few examples of detecting oil leakage or other types of hydrocarbon contaminations along some parts of Iranian coastline of the Persian Gulf by assessing degree of deformity of benthic foraminiferal assemblages in sediments. For this, 32 surficial samples were collected at sites throughout the area which were suspected to be contaminated by oil leakage. By considering the foraminifera deformity index, the approximate leakage location was estimated, which was in fair agreement with the real conditions. In short, a look at the forams can pinpoint the location of a chronic seepage.

Comparison of Two Methods for Extracting PAHs from Fish Liver and Muscle

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Reproducible and accurate extraction of polycyclic aromatic hydrocarbons (PAHs) from fish tissues is a critical step in quantifying hydrocarbon exposure and effects in the environment. There are a number of methods which are commonly used to extract hydrocarbons from tissues, including Pressurized Liquid Extraction (PLE, aka accelerated solvent extraction, or ASE) and the QuEChERs (Quick, Easy, Cheap, Effective, Rugged, and Safe) method. Both methods are used broadly by the scientific community, and it is important to ensure consistency of results between methods. It is also useful to understand how they compare with respect to recovery, accuracy, and precision, as well as speed and convenience when processing a large quantity of samples. This study compared the performance of ASE and QuEChERs extraction of fish tissues. Splits of liver and muscle tissue of 20 fish were extracted and PAHs were quantified by GC-MS/MS. Two species of fish (Gaff-topsail Catfish (*Bagra marinus*) and Yellowedge Grouper (*Hyporthodus flavolimbatus*) were used to assess the impact of different types of liver and muscle matrix. All fish sampled were collected from the Southern Gulf of Mexico during the summer of 2015. Presented results will compare the concentrations reported by the two methods for both low and high molecular weight PAHs. Differences in precision of the methods, based on results from replicate extractions, will also be presented. The relative strengths and weaknesses of both methods will be discussed across varying types of fish tissues, and the ability to compare and use data from both methods interchangeably will be assessed.

Temperature and salinity effects on partitioning co-efficient ($K_{PDMS\text{-}water}$) of selected hydrophobic organic carbons (HOCs): their use for passive dosing.

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Passive dosing is a modern methodology predominantly used in risk assessment of various chemical compounds for human and environmental safety. Successful risk assessment of chemicals of concern through passive dosing requires precise measurement of the partitioning co-efficient of a chemical between a polymer (e.g. PDMS) and water (in our case $K_{PDMS\text{-}water}$). Researchers generally calculate

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toxicity based on $K_{PDMS\text{-}water}$ measured at room temperature and for fresh water/distilled water. Measurement of $K_{PDMS\text{-}water}$ at ambient temperature and salinity provides accurate dosing level and actual toxicity measurement imposed from chemical compounds. For Deep-sea Risk Assessment and species sensitivity to WAF, CEWAF and Dispersant project (DeTOX), $K_{PDMS\text{-}water}$ has to be measured at 35 ppt and 7°C, as toxicity measured through $K_{PDMS\text{-}water}$ at room temperature and zero salinity may result in overestimation of toxicity. In this work, we investigate the effect of temperature and salinity on the partitioning co-efficient of a series of hydrophobic hydrocarbons (e.g. toluene, 1-methylnaphthalene). Data from this study can readily be used for toxicity measurements for various environments with different temperature and salinity or for measurements of bioaccumulation factor (BCF) for several PAHs where PDMS is proxy for lipid.

Coupling Line Narrowing Spectroscopy to Liquid Chromatography for the Determination of Polycyclic Aromatic Compounds in the Gulf of Mexico <u></u>

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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. The dispersion of harmful oil components into the ocean waters could pose long term risks to flora and fauna. 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) with diverse chromatographic behaviors. The general approach follows the sequence of sample collection, PAHs extraction and analysis by high-performance liquid chromatography (HPLC) with UV absorption and room temperature fluorescence detection. When HPLC is applied to “unfamiliar” samples, the use of a supporting analytical technique such as gas chromatography-mass spectrometry (GCMS) is necessary to verify compound identification and to check peak-purity of HPLC fractions. Herein, we present an alternative approach for the analysis of high molecular weight - polycyclic aromatic hydrocarbons (HMW PAHs) with molecular mass 302 Da in complex environmental samples. This is not a trivial task due to the large number of molecular mass 302 Da isomers with very similar chromatographic elution times and similar, possibly even virtually identical, mass fragmentation patterns. The new approach is based on the combination of HPLC and high-resolution photoluminescence spectroscopy. The spectral information obtained at cryogenic temperatures provides the required selectivity for the unambiguous determination of PAH isomers in the HPLC fractions. Complete spectroscopic analysis is possible with microliters of HPLC fractions and organic solvent. The excellent analytical figures of merit associated to its non-destructive nature - which provides ample opportunity for further analysis with other instrumental methods - makes this approach an attractive alternative for the analysis of isomers of HMW PAHs in heavily contaminated samples.

A User-Friendly High-Resolution Photoluminescence Approach to the Low-Temperature Analysis of Polycyclic Aromatic Compounds in the Gulf of Mexico

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High-resolution photoluminescence techniques deal with fluorescence and phosphorescence measurements at cryogenic temperatures. Analysis at 77K or below often improves spectral resolution, increases photoluminescence quantum yields and minimizes complications with oxygen quenching and

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energy transfer. The widespread use of low-temperature techniques have been hampered by several reasons. These include inconvenient sample freezing procedures and questions about signal reproducibility for calibration purposes. We have removed these limitations with a bifurcated fiber-optic probe (FOP) that delivers the excitation light directly into the frozen matrix. This approach eliminates the need for an optical Dewar and/or helium cryostat, eliminates all interfaces that scatter exciting light into the detection system and retains the simplicity of dunking the sample into the liquid cryogen for fast and reproducible freezing. 77K and 4.2K samples are prepared in a matter of seconds. Herein, we combine the FOP to a commercial spectrofluorimeter for the analysis of organic pollutants in the Gulf of Mexico. These include polycyclic aromatic hydrocarbons (PAHs), alkylated PAHs (APAHs) and sulfur containing PAHs (PASHs). When compared to un-substituted PAHs, APAHs comprise a relatively large fraction of the total number and mass of PAHs found in crude oil and crude-contaminated seafood samples. Sulfur is the principal heteroatom in coal, crude oil, tar and their by-products. The development of a single analytical approach with the ability to efficiently and reliably detect the presence and quantitate the amounts of PAHs, APAHs and PASHs would be extremely valuable within the context of the Deepwater Horizon event.

High-Resolution Spectroscopy for the Isomeric Determination of Polycyclic Aromatic Hydrocarbons with Molecular Weight 302 in the Gulf of Mexico

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The dispersion of harmful oil components into the Gulf of Mexico (GM) could pose long term risks to flora and fauna. One of the main concerns focuses on polycyclic aromatic hydrocarbons (PAHs). Particular attention has been paid to the sixteen PAHs currently listed as priority pollutants by the Environmental Protection Agency with molecular weights (MW) ranging from approximately 128 to 278 g mol^{-1}. This project tackles a different aspect of PAHs analysis as it focuses on detection and characterization of higher-molecular weight PAHs (HMW-PAHs), i.e. PAHs with MW equal or higher than 302 g mol^{-1}. The HMW-PAHs isolated from environmental and combustion-related samples exhibit mutagenic activity and petroleum transformation products from HMW-PAHs persist in the environment longer than their lighter counterparts. Studies have shown significant sedimentation of HMW-PAHs that may be increased with the addition of dispersants in a coastal setting. Their continued monitoring will ensure that HMW-PAHs present in sediments are not being redistributed and accumulating through the food chain. Individual isomers of HMW-PAHs are not routinely identified or quantified. Difficulties in the determination of HMW-PAHs arise from their low concentration levels in environmental samples compared to those of the priority pollutant PAHs. The number of isomers increases dramatically with each additional aromatic ring, which makes separation and identification difficult by gas chromatography-mass spectrometry and liquid chromatography. Herein, we demonstrate our ability to differentiate individual PAH isomers of MW 302 on the basis of their low-temperature (77K and 4.2K) fluorescence spectra. Vibrational resolution with fingerprint spectral information is obtained by dissolving HMW-PAHs in n-octane. Quantitative analysis at the parts-per-billion concentration level ($ng.mL^{-1}$) is made possible with no need of sample pre-concentration. Strategies are presented for the analysis of GM samples.

* Student Presenter

Visualizing the structure of freshwater plumes in the coastal Gulf of Mexico using high frequency multibeam sonar water column backscatter

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As part of the GoMRI CONCORDE Spring 2016 cruise aboard the R/V Point Sur, a 200/400 kHz Reson Seabat 7125 multibeam sonar was operated to investigate water column anomalies in the near shore waters of the Gulf of Mexico, south of Mobile Bay. One of the main focuses of the spring campaign was to investigate the mixing of pulsed freshwater plumes, into the Mississippi Bight. The stratification generated by the plume between the fresh and salt water layers generates a strong acoustic impedance contrast, which is apparent in the water column backscatter. The multibeam system was operated simultaneously with a towed profiling In Situ Ichthyoplankton Imaging System (ISIIS), which measures zooplankton abundance, salinity, temperature, dissolved oxygen, fluorescence and PAR. Comparing preliminary three dimensional acoustic water column data with observational data from the ISIIS, the detailed stratification of the halocline can be analyzed within the convergence zones present off of Mobile Bay in early April 2016. The structure of the halocline is examined, including turbulence and thickness of the mixing, using multibeam sonar water column data. Fine scale spatial and temporal structure of the freshwater/saltwater interface is observed beyond the resolution achievable by current coastal circulation models. Combining the ISIIS and acoustic data allows for detailed interpretation of the water column backscatter and examines the effectiveness of using a multibeam sonar to describe mixing along the halocline.

Examining how DOSS alters eicosanoid biosynthesis in stem cells through targeted lipidomics

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Eicosanoids are bioactive lipid messengers that mediate the immune response in a variety of different cell types. Due to their structural, as well as biological diversity, lipidomics technology for their direct measurement is needed for a systematic look into their actions in cells. In this study, human embryonic stem cells (iPSC) were exposed to a component of the COREXIT mixture - Dioctyl Sodium Sulfosuccinate (DOSS), which has previously been shown *in vitro* to activate the peroxisome proliferator pathway gamma (PPAR-γ) nuclear receptor. Taking this work a step further, this investigation looks at the effects into eicosanoid pathway following DOSS exposure. The technique employed examined over 100 signaling eicosanoids in iPSC cells using Liquid Chromatography/Tandem Mass spectrometry, and validated with RNAseq and colorimetric enzymatic assays. Preliminary eicosanomic data identifies that DOSS exposed cells have increased Prostaglandin D2 and 15-HETE production in the media, but the effect is mitigated after 72 hours of exposure. RNAseq results also indicate that several genes associated with fatty acid transport and prostaglandin production show increased expression over the control. Further enzymatic analysis indicates that this response is mediated through increased cyclooxygenase-2 expression, and it highlights an increased inflammatory response in the iPSC cells following DOSS exposure.

* Student Presenter

An Opportunistic Maintenance Policy for A Multi-unit System

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Modern drilling equipment have to operate under high temperature and pressure. Failures of drilling equipment not only induce profit shrinkage for the drilling company, but could also increase the potential risk of oil spill in working scene. In order to achieve a high reliability, systematic maintenance strategies should be applied to the maintenance of drilling equipment. Typically, a drilling equipment system consists of several functional components. Preventive maintenance or corrective maintenance on any unit often incur a system setup cost due to the system shut-down, regardless the number of components needs to be maintained. System availability/maintenance cost may be improved by grouping maintenance activities on several components. In this research, we propose an opportunistic maintenance policy for a multi-unit system. Unlike conventional condition-based maintenance with periodic inspection schedule and a fixed preventive maintenance threshold, the proposed policy dynamically changes the inspection interval, preventive maintenance threshold, and opportunistic maintenance threshold based on system's current degradation level. A simulation model based on Matlab is developed to optimize the long-run cost rate by considering preventive maintenance cost, corrective maintenance cost, inspection cost, and setup cost. The comparison result between proposed policy and benchmark maintenance policy shows that a lower cost rate can be achieved using the proposed opportunistic maintenance policy for a multi-unit system.

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Session 022: Deepwater Horizon Oil Spill Natural Resource Damage Assessment: Comprehensive Integrated Ecosystem Restoration

Valuating Marine Ecological Loss Caused By Oil Spills: Framework and Case Studies

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Marine ecological loss is assessed based on marine ecological capital theory. Marine Ecological Capital (MEC) is defined as marine ecological resources which have direct or indirect contributions to humans' social and economic production and provide benefits for humans. Marine ecological resources (MER) consists of marine living resources and their habitats (i.e. seawater, surface seabed), as well as the marine ecosystem that they act as a whole. The value of MEC is defined the monetized benefits for humans from marine ecological capital, including both the standing stock value of marine ecological resources and value of marine ecosystem services. A framework of valuating marine ecological loss caused by oil spills is developed. The marine ecological loss equals the baseline value of MEC of the sea area times the damage coefficient, the damaged area and the damage duration period of oil spill. The marine ecological loss includes two parts: (1) the loss in marine ecological resources, i.e. the loss in marine living resources, seawater and surface seabed; (2) the loss in marine ecosystem services, i.e. the loss in the provisioning services, regulating services, cultural services and supporting services. The baseline value of MEC before oil spill is assessed in accordance with the Technical Guidelines for Marine Ecological Capital Assessment of China. The damage coefficient indicates the degree of damage of marine ecosystem by oil pollution which is usually classified as four grades based on China's standards on seawater and marine sediment quality. The coefficient varies from 0 to 1, 1 mean the marine ecosystem is completely and fully damaged, e.g. no any fish, crab and shrimp; 0.5 mean the marine ecosystem is damaged at 50 percent level, e.g. some fish, crab and shrimp still survive; while 0 mean no any obvious damage of marine ecosystem. The damaged area is all area of by oil pollution, except for the overlapped and repeated areas. The damage duration period is the time period from the occurrence of oil spill until the time that oil concentration in seawater and sediment decrease to the baseline concentration before oil spill. This framework was applied to the marine ecological loss caused by the oil spill of US's Conocophillips Company in Bohai Sea, China in June 2011. The total marine ecological loss is about 1 billion CNY.

Reduction of Post-release Mortality in Red Snapper (*Lutjanus campechanus*) and Other Recreationally Caught Reef Fish in the Gulf of Mexico Using Fish Descender Devices

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Fish descender devices are designed to reduce post-release mortality resulting from rapid decompression and related injuries (barotrauma) during recreational fishing operations. We estimated the ecological benefits of distributing fish descender devices to recreational anglers by quantifying the reduction in post-release mortality of recreationally caught red snapper (*Lutjanus campechanus*) and other reef fish in the Gulf of Mexico. We conducted a meta-analysis to evaluate differences in post-release mortality for two barotrauma mitigation treatments (fish descender devices and venting) compared to a control (non-venting), accounting for differences in season and depth. Mortality rate was estimated using weighted mixed effects logistic regression models. Two sets of estimates were

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generated: the first used only summer data, and the second pooled the data from spring, summer, and fall. Winter data were excluded from the model because the fishery is small compared to warmer months and data are limited for that time period. Model results were applied to data from the Marine Recreational Information Program (MRIP) to estimate the ecological benefits of increasing descender device use across the Gulf of Mexico. Benefits for red snapper were measured on a per vessel basis by dividing the number of total mortalities by the number of active fishing vessels, and ranged from 18 to 850 (2-99% of average red snapper mortalities per vessel) additional surviving fish per vessel annually when descender devices were used, compared to non-venting, in summer months. Using this model, the greatest benefit was in Alabama, followed by Northwest Florida, Louisiana/Mississippi, and lastly, Southwest Florida. Benefits of fish descender devices were also estimated for vermilion snapper, red grouper, and gag grouper. Estimating the benefits of fish descender devices by region and season allows programs to be targeted such that the devices are used when and where they provide the maximum reduction in post-release mortality. Successful implementation would likely reduce recreational fishing mortality and provide a benefit to the red snapper population. This methodology can be applied to other fish species and locations that experience high post-release mortality rates due to barotrauma.

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