Abstracts for Poster Presentations

Organized by Session

* Student presenter

Session 001: Modeling for Synthesis – Integrated Assessment of Ocean Environment, Ecosystems, Human Health, and Socioeconomics

Towards Integrated Assessment Modeling of the Long-Term Impacts of Oil Spills

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Through the efforts of the Gulf of Mexico Research Initiative (GoMRI) great progress has been made in advancing the scientific understanding of oil spills. One objective of GoMRI synthesis and legacy efforts has been to integrate this new knowledge and develop a conceptual framework that could be used to address long-term societal questions about oil spill impacts. Given the breadth of the questions to be addressed, the assessment was separated into four knowledge domains (ocean environment, ecosystems, socio-economics and human health) from which a systems dynamics approach was used to develop the conceptual framework. A series of online workshops solicited expert input, defining the state-of-the-art within each knowledge domain and connecting models to stakeholder questions. This exercise resulted in causal loop diagrams and an initial quantitative stock and flow model from which the interconnectivity of the system could be better understood. Mapping the extent of existing models to the underlying system structure indicates that the system naturally separates in two tiers, ocean environment and ecosystems versus socio-economics and human health. The systems and existing models within each of these tiers are intertwined with each other. As a result, the existing detailed ocean environment and ecosystem models can be used to drive rich human health and socio-economic scenarios. Although data gaps are identified in all four model domains, the socio-economics and human health domains are the least developed and require considerable future work in order to develop reasonable quantitative models that can be used for longer term decision-making.

Consequences of Climate Change and Sea Level Rise on Cultural and Historical Resources Along the Northern Gulf Coast of Mexico

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Centuries of fossil fuel extraction and use have warmed the planet; consequently, melting ice and rising sea levels are directly threatening our cities, our cultural heritage, and the abundant bounty of coastal ecosystems. With 39% of Americans living in counties directly on the shoreline, this is a serious concern, especially considering that the Intergovernmental Panel on Climate Change (IPCC) predicts anywhere from .5 meters to 1.2 meters of sea level rise by 2100. What does this mean for our coastal resources both rural and urban? Historic and modern? To answer these questions, we assess threats to archaeological and cultural resources in two regions - Florida's Big Bend and Louisiana's Mississippi River Delta. We predict the effects of sea-level rise on archaeological sites and describe direct observations of archaeological site loss. Furthermore, we describe changes to modern coastal populations because of sea level rise and make efforts to understand the factors influencing abandonment of specific coastal areas, in the past, present, and future. While loss in inevitable, we can predict where this loss will be greatest, and herein, propose measures to mitigate these devastating losses.

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Changes in Remotely Sensed Aerosol Optical Depth from the Deepwater Horizon Oil Spill

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During the DWH disaster, the oil spill and response operations generated various atmospheric pollutants. Changes in pollutant composition and concentration with downwind distance from the DWH site, resulted in different air quality conditions and exposures for populations along the coast. Studies have found that secondary organic aerosols from the oil spill were a significant air quality issue for populated areas along the Gulf Coast. Atmospheric remote sensing offers a unique opportunity to estimate how oil spills impact air quality by analyzing changes in aerosol particles in the atmospheric column before and after a spill. Here we assume that these changes in aerosol particles can be mostly attributed to evaporation from the surface oil and secondary chemical reactions. Studies have shown that the mass flux of secondary organic aerosol to the atmosphere was substantially larger than the emission of soot from periodic surface oil burning. This study examines AOD measurements from MODIS (MODerate resolution Imaging Spectroradiometer) before and after DWH. MODIS, onboard Terra (local cross-time ~ 10:30AM) and Aqua (local cross-time ~ 1:30PM) satellites, data were used to estimate daily AOD at 2km and 3km spatial resolutions for all Gulf Coastal areas for 2010. AOD measurements were collocated with meteorological conditions, and adjusted for these conditions using region-specific regression. We computed beach specific estimates of AOD and monthly averages for three sites randomly selected from north, west and east Gulf Coastal areas. Northern and western sites showed a significantly higher increase in the AOD as compared to the eastern site. In relation to the annual average, AOD was about 100% higher than the annual average around the northern and western site in August 2010, and about 50% at the eastern site. Using this approach coupled with spatiotemporal imputation techniques, daily beach specific concentration of AOD can be developed for exposure studies.

Analyzing the Contribution of Vertically Migrating Mesopelagics to the Diets of Large Pelagic Predators

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Following the 2010 Deepwater Horizon spill much of the leaked oil was entrained in deep water plumes and eventually deposited out of the water column into sediments, resulting in the presence of oil toxins in the tissues of many benthic and deep-sea species. Because both mesopelagic species and multiple epipelagic predators in the Gulf exhibit some form of vertical migration in their foraging habits, it is reasonable to suspect that 1) large predators exhibit some level of trophic dependency on mesopelagic prey and 2) predation by these predators is one potential pathway by which oil may contaminate the pelagic food web. This study seeks to characterize the availability of mesopelagic prey species to large epipelagic predators and to quantify these trophic interactions. We used diet data from the Gulf of Mexico such as those acquired through long line sampling of high trophic level pelagic predators. We characterized error around predator diet compositions by fitting bootstrapped diet data to a Dirichlet distribution, which is the multinomial generalization of the Beta function. This allows us to account for co-variation between prey items and is insensitive to rare feeding events. Results from this project will support Atlantis ecosystem modeling to examine food web effects and potential fisheries losses following a hypothetical mortality event of mesopelagic prey species due to effects of oil toxicity.

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Session 002: On the Resiliency of Living Marine Resources to Gulf Oil Spills

Recovery of the Salt Marsh Periwinkle (*Littoraria irrorata*) Nine Years After the Deepwater Horizon Oil Spill: Size Matters

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Salt marshes in northern Barataria Bay, Louisiana, USA were oiled, sometimes heavily, in the aftermath of the Deepwater Horizon (DWH) oil spill. Previous studies indicate that salt marsh periwinkles (*Littoraria irrorata*) were negatively impacted by oiling at least five years post spill. Here, we detail longer-term effects over a 9-year span. *L. irrorata* density increased from initial oil-induced declines at reference, moderately and heavily oiled marshes for about 66 mo, and highest densities were observed at moderately oiled sites where *Spartina alterniflora* aboveground biomass was highest. From 66 to 108 mo a trend of higher densities in heavily oiled marshes was observed along a seasonal pattern of spring high and fall low densities. Mean *L. irrorata* shell length at reference sites increased from 16 to a maximum of 20 mm over the study period; at moderately oiled sites, it increased nearly linearly over the study period from 17 to 19 mm; and at heavily oiled sites, it increased linearly from 14 to 16 mm. Lower mean shell lengths at oiled marshes were associated with a decline in the relative abundance of large adults (shell length >20 mm). Overall, the recovery of *S. alterniflora* facilitated recovery of *L. irrorata* density but not population size structure. Aboveground vegetation was slow to recover in the heavily oiled sites and the resulting more open canopy may have stimulated microalgal and microbial food resources for *L. irrorata* and contributed to high densities but also may have left the population of subadult and small adult individuals susceptible to predation. Our long-term data indicates that recovery from the DWH is slower than recovery from marsh restoration and may require 9 more years before the reference population structure is regained.

Microzooplankton Communities Associated with Oiled Marine Snow

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During the Deepwater Horizon spill, oil related marine snow formed in surface waters and sank to the seafloor, temporarily increasing the sedimentation rate to six to eight times that preceding the spill. Oiled marine snow has been recognized as an important vehicle for transporting oil to the benthos following some spills, which has prompted studies on the properties of oil related marine snow and on the mechanisms by which it forms. Phytoplankton and bacteria are both thought to play important roles in marine oil snow formation, but associations between marine oil snow and zooplankton have received less attention. Here we present a comparison of the microzooplankton communities colonizing oiled marine snow (OMS) and non-oiled marine snow (MS). We created marine snow in the laboratory by incubating seawater in the presence or absence of Deepwater Horizon surrogate crude oil for 1 week. Marine snow flocculants were transferred to new seawater and incubated for an additional 72 hours to allow natural communities to interact with the marine snow. Using high-resolution video microscopy, we characterized the microzooplankton communities associated with OMS and MS. Ciliates and flagellates were both found associated with both types of marine snow, as were diatoms, which were

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often a major component of the snow. However, significantly more microzooplankton were associated with OMS than MS, and organisms in OMS tended to be smaller on average. The elevated microzooplankton activity associated with OMS suggests several taxa may be able to take advantage of bacterial communities and/or secondary metabolites in the OMS flocculants.

Population Demographics of Tilefish *Lopholatilus chamaeleonticeps* in the Gulf of Mexico Before and After Deepwater Horizon

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The Deepwater Horizon (DWH) oil spill impacted aquatic organisms in the Northern Gulf of Mexico (GoM). Demersal habitat use and apparent high contaminant levels in tilefish make them potentially vulnerable to oil spills such as DWH. Longline gear was used to sample Tilefish at 344 locations distributed throughout the GoM in the seven years following DWH. Sampling was accomplished deploying 450-500 baited hooks per station in depths ranging from 20-600 m. Using data from these surveys, length and age frequency, condition, growth, and mortality rates of tilefish were analyzed throughout the GoM. Comparing population resiliency by analyzing rates of growth and mortality can be used to understand the effects of anthropogenic perturbations and how vital rates vary spatially. Data were compared from within the DWH spill perimeter to outside the DWH perimeter and pre- and post-DWH. Growth curves fit to length-at-age data from the DWH spill site and all other US sites post-spill showed slight differences, although those differences decreased in pre- and post-DWH spill site comparisons. Despite the total mortality rate being higher in fish from within the DWH spill perimeter compared to all other US sites, there was no discernible difference in the Z statistic pre- vs. post-spill for sites within the DWH perimeter. Thus, any differences in growth and mortality observed in post-spill fish from the DWH spill perimeter compared to post-spill fish from elsewhere in the US appear to be endemic to the northeastern GoM. While further study is needed to analyze the impacts from oil exposure on tilefish eggs and larvae, this study did not observe a difference in adult tilefish growth and mortality pre- and post-spill.

Hepatic Concentrations of Polycyclic Aromatic Hydrocarbons, Polychlorinated Biphenyls, and Organochlorine Pesticides in Snappers from Cuba and the Wider Gulf of Mexico

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This study measured concentrations of polycyclic aromatic hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), and Organochlorine Pesticides (OCPs) in hepatic tissues from seven snapper species caught along the north-western coast of Cuba. Additional specimens from the gulf-facing coasts of the United States and Mexico provide spatial context for these results. Spatial trends observed in Cuban specimens indicate that PCBs and select OCPs in snapper livers may correspond to patterns of anthropogenic use onshore. One example of this is the spatial gradient in PCB concentrations, which appear to decrease with increasing distance from the heavily industrialized Havana harbor. Species specific variations in contaminant concentrations along the Cuban coast are likely the result of species-specific differences in metabolism and life histories. Contaminant concentrations are correlated with several fish biometrics and health indicators, including a negative relationship observed between PAH

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concentrations and Fulton's condition factor. Regional variations in contaminant compositions and total concentrations will be explored. The results of this study explain possible connections between onshore development/industrial activity and impacts to offshore ecosystems. These data also serve to establish contaminant baselines for this group of economically important GoM fishes.

Chronic PAH Exposures and Associated Declines in Fish Health Indices Observed for Ten Grouper Species Collected in the Gulf of Mexico

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Ten species of grouper (*n* = 584) were collected throughout the Gulf of Mexico (GoM) from 2011 through 2017 to provide information on hepatobiliary polycyclic aromatic hydrocarbon (PAH) levels. Liver and bile samples were analyzed for PAHs and their metabolites using triple quadrupole mass spectrometry (GC/MS/MS) and high-performance liquid chromatography with fluorescence detection (HPLC-F), respectively. Data were compared among species and sub-regions of the GoM to understand spatiotemporal trends in exposures in these economically important species. Significant differences in the composition and concentrations of PAHs were detected both regionally and by species. The West Florida Shelf, Cuba and the Yucatan Shelf had a greater proportion of the pyrogenic PAHs, thus we can see the differential impacts between the oil industry and anthropogenic sources (e.g., marine vessel traffic) in the regional composition profiles. Mean PAH liver and bile concentrations were highest in Cuba followed by the north central and northwestern regions of the GoM. Biliary PAH concentrations and health indicator biometrics initially decrease during the first three years following the Deepwater Horizon (DWH) oil spill, followed by significant increases over time in groupers collected in the north central region of the GoM. Increased exposures are likely explained by the resuspension of residual DWH oil as well as the continued inputs from additional anthropogenic (e.g., riverine runoff, other oil spills, and leaking oil and gas infrastructure) and natural (e.g., seeps) sources. The increasing trend of PAH concentrations in the bile and liver of grouper species in the north central region of the GoM post-DWH suggest continued chronic exposures, however the critical stage at which permanent, irreparable damage may occur is unknown. These data justify the need for continued monitoring of PAH levels and health indices in this economically important species.

A Comprehensive Petrochemical Vulnerability Ranking for Marine Fishes in the Gulf of Mexico

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The vast majority of marine species in the Gulf of Mexico lack toxicological information on the biological and ecological impacts of exposure to petrochemicals. To help prioritize species recovery, mitigation, and conservation in light of data gaps, a trait-based vulnerability index was developed and applied to the more than 1,600 marine fishes present across the entire Gulf of Mexico, including all known bony fishes, sharks, rays and chimaeras. Here we present the methods used to estimate each species' overall petrochemical vulnerability ranking based on likelihood of exposure, relative sensitivity to exposure, and measure of population resiliency using life history and other traits. These rankings highlight species and

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geographical areas with high vulnerability and/or resilience. Statistical methods that will be employed to account for large data gaps or other uncertainties are also discussed, as well as the application of the ranking method for other taxonomic groups, including marine tetrapods, invertebrates and plants.

Oxidative Stress Response of the Seaside Sparrow (*Ammospiza maritima*) Following the Deepwater Horizon Oil Spill

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The Deepwater Horizon (DWH) oil spill introduced massive amounts of oil into Louisiana saltmarsh ecosystems. Exposure to oil was observed in Seaside Sparrows (*Ammospiza maritima*). Carbon isotopic evidence showed a food-web link between oiling of marshes and exposure of the birds. Additionally, Seaside Sparrows from oiled sites had increased activation of cytochrome P4501A (CYP1A), a gene involved in the metabolism of polycyclic aromatic hydrocarbons (PAHs). PAHs are toxic in part because metabolites react with molecular oxygen and generate reactive oxygen species (ROS). These ROS can then cause oxidative damage to biomolecules, inducing oxidative stress when they overcome the antioxidant capacity of organisms. Our goal is to quantify the oxidative stress response of Seaside Sparrows exposed to DWH oil. We measured the concentration of reactive oxygen metabolites and antioxidant capacity in the plasma of exposed and control birds using commercial kits. Our preliminary results indicate that average antioxidant capacity is elevated in birds from oiled plots compared to birds from control plots in 2013 and 2015. This suggests that exposed birds mobilized antioxidants from storage tissues to adjust to chronic PAH exposure over time. Such mobilization of antioxidants may trade off with the ability of those birds to provision offspring or fight inflammation. We will also measure protein carbonylation, a measure of oxidative damage to proteins, in the heart of exposed and control birds using a PAGE-Western blot assay. In the same tissue, we will also quantify the expression of *jun*, a proto-onco gene linked to cardiac enlargement and congenital anomalies, using qPCR analysis. These measurements will reveal the oxidative stress response of DWH oil exposure in Seaside Sparrows and help clarify its possible fitness consequences.

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

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Epigenetics is the study of heritable change in gene expression mediated by modifications to chromatin/DNA, one of which is DNA methylation. This addition of a methyl group to cytosine can be induced by environmental change, such as exposure to environmental contaminants, and maintained through cell lines and passed from parent to offspring. Environmentally induced epigenetic alterations can alter the regulation of functionally important genes; however, there is a lack of information about patterns of epigenetic response to oil exposure, particularly in the wild. This study aims to assess differences in DNA methylation patterns of wild-caught juvenile red drum (*Sciaenops ocellatus*) collected in historically designated chronic high-oil and low-oil impacted areas within a single bay system. Using reduced representation bisulfite-converted sequencing and bioinformatic analyses, we quantified the

total methylation across the genome and examined patterns in specific gene regions. Acute total polycyclic aromatic hydrocarbon (tPAHs) exposure measurements and composition profiles between red drum liver tissue will be compared to results of methylomics to look for marks of exposure within and between different tissue types. Overall, this project will contribute to our understanding of epigenetics and oil exposure and potentially provide biomarkers for assessing the exposure of economically and ecologically important food fish to oil-based contaminants.

The Role of Biodiversity on the Resistance and Resilience of Coastal Ecosystems to Oil Disturbance

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Biodiversity - including genes, species and functional traits - can enhance community stability (i.e. resistance and resilience) in response to both natural and human-induced disturbances (e.g. predation, extreme temperature events). Initial findings from the Deepwater Horizon oil spill found that the ecological impacts on coastal ecosystems varied greatly across habitat-type and trophic groups; however, to date, few studies have tested the influence of local biodiversity on these responses. Using a meta-analysis, we have synthesized 6 mesocosm experiments conducted by the Alabama Center for Ecological Resilience (ACER) to evaluate whether biodiversity increases the resistance and/or resilience of coastal ecosystems to oiling and dispersant exposure. These experiments have tested diversity effects across a range of habitats - from intertidal wetlands to pelagic open water - and taxonomic groups (e.g. microbes to fishes). Therefore, we have also assessed how this diversity-disturbance relationship varies across trophic groups, level of biodiversity manipulated (e.g. genetic, species), and response metrics including both population- (e.g. survival, growth) and ecosystem-level processes (e.g. bioturbation, denitrification). Preliminary results suggest few effects of diversity on resistance, perhaps as a consequence of limited variation in the immediate responses of individuals to oiling, however, there is some evidence that diversity effects can increase over time, potentially providing a benefit to long-term recovery. The results from our synthesis will highlight areas of high vulnerability to future oil disturbances and provide valuable insight into the incorporation of diversity in coastal management and restoration efforts.

Establishing/Reestablishing Baselines for Invertebrate Populations in Louisiana Tidal Marsh Estuaries

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The 2010 Deepwater Horizon explosion (DWH) and subsequent oiling of Louisiana estuaries was both unexpected and yet instructive. Oiling of Louisiana marshes is unavoidable given the proximity of petrochemical activity. The scientific activity to address the oiling that followed the DWH was hampered in measuring the impact due to the absence of clear baseline data. We originally measured the impact of the oiling on the population abundance and genetic profiles of a single species of horse flies and the results of those studies are described in other presentations. In other studies, more emphasis was made upon measuring the impact of oiling at a higher level of arthropod classification, and focused on presence/absence or numerical level at a high taxonomic level and were limited to oiled vs. unoiled sites in retrospective analysis without baseline data. Our recent attempts to describe the natural fauna of the

estuaries of La. are done with the knowledge that pristine sites are rare in La., but also are done in areas with data supporting the absence of oiling from the DWH incident. We have surveyed invertebrate population levels found within 3 marsh salinity level zones in La. for one year. Sites were selected along the salinity gradient in Cailou and Barataria Bays. In total, 18 sites were selected: six at low-salinity marsh, six at mid-salinity marsh, and six at high-salinity marsh. Plant cover was measured monthly for 1 year. The sites also were each sampled once monthly for insects which were identified to the family level as well as species identification for select groups. The vital estuaries in La. will be challenged with changing salinity due to saltwater intrusion or freshwater diversions as well as sea level rise and subsidence. Having baseline data of invertebrate populations collected among salinity zones and spatially within our estuaries will be valuable for measures of change in our estuaries.

The Greenhead Horse Fly as Bioindicator of Marsh Health — Population Decline and Recovery After the Deepwater Horizon Oil Spill

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Population census and genetics studies in the aftermath of the Deepwater Horizon oil spill established the greenhead horse fly (*Tabanus nigrovittatus* Macquart) as an invertebrate bioindicator of marsh health. This species is bound to coastal marshes, since its larval stages develop as top invertebrate predators in the marsh soil and are thus dependent on a diverse food web in the Spartina saltmarsh. Immediately after the oil spill (2010-2011) populations of this horse fly crashed in oiled areas of Louisiana marshes with significant impacts on genetic structure detected via microsatellite genotyping. However, five years after the catastrophic event (2015-2016) we observed signs of recovery of populations in oiled areas. Fly numbers were rising. Genetic bottlenecks detected in formerly oiled populations were disappearing. Migration into oiled areas replenished formerly depleted horse fly populations in impacted regions. Parameters of family structure that had been impacted by the oil spill (number of breeding parents, effective population size, number of family clusters) rebounded to levels similar or exceeding those in non-oiled control areas. The horse fly is an integral part of the saltmarsh invertebrate community. Together, with other macro-and meiofauna bioindicator species saltmarsh horse flies will be useful for the assessment of changes in Spartina marsh caused, for example, by pollution, sea level rise or freshwater diversions.

Impact of Fish Liver Health on Population Resiliency

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The Gulf of Mexico receives the influence of several sources of heavy metals and oil-derived organic compounds: river runoff, natural seeps, oil industry activities and the two mega oil spills (Ixtoc 1, 1979-1980 and Deepwater Horizon, 2010). Exposure to these contaminants may have a direct impact in fish health condition. PAH and heavy metals content in 81 liver samples of seven fish species (Snowy Grouper, Yellowedge Grouper, Red Snapper, Speckled Hind, Blackfin Snapper, Red Hind and Scam) collected in the Southern Gulf of Mexico onboard the Weatherbird II (2016) were analyzed. PAH liver concentrations ranged from 2,602 to 21,390 µg/kg with an overall mean of 4701 ± 2855 µg/kg. Fish liver

heavy metals concentrations were found in the following order: Fe > Zn > Cu > Al > Hg > Cr > V > Cd > Ag > Co > Pb > Ni> Ba. Concentrations of Hg, Cr, V, Cd and Pb were found at potentially toxic levels. A significant correlation between PAH and heavy metals was found. Histopathological analysis showed that 77% of fish livers presented lesions of different kind. Higher damage percentages seem to be associated to areas related to oil seeps and oil extraction activities. Liver health condition compromises individual survival, which may have an impact on fish population resiliency considering that most of these species are under heavy fishery exploitation.

Session 003: New Tools and New Strategies in the Assessment and Forecasting of MOSSFA in Support of Emergency Response and NRDA

Tracing Microbial Transformation of Diluted Chemically Enhanced Water Accommodated Fraction of Crude Oil Through Targeted Metabolomics

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Microbial oxidation is a key crude oil degradation mechanism in the ocean. During the Deepwater Horizon oil spill, dispersant was applied at the wellhead and on surface slicks to in part facilitate biodegradation of the oil. The fate of crude oil constituents under such a condition is poorly understood. Previous research of microbial oil oxidation using ultrahigh resolution mass spectrometry has shown the formation of oxygenated compounds, which may have longer environmental residence times than their parent crude oil compounds. To understand the fate and residence time of oil hydrocarbons and their degradation products, we conducted a 16-day mesocosm experiment comparing two treatments: (1) seawater only controls and (2) seawater amended with chemically dispersed oil (1:20 v:v dispersant:oil, ~0.5 mg/L oil). At each time point, samples were fractionated into particulate (>2.7um) and dissolved phase (<0.2 um), and individual aliphatic and PAH concentrations were monitored. In parallel to this effort, we performed a targeted analysis of the hydrocarbon metabolites released into the seawater due to microbial oxidation. The targeted hydrocarbon metabolites were selected based on previous untargeted metabolomics and metagenomics screening. These extracellular metabolites are an integral part of the dissolved organic carbon (DOC) pool created during an oil spill or natural seepage. A better understanding of the production of these biodegradation products and their evolution through time will not only provide critical information on the fate of spilled oil in the presence of dispersant, but will also will provide information on the chemical dynamics within the DOC pool during/after oil spills or from natural oil seeps.

Exposures Methodologies GOMRI Working Group: How to Make Oil and Water Mix

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Several working groups have been established to document how GOMRI research support has advanced our understanding of oil spills. Our team was tasked to describe the various past exposure methodologies and new techniques used for toxicity testing and oil fate studies. We established a working group to represent governmental, industrial, consulting firms and academic researchers. A

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combination of approaches has been used historically to provide better understanding of petroleum toxicity and fate in marine systems including theoretical, laboratory, microcosms/ mesocosms and field studies including purposefully spilling oil. Laboratory studies of oil have used individual dissolved hydrocarbons, dissolved oil hydrocarbons, oil water dispersions (OWD), water accommodated fraction (WAF) and chemically enhanced WAF (CEWAF) using various dispersants. Many studies use the standard CROSERF method for the generation of relatively small volumes (0.25 to a few L) of WAF or CEWAF. Baffled recirculation tanks and OWD have also been used in order to prepare larger volumes (100's of L) of WAF and CEWAF required for example for MOSSFA large mesocosm studies. In addition, some researchers have used higher mixing energies that produce higher oil concentrations. This working group's efforts will provide a synthesis of historical and recent methods for the production of dissolved only, OWD, WAF and CEWAF. This is of importance as studies results comparing degradation of oil alone and with dispersant present is critical to document any adverse effect of dispersant use as dispersants are valuable tool in keeping oil from reaching estuaries.

A Synoptic Eight-Year Analysis of Microbial Community Associated with Marine Oil Snow Deposits in the Gulf of Mexico Since the Deepwater Horizon Spill

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An estimated 111 million liters of oil from the Deepwater Horizon oil spill was transported to the seafloor by marine oil snow sedimentation and flocculent accumulation (MOSSFA). The MOSSFA process occurs when natural organic rich material along with inorganics form aggregates that entrain and transport oil droplets from the water column to the benthos. During the Deepwater Horizon, the MOSSFA process formed "marine oil snow'" a previously unknown phenomenon. Numerous microbes are able to utilize the carbon sources in marine oil snow as a source of structural carbon and energy, yet the spatial and temporal variability of marine oil snow microbial communities is undocumented. Here we present a time series of microbial community change in recently deposited sediments from a deep-water site in the Gulf of Mexico (OC-26). This site was highly impacted from Deepwater Horizon MOSSFA derived oil input. We characterized the biogeochemistry of this layer, determined rates of microbial activity and assessed the microbial community composition in both the MOSSFA layer and the associated deep sediment. The MOSSFA layers were organic rich, yet they remained oxic. Rates of sulfate reduction in these layers were muted but rates of nitrate reduction were elevated. The microbial community in MOSSFA layers was originally very similar to the community observed in surface oil slicks. Over time, the community changed but even after several years, compositional differences between MOSSFA layers and the deeper sediments layers remained. MOSSFA layers were also distinct from microbial populations in control (no MOSSFA layer) surface sediments. Surprisingly long time periods were required for benthic microbial populations to respond effectively to such pulses of MOSSFA-derived material deposition.

Synergistic High-Flux Oil−Saltwater Separation and Membrane Desalination with Carbon Quantum Dots Functionalized Membrane

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The treatment of offshore oil spills requires effective oil−water separation, where oil would be recovered and the collected seawater would be used to generate fresh water for an emergency water supply. Herein, a hydrophobic membrane was fabricated simply by a controlled cross-linking reaction between C18-CQDs (octadecylamine-functionalized carbon quantum dots) and commercial textiles using tolylene- 2,4-diisocyanate. The modified membrane not only achieved efficient oil−saltwater separation (up to 99%) but also exhibited unique permselectivity: highly permeable to water vapor yet impermeable to liquid water, which is feasible for water desalination. Our research offers an “all-in-one” prototype for oil−water separation and saltwater desalination using a single type membrane.

Session 004: Understanding and Predicting the Gulf of Mexico Loop Current

Investigation of Variability of Sea Surface Temperature (SST) and Sea Surface Height (SSH) in the Gulf of Mexico Using Multiple Statistical Tools

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Gulf of Mexico (GoM) is an important water system and experiences various environmental stresses such as hurricane, hypoxia, oil spills, sea-level rise, etc. Understanding and forecasting environmental variability and dynamics of water movement in the Gulf is an important task to coastal management, commercial and recreation fishing, safety of offshore operations, and tourist. One unique challenge in the GoM is to predict the stability and intrusion of the Loop Current (LC) as well as the shedding of the Loop Current Eddy (LCE). We seek the possibility of using sea surface temperature (SST) and sea surface height (SSH) to understand the environmental dynamics in the GoM using multiple statistical tools that emphasize multi-scale analysis. We work on the satellite data of SST and SSH to obtain the trend and variability of these environmental parameters. Fast Fourier Transform Algorithm (FFT) is applied to illustrate the variations of SST and SSH and to identify the dominant frequencies. In addition to the well-recognized annual and decadal trends, we show that the spatial map of dominant frequencies is useful to identify the time scale of large-scale ocean features in the GoM, which was compared to the primary mode identified using the Empirical Orthogonal Function (EOF) method. The multi-dimensional Empirical Model Decomposition and coupled FFT-EOF method were used to connect temporal and spatial structure of SST and SSH in the GoM. Sea surface temperature anomaly (SSTA) and sea surface height anomaly (SSHA) were investigated to study long-term climate trends and fluctuations.

Predicting the Loop Current System in Gulf of Mexico: A Hybrid Modeling Framework

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Ever-increasing stream of geospatial big data have attracted researchers utilizing machine learning approaches to extract patterns and insights for understanding, analyzing, and predicting. However, current approaches may not be optimal when system behaviour is dominated by spatial or temporal context. Rather than amending classical machine learning, we argue that deep learning, an approach that is able to extract spatio-temporal features automatically, is able to gain further process understanding of Earth system science problems, improving the predictive ability of seasonal forecasting

* Student presenter

and modelling of long-range spatial connections across multiple timescales. In this research, a data-driven framework based on deep learning is developed for the long-term prediction of the Loop Current System (LCS) and its eddies in Gulf of Mexico. Utilizing the sea surface height (SSH) data collected over 20 years from the AVISO/Altimetry Center, a motion field of the Loop Current (LC) is learned with a convolutional-deconvolutional neural network, and the motion field is further processed with a physical model to predict future states - the timing of eddy separations from the extended LC and their positions. Experiments results validate that the proposed hybrid modelling framework, coupling physical process models with the versatility of data-driven machine learning, is a powerful tool for predicting the LCS.

Session 005: Gulf Restoration: Planning, Tools, and Collaboration

Disruptive Technologies for Oil Spill Response

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Gran Tarajal Harbour is located on the South East shore of Fuerteventura Island, 80 km off the African Coast, within the Canary Islands Archipelago. During the last week of February 2018, the Tropical Storm Emma, arrives to Canary Islands sinking three Tugboats, Five Pontoons and producing a huge Oil Spill (Roughly 130.000 l) taking account the small harbour dimension. The difficult conditions of the Spill constraints us to use three new technologies we were developing in that moment: reusable absorbent foam, granulate absorbent and a very efficient cocktail of bacteria. The first technology used was a new reusable foam absorbent. With a very simple design and use, during the afternoon of 3rd and the morning and the afternoon of 4th of March, 42 tons of oil with less than 5 per cent of water, were removed from the water surface with 8 workers without any previous training. The second technology used was the granulate absorbent. The oil absorption capacity is very high, it removes even the hard oil odour from the surfaces: that increases the work conditions, cleaning the tools and becoming floor non slippery. In addition of the oleophilic capacity has a high hydrophobic property that gave us the opportunity to develop a filtering system to block the oiled water return to the port basin, every time we recover a piece of ship, absorbing only the oil from the mixture with water. The third was a bacteria cocktail, based on *Pseudomona putida* inoculated on polluted surfaces, water or sediments. The Bacteria have cleaned the concrete walls of the harbor, the rocks and the sands in few weeks with a completely restoration result of the Harbor. Those three new technologies tested at Canary Islands represent a different approach to the Oil Spill Response, improving the capacity to reduce the environmental impact, increasing the actuation threshold for the Contingency Plans and Protocols. Using these technologies could improve the very high limited capacities to the standard systems like barriers, absorbents, skimmers, etc. APHs, LHs, PCBs, 9 Heavy Metals, TBTs, in sediments, water and organism were analysed, including Ecotoxicity Tests, Macrofauna and Meiofauna Biodiversity index. The data from the sampling program certify a completely restoration of marine environment in few months.

Creation of Hard Bottom Habitat: The Texas Artificial Reef Program Is Giving Nature a Helping Hand

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The ecological and economic effects of the 2010 Deepwater Horizon oil spill were far-reaching across the five Gulf of Mexico (GoM) states. The impacts to coastal Texas were largely from lost fishing and diving recreational activities. These activities were impacted because the few charter vessels available were diverted to Louisiana waters to assist with clean-up efforts or provide berthing for workers. In April 2011, a Natural Resources Damage Assessment (NRDA) resulted in BP agreeing to provide funds toward Early Restoration Projects in which injuries to natural resources and services caused by the spill could be addressed. Some of these NRDA funds were distributed to the Texas Artificial Reef Program for the purpose of creating three artificial reef enhancement projects to mitigate against the lost value to recreational fishing and diving opportunities. The projects included: (1) the Ship Reef Project, in which the *Kraken* - a 371-ft long cargo carrier - was sunk in 136 ft of water to create an offshore artificial reef; (2) the Freeport Artificial Reef Project, in which 800 prefabricated concrete pyramids (height, 8 ft; base, 10 ft) were added to the nearshore George Vancouver Liberty Ship reef site in 55 ft of water; and (3) the Matagorda Artificial Reef Project, in which a new nearshore reef was created from 1,600 pyramids deployed in 60 ft of water. This talk will review some of the biological recruitment data obtained since the installation of these artificial reefs in 2017, with a focus on the *Kraken* ship reef. In the GoM, the dominant bottom composition is soft sediment; natural hard bottom habitat vital for many marine species to thrive is severely limited. Increased frequency and intensity of hurricanes, as well as hazardous events such as oil spills, will undoubtedly threaten the existence of these sparse hard bottom habitats and the flora and fauna they support. These impacts may be felt beyond the biological communities themselves - coastal communities reliant on revenue from commercial and recreational fishing, boating, diving and other watersports may be severely affected. Therefore, by creating more hard-bottom habitats that support a rich diversity of marine life, the Texas Artificial Reef Program is giving nature a helping hand and ultimately increasing resiliency for the coastal communities of the northern GoM.

Microparticles Mediated Bioremediation of Crude Oil

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Each year, billions of tons of crude oil are drilled from onshore and offshore locations to satisfy the global fuel demand, increasing the risk for spills and major ecological disasters. Remediation strategies involving chemical surfactant and oil burning are employed, but the toxicity and undesired environmental effects of these treatments raise more concerns and prompt the investigation for alternative approaches. Organic sorbents present interesting advantages in addition to their low-cost and eco-friendly properties, they are capable to absorb oil molecules and facilitate oil recovery and spill cleanup. Here, we are exploring the ability of organic microsorbents to improve crude oil bioremediation. Because interfacial stresses at the oil-water interface could alter the metabolic activities of microorganisms, we hypothesize that the substrate provided by the microparticles could lower the interfacial energy and expedite crude oil bioremediation. We investigate the efficacy of various organic sorbents in assisting crude oil remediation in the presence of *Alcanivorax borkumensis* and *Pseudomonas aeruginosa*, known to degrade alkane and polyaromatic hydrocarbons, respectively. Our results show that the use of these microparticles reduce the interfacial tension at the oil-water interface. This has led to the adsorption of bacteria at the microparticle-oil interface, thus forming a network of cells. Future studies involving the effects of pH and temperature on microparticle-assisted bioremediation will provide new insights on how the design of the microparticles could be tailored to fit various ecosystems.

* Student presenter

Session 006: Evolution and Development of Spatially Related Response and Restoration Data Collection, Use, and Retrieval Tools

Evaluation of Marsh Terraces as a Restoration Technique Utilizing a Wave Model

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Marsh losses in the northern Gulf of Mexico are mainly due to subsidence, altered hydrology and land erosion caused by wind driven waves. Ten years ago, the Deepwater Horizon oil spill damaged marsh ecosystems and introduced additional risks for marsh loss in the Gulf of Mexico. To offset these land losses and restore injured marshes, marsh terracing has been applied in the northern Gulf of Mexico as a restoration technique. Marsh terraces are segmented earthen berms built in inland, shallow open-water areas. The objective of this restoration technique includes creating new marsh within the terrace field, reducing fetch, and dissipating wind driven waves. Marsh terraces have been implemented for almost 30 years; however, little research has been conducted to determine their effectiveness. The objective of this study is to identify which terrace design (rectangular or chevron) is most effective at reducing wind driven wave energy. The Simulating Waves Nearshore (SWAN) model was used to simulate wind waves at two terrace fields in coastal Louisiana. Simulations were based on real terrace field conditions with and without terraces. Model input parameters included bathymetry, water level, as well as wind and wave characteristics. Model validation was performed using on-field measurements collected for 5 months at each study field by an acoustic anemometer (wind time series), four doppler profilers (wave spectra and water level) and a wave buoy. Results from this study help us to understand the dynamics of wave energy related to the erosive forces exerted in two different marsh terrace designs under different field environments (water depth and soil strength), and weather conditions (normal, cold fronts, storms). At the end of the study we expect to identify the terrace design that provides the greatest benefits for reducing land erosion and enhancing sediment deposition, leading to marsh creation within this fragile ecosystem.

Session 010: Movement Ecology and Ecosystem-Based Management in the Gulf of Mexico: Lessons learned and solutions for moving forward

Movement, Home Range, and Predation of Adult Invasive Lionfish Revealed by Fine-Scale Acoustic Telemetry in the Northern Gulf of Mexico

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Fine-scale movement dynamics of adult invasive lionfish are not well-known but may inform the spatial scale of negative impacts to local food webs, the design and efficacy of ongoing removal efforts, and the speed at which lionfish may spread into new habitats. To address this data need, a 3.5-km^2 acoustic Vemco positioning system (VPS) was deployed to track fine-scale movements of adult lionfish (288-395 mm total length; *n* = 20) tagged externally *in situ* at artificial reefs off Destin, Florida (USA). We estimated individual home ranges, activity patterns, and spatial scale of movements, and also identified

* Student presenter

biotic and abiotic factors affecting movement. Lionfish were tracked up to 89 days, revealing high reef association but variable movement dynamics among individuals. Home range areas were relatively narrow (95% kernel utilization distribution (KUD) range: 181-4,609 m^2); however, 40% of tagged lionfish traveled up to 2 km to neighboring reefs and daily distances moved far exceeded previous estimates (range: 117-1,030 m). As many as 27 long-distance (>110 m) transits were made by one lionfish tracked over 61 days. Fine-scale telemetry data identified emigrations (*n* = 2) from the array, as well as the apparent consumption of lionfish by fast-moving predators (*n* = 2). Patterns in lionfish activity (i.e., foraging and sheltering behavior) were driven by bottom temperature, diel period, and intraspecific density. The lack of relationships between KUD home range (50% and 95%) and TL or density suggests home range size of large adult lionfish is driven by other factors. Acoustic telemetry using a VPS was effective in tracking precise lionfish movements, but the effect of two hurricanes on detection rates and fish behavior, which could be detected across multiple analyses, may have reduced the temporal scale of data collected via tag loss or death. Study results have important implications for artificial reef management in Florida, and elsewhere, in response to the lionfish invasion.

Effects of Oil on Mahi-Mahi (*Coryphaena hippurus*)—Impacts on Fitness Relevant Physiological and Behavioral Traits

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The 2010 Deepwater Horizon (DWH) blowout coincided spatially and temporally with the spawning window of several pelagic top predators. Mahi-mahi (*Coryphaena hippurus*, “mahi” in the following) were one of the pelagic fish species likely affected by the DWH and may serve as a model for assessing the effects of oil exposure in pelagic species. Mahi are spawned in captivity at the University of Miami allowing for experimental oil exposures in captive animals and the characterization of detailed physiological effects that are impossible to measure in wild fish. Isolated heart cells from mahi show reduced shortening when electrically stimulated during oil exposure, a response likely associated with impaired calcium cycling. The reduced ability of heart cells to contract explain observations of reduced cardiac output in intact, oil exposed, mahi. Data additionally show reduced maximal sustained swim speed (Ucrit) and reduced maximal metabolic rate (MMR) leading to reduced aerobic scope (AAS), which may be explained in part by reduced cardiac output. Work on captive mahi has also illustrated that thermal optima, as assessed by Ucrit, MMR and AAS, closely reflect preferred temperatures in wild mahi and measurements of this trait under laboratory conditions may therefore serve as a fitness indicator for wild fish. In addition to impacts of oil exposure on heart function, oil exposure affects fitness relevant sensory systems. Brief oil exposures during early development results in impaired vision and exposure to later life stages affects behavior in mahi and other GOM fish species. Relating lab-based impact to wild populations is challenging. To examine the possibility of using pop-up satellite archival tags (PSATs) to assess oil effects on wild fish, hatchery reared mahi were tagged with PSATs. Work on these captive fish revealed nearly perfect tag retention and survival following tagging. Although Ucrit, MMR and AAS, obtained during forced swimming, was somewhat reduced in tagged fish, average swim speed, maximal swim speed and prey capture ability of free swimming captive fish were not affected by tagging, demonstrating that mahi are candidates for PSAT work to assess survival and movement ecology of oil exposed fish in the wild. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

* Student presenter

Using Autonomous Underwater Gliders to Track and Map Fish in the Eastern Gulf of Mexico

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While underwater gliders evolved as tools influenced by the needs of physics observations and modeling, their utility has blossomed into many areas of research. Fisheries stock management is an area where consistent and sustained observations from gliders could provide valuable information, especially in the context of moderate scale baseline biomass or species level population distribution and behavior in the context of event responses, such as oil spill impacted regions.

Efforts to combine traditional glider collected water column variables with three types of acoustical data sets to track and enumerate fish populations have provided promising results in the eastern Gulf of Mexico. A team of academic, federal, state, and private collaborators has been utilizing gliders in the eastern Gulf of Mexico to track acoustically tagged fish with tag telemetry, quantify somniferous species with passive acoustic recording devices, and estimate water column biomass with scientific echosounders. This is in addition to traditional CTD, fluorometer, and dissolved oxygen parameters collected by the gliders. The data sets collected by the glider have been compared to traditional moored and vessel mounted methods.

All three glider-borne acoustic technologies detected fish in areas not only known to be populated, but also outside these areas, demonstrating some added capability of the spatial context gliders can provide. However, detection rates by sensors on the gliders were demonstrably lower than other traditional methods. These efforts provide some quantification of advantages and disadvantages of using this mobile platform for fish tracking and observing.

Comparative Environmental Sensitivity of Offshore Gulf of Mexico Waters Potentially Impacted by Ultra-Deep Oil Well Blowouts

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In the Gulf of Mexico, oil production by the United States and Mexico has increasingly focused on deep water sources. As oil exploration and production continue further offshore, deep water and open ocean pelagic resources increasingly become the focus of susceptibility to oil well blowouts. Methodologies are proposed to spatially quantify ESIs specifically for offshore living marine resources. A multi-attribute utility model is used to integrate biological resource sensitivity measures and measures of potential economic losses to define spatially explicit environmental sensitivity. The sensitivity of the tradeoffs between resources is visualized. The relative environmental sensitivities of four simulated deep-water blowouts in the Gulf of Mexico are analyzed and compared. The use of spatial planning software to protect environmental sensitivity in an ecosystem based management system is discussed.

Marine Movements of Gulf Sturgeon

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Understanding movement patterns of animals through aquatic environments, both spatially and temporally, is important for effective management of imperiled species. The federally threatened Gulf sturgeon (*Acipenser oxyrinchus desotoi*) inhabits the northeastern Gulf of Mexico and coastal rivers. Following the Deepwater Horizon (DWH) oil spill in April 2010, a Natural Resource Damage Assessment (NRDA)-funded multi-agency collaboration installed a coastal acoustic telemetry array from Lake Pontchartrain, LA, to Cedar Key, FL, for tracking coastal movements of Gulf sturgeon. During Fall 2010 and 2011, Gulf sturgeon were tagged in seven river systems during their out- migration. The array was maintained during Winter 2010-11 and Winter 2011-12. Telemetry data used in the DWH settlement proceedings were under a litigation hold until 2016. These telemetry data, coupled with data collected from sturgeon tagged for non-NRDA projects, were reanalyzed using network analysis techniques to gain insight into Gulf sturgeon movement and behavior along the Gulf Coast after the DWH oil spill.

Estimates of Red Drum (*Sciaenops ocellatus*) Mortality and Movement via Acoustic Telemetry

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Sub-adult (< age 3) Red Drum (*Sciaenops ocellatus*) support a valuable recreational fishery and estimates of mortality and movement are needed for proper management. To obtain these estimates, Red Drum were implanted with acoustic transmitters in two coastal Alabama rivers (Fowl and Dog Rivers). States of tagged Red Drum were inferred from stationary receiver detections and active relocations, over one year. These states were used in a Bayesian multistate model to estimate monthly and annual mortality and emigration rates. Fishing mortality (*F*) in Fowl River ranged from 0.001 - 0.130 (annual, 0.310) and natural mortality (*M*) ranged from 0.001 - 0.037. Dog River *F* ranged from 0.001 - 0.105 (annual, 0.464), and no *M* was detected. A combined river model produced an estimate of 0.472 for annual *Z*, resulting in discrete survival of 0.624. The median escapement estimate obtained from both rivers (0.324, 95% CrI = 0.166 - 0.520) is close to the 30% escapement goal of juvenile Red Drum to the adult population; however, the error on this estimate is large. Daily movement was estimated as the distance between daily sequential adjusted center of activity positions. Monthly movement was the sum of daily movements in a given month and mean monthly movement estimates were 7019 and 5222m in Fowl and Dog River respectively. However, monthly movement was not related to salinity or temperature experienced by fish. Red drum also had monthly residency estimates greater than 0.90 and annual residency of 0.69 within rivers. These mortality estimates are higher than recent catch-curve analyses and provide needed data for the sub-adult Red Drum fishery in coastal Alabama. Furthermore, riverine residency coupled with river specific *F* values indicate regional-specific groupings that experience different mortality and abiotic conditions could occur and should be investigated further.

Does Crude Oil Exposure Alter Behavior in Fish?

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Crude oil is a common environmental toxicant of concern in aquatic environments, and the impact it has on marine fishes has been well studied. A majority of these studies have focused on cardiotoxicity and its downstream ecological effects. However, recent work has demonstrated that neurological function and behavior may be just as sensitive as the cardiotoxic endpoints. Transcriptomic work from larval red drum (*Sciaenops ocellatus*) has shown significant alteration in pathways related to neurological and cognitive function following oil exposure; this was accompanied by a reduction in brain size. Based on this information, several follow up studies sought to examine the influence that oil exposure may have on fish behavior and performance. In open field tests, acutely exposed larval red drum showed a reduction in thigmotaxis or "wall hugging" behavior and increased area explored compared to control conspecifics. Interestingly, small shoals of Atlantic croaker (*Micropogonias undulatus*) in an open field test also demonstrated differences in thigmotaxis based on the concentration of exposure and the number of individuals exposed. Exposed groups also demonstrated increasing nearest neighbor distance, suggesting a decrease in sociability. While these studies examined specific personality behaviors, recent work on zebrafish (*Danio rerio*) has examined the effect of oil on behavioral syndromes. Preliminary data does not suggest a shift in behavioral syndromes following oil exposure, however there is a shift in the correlation between behavioral traits. These findings suggest that more research is needed to understand how sub-lethal exposure can impact fish behavior and the downstream ecological significance this can have for populations.

Session 011: Understanding the Drivers of Biological Patterns in the Pelagic Seascape of the Gulf of Mexico

Do Produced Waters Contribute to Elevated PAH and Other Pollutant Concentrations Found in Large Pelagic Fishes of the Gulf of Mexico?

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Pelagic longline sampling in the north central Gulf of Mexico in 2018 collected a wide diversity of large pelagic predators and their prey. Subsequent analyses of polycyclic aromatic hydrocarbons (PAHs) in fish tissues, and PAH metabolites in fish bile revealed elevated and, in some cases, extreme PAH concentrations in a number of pelagic species and especially yellowfin tuna (*Thunnus albacares*). Given the lack of an identifiable ongoing source of oil contamination in pelagic waters from the Deepwater Horizon accident and the low concentrations of PAHs in Gulf waters measured subsequent to DWH, it begs the question of the source of PAHs contaminating pelagic fishes. We systematically evaluate a number of potential sources, including natural seeps, the ongoing Taylor Platform oil leak, coastal runoff and contamination from ongoing discharges of produced waters by the offshore oil industry. Contamination vectors (prey, water) are also considered. This paper uses the considerable data set of monitoring information from various sources, as well as models of the distribution and concentration of PAHs emanating from various sources to evaluate various hypotheses contributing to PAH contamination in large fishes. As well, we evaluate ^{226}Ra and ^{228}Ra as potential tracers of produced water pollution in fish tissues. The well-known propensity of yellowfin tuna to congregate around offshore oil rigs may result in localized contamination from produced waters discharged from 10 to 100 meters below floating platforms despite the rapid dilution of produced waters with distance from source.

* Student presenter

Pteropods of the Northern Gulf of Mexico: Abundance and Distribution of Large Thecosomes, and Their Shell Thickness

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Large thecosome pteropods are key taxa in the pelagic ecosystem of the northern Gulf of Mexico (GoM). This research analyzed species abundances, vertical and horizontal distributions, and trends in shell thickness between 2011 and 2015. Pteropod samples were collected following the 2010 Deepwater Horizon oil spill by two midwater sampling programs: the Offshore Nekton Sampling and Analysis Program (ONSAP, 2011) and the Deep Pelagic Nekton Dynamics of the Gulf of Mexico (DEEPEND, 2015). All samples were collected using 10-m^2 Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) midwater trawls, with 3 mm mesh size. This gear sampled discrete depths ranging from 0-1500 m. To date over 13,000 pteropod specimens have been examined, with 27 species identified. *Clio pyramidata* was the most abundant species during both collection periods and five genera (*Diacria, Clio, Styliola, Cuvierina*, *Cavolinia*) are vertical migrators from the meso- to epipelagic zone. Shell thickness comparisons between 2011 and 2015 will be discussed for several species.

Hepatobiliary PAH Concentrations in Pelagic Fishes of the Gulf of Mexico

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Between 2011 and 2017, multiple studies were undertaken to document polycyclic aromatic hydrocarbon (PAH) concentrations in primarily demersal fish species throughout the Gulf of Mexico. These studies have provided insight on how PAHs are metabolized and partitioned to various tissues by demersal species. However, these studies have not directly addressed these questions in pelagic fishes. This study extends the analysis to include pelagic fish species by quantifying PAH concentrations in 12 pelagic fishes from the Gulf of Mexico. PAH concentrations were quantified in liver samples using QuEChERS extraction methods and GC-MS/MS to understand long-term exposure and accumulation. Biliary PAH metabolites were analyzed using HPLC-FLD to indicate short-term exposure in pelagic samples. Analyses document significant spatial, temporal, and interspecies differences. Concentrations were also compared with tissue and biliary concentrations from fish species with different life histories, including sediment (Golden Tilefish, *Lopholatilus chamaeleonticeps* and hakes, *Urophycis* spp.) and reef (groupers and snappers) associated species. Yellowfin tuna (*Thunnus albacares*) had the highest observed mean biliary PAH metabolite concentration of 690,000 ng/g ∑PAHs. These concentrations are comparable to those of Golden Tilefish, which previously had the highest know concentrations in the Gulf. Mean biliary PAH metabolite concentrations ranged from 49,000 to 690,000 ng/g ∑PAHs, indicating a wide range of short-term PAH exposure in pelagic species. This study improves our collective understanding of how these highly migratory and economically important species are impacted by chronic and intermittent oil inputs into the Gulf of Mexico.

Analysis of Organic Pollutants in Gulf of Mexico Gelatinous Zooplankton

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Organic pollutants in gelatinous zooplankton species have yet to be studied as potential bioindicators for surface to bathypelagic depths in the Gulf of Mexico (GoM). These faunae could be used to assess water quality more accurately than vertebrate species (e.g., fishes) due to their thin integumentary system, lifestyle, and lack of xenobiotic-metabolic enzymes. Additionally, these organisms possess a mucus layer that can store organic chemicals, presenting an alternative method for coping with oil exposure. To test if gelatinous zooplankton accumulates more organic pollutants than fishes, we analyzed polycyclic aromatic hydrocarbons (PAHs) and pesticides in *Atolla wyvillei*, *Aurelia aurita*, and *Sigmops elongatus*. Samples were collected in the northern GoM in 2018 as part of the Deep Pelagic Nekton Dynamics Consortium (DEEPEND). Ultra-sonication and ASE extraction methods were utilized, followed by gas-chromatography analysis in reaction monitoring mode (GC/MS/MS-MRM). Statistically higher (~50 times) concentrations of organic compounds occurred in *A. aurita* as compared to *A. wyvillei* and *S. elongatus*. Also, high molecular weight PAHs (HMW PAHs) were 3.5 times higher in the two cnidarian species than in *S. elongatus*. However, no significant differences in low molecular weight PAHs (LMW PAHs) were found. These results showed that the medusae are unable to metabolize HMW PAHs as efficiently as *S. elongatus*. Therefore, these gelata can be used to assess bioavailability of chemicals in offshore waters due to their increased ability to accumulate organic contaminants as compared to vertebrates. In addition, we will present results for the tunicate *Pyrosoma atlanticum* collected before (2010) and after (2011, 2016, 2018) the Deepwater Horizon oil spill to better evaluate exposure, uptake, and storage capacity of hydrocarbons in deep-pelagic gelatinous zooplankton.

Trophic Ecology of Mesopelagic Larval Fishes in the Northern Gulf of Mexico

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The mesopelagic environment includes ocean waters between 200 and 1000 m depth and encompasses a large portion of the Gulf of Mexico. Mesopelagic fishes are important prey for many oceanic consumers, but relatively little is known about their early life history. An understanding of the role mesopelagic fish larvae have in pelagic food webs is needed to develop ecosystem models that aim to quantify the connectivity between the mesopelagic and epipelagic environments with respect to trophic interactions, nutrient cycling, and carbon transfer. In this study, plankton samples collected during Natural Resource Damage Assessment deep-pelagic cruises conducted after the Deepwater Horizon Oil Spill were used to describe the trophic dynamics of the most ubiquitous mesopelagic larval fish taxa in the northern Gulf of Mexico. Bulk-tissue stable isotope analyses of $\delta^{13}C$ and $\delta^{13}N$ were performed on larvae from four families: Sternoptychidae (Hatchetfishes), Myctophidae (Lanternfishes), Phosichthyidae (Lightfishes) Gonostomatidae (Bristlemouths). Gut contents were counted and identified to the lowest feasible taxonomic level. Gut fullness indices were assigned to each larva and compared across ontogenetic stages, notochord lengths, sampling depths, and diel period. Preliminary analysis of isotopic data using Bayesian standard ellipses revealed that isotopic niche areas varied among six myctophid genera, with *Lampanyctus* spp. having the broadest niche area and *Ceratoscopelus* spp. having the narrowest. Future work will include the quantification of isotopic niche overlap between taxa and ontogenetic stages. Characterizing mesopelagic ichthyoplankton trophic ecology will contribute to understanding the potential effects of future perturbations to the deep-pelagic ecosystem.

* Student presenter

The Two Different Sides of Diatom's Response to Oil Exposure

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The 2010 Deepwater Horizon oil spill exposed the marine life in Gulf of Mexico to unprecedented amounts of oil. Determining the response of phytoplankton to oil spill is crucial to understanding the effects of this event on the marine food-web. Accounting for nearly 40% of the primary productivity in the sea, diatoms play a significant ecological role. Moreover, diatoms represent a significant proportion of the Gulf of Mexico phytoplankton community, which underscores the significance of understanding their response to oil spills. Previous study demonstrated a spectrum of response by diatoms to oil exposure depending on the species tested. Our study focuses on understanding the mechanism behind the effects of oil exposure on resistant (*Phaeodactylum tricornutum*) and sensitive (*Thalassiosira pseudonana*) species of diatoms. We show that oil exposure leads to extensive oxidative stress, and the anti-oxidant abilities of the diatoms species determine their sensitivity. *P. tricornutum* showed higher anti-oxidative abilities demonstrated by higher activities of intracellular enzymes. On the other hand, *T. pseudonana*, poor anti-oxidative abilities resulted in cellular damage, specifically to photosynthetic light harvesting proteins caused by oxidative damage. Overall, this study provides a mechanistic understanding of varying degree of response demonstrated by diatoms to oil exposure.

Journey into Midnight: Faunal Composition and Vertical Distribution of Whalefishes and Their Allies in the Bathypelagic Gulf of Mexico

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Despite comprising the largest biome on Earth, the bathypelagic zone and its inhabitants represent a "black hole" in our understanding of the deep ocean and its functioning. Physical and monetary limitations have resulted in large knowledge gaps regarding deep-pelagic ecosystems. The global bathypelagic realm is characterized by high pressure, low temperature, an absence of sunlight, and low food availability. These features create a limiting environment only inhabitable by specially adapted groups of fishes. Whalefishes (Cetomimidae, Barbourisiidae, and Rondeletiidae) are a taxonomically and systematically challenging group of deep-sea fishes that are considered solely bathypelagic; however, assemblage and vertical distribution data on these taxa are lacking, globally and in the Gulf of Mexico (GoM). The DEEPEND Consortium and ONSAP project have collected whalefish specimens from the GoM utilizing various net types, including a high-speed rope trawl and a multiple-opening-and-closing net system. The variance in gear type allowed for the collection of larger female specimens and smaller male, juvenile, and larval specimens. Project aims of this study are to (1) describe and (2) analyze the faunal composition (i.e., species diversity, sex, life-history stage) of the GoM assemblage, and (3) determine the vertical distribution of each species and life stage. We will present: percent frequency of occurrence for each species, comparisons between specimen standard length (SL) and gear type, length-weight regressions by species, sex ratios by species, difference in time of day catches per species, and comparisons of capture depth with species and SL. This study will significantly increase the fundamental knowledge of the taxon, as only 770 whalefish records exist worldwide. We have 520 specimens in our collection from the GoM.

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Addressing Data Gaps in Deep-Pelagic Fauna: A Case Study of an Apex Predatory Fish Family in the Meso- and Bathypelagic Domains

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Prior to the Deepwater Horizon Oil Spill in 2010, very little was known about what lives in the deep-pelagic Gulf of Mexico, especially at the depths surrounding the wellhead. Only a handful of surveys had ever sampled the water column below 1000 m anywhere in the world, and none in the area of the oil spill. After the spill occurred, two consecutive projects were conducted between 2010 and 2019 to survey the deep-pelagic (meso- and bathypelagic zones; 200-1500 m depth) fauna of the Gulf of Mexico. The first project, associated with the 2010-2011 NRDA, employed two types of midwater trawls to collect deep-pelagic fauna: a 10-m^2 MOCNESS (MOC10) and a commercial-sized, high-speed rope trawl. The second project, DEEPEND, used the MOC10 and followed the same sampling scheme as the first. Here, we present results of a monographic treatment of a top meso/bathypelagic predator fish family, Chiasmodontidae (swallowers), including species composition, abundance, biomass, and size distribution. Over 1,200 individuals were collected representing 17 species from four genera. The dominant species were *Chiasmodon pluriradiatus/asper*, *Pseudoscopelus altipinnis, P. scriptus*, and *Dysalotus alcocki*. Six species collected are new records for the Gulf of Mexico including *Kali colubrina, K. parri, P. aphos, P. cordilluminatus, P. scutatus*, and *Chiasmodon braueri*. Species of *Pseudoscopelus* were collected in the mesopelagic (above 1000 m) while species of *Dysalotus* and *Kali* were collected in the bathypelagic (below 1000 m). Species of the genus *Chiasmodon* were collected throughout the water column. Comparisons of these results between the two gear types highlights a major data gap with respect to larger-sized predatory deep-sea fishes. Given the importance of top-down control by apex predators in open ocean systems, filling these data gaps is an essential step to gain a more comprehensive understanding of deep-pelagic ecosystems, earth's largest by both volume and animal number.

Session 012: Transport, Dispersal, and Connectivity in the Gulf of Mexico: Patterns, Processes, and Implications

Influence of Diurnal Winds on Exchange Through Barrier Island Passes and Associated Biogeochemical Processes in the Mississippi Sound and Bight

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The northern Gulf of Mexico is home to one of the largest seasonal hypoxic events in the world located along the Texas/Louisiana shelf. Significant attention has been placed on the event that extends westward from the Mississippi River inflow towards the Texas Shelf. A smaller, yet notable hypoxic event also manifests to the east of the Birdfoot Delta in the vicinity of the barrier islands that separate the Mississippi Sound and Bight. A coupled physical-biogeochemical model has been developed to investigate the connectivity pathways between the Mississippi Sound and the inner shelf of the Mississippi Bight. Recent studies have found that this area is less influenced by the high nutrient loads

* Student presenter

associated with the large Texas/Louisiana shelf event than previously thought; rather it is more directly influenced by the local riverine sources flowing into the Mississippi Sound. The coupled model provides insights into the seasonal variations of the biogeochemical and physical interactions in this coastal ecosystem that is heavily influenced by freshwater plumes. Seasonal dye experiments were set up to examine the exchange pathways between the Sound and Bight. The region's estuarine circulation is heavily influenced by the diurnal sea breeze that occurs and the rate of freshwater flow into the system is a primary control on the productivity and biogeochemical cycling in the region. The model is forced by a high temporal (hourly) and spatial (0.01 deg) resolution wind field that resolves this sea breeze. Twin experiments with full resolution winds and temporally filtered winds have been performed to investigate the influence of the diurnal sea breeze on the flushing of the estuarine system. Results from these numerical experiments provide insight into the connectivity of the shore and shelf physical and biogeochemical processes and how they affect the poorly understood hypoxic events that appear in these coastal waters.

A Synthesis of Modeling Results to Study Cross-Shelf Transport in Mississippi Bight

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Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST) modeling system is used to study seasonality of cross-shelf flow and transport in the Mississippi Bight using results from May 2015 to May 2018. A high spatial resolution (400-m) modeling system with Regional Ocean Modeling System (ROMS) at its core was developed during the GOMRI-funded Consortium of oil spill exposure pathways in river dominated ecosystems (CONCORDE) project. This CONCORDE model product is used to identify the cross-shelf transport pathways in the study area. Understanding the transport pathways between open waters of the Gulf and coastal waters is important for response and coastal protection in the event of an oil spill, for ecosystem management on the shelf and for ecosystem functions such as harmful algal bloom dynamics and distributional patterns of coastal species in this river plume dominated area. A high temporal and spatial resolution (hourly at 1-km) atmospheric forcing product is used to study the resulting circulation in shelf waters of Mississippi Bight. The model was forced with 1-km resolution Navy Coastal Ocean Model (NCOM) for Gulf of Mexico at the open boundaries. The results of the ROMS-based coastal circulation CONCORDE model are synthesized with those of the regional NCOM model for circulation in Mississippi Bight and compared to understand the impact of modeling at different scales. Depth varying across-shelf transport is computed across isobaths in inner-shelf, mid-shelf and outer-shelf. An analysis of transport across the isobaths show seasonal N-S transport corridors. A NE-SW transport pathway was observed year-round at variable strength showing connectivity in between the identified corridors. An empirical orthogonal function (EOF) analysis on current and wind variability revealed spatial and temporal patterns of across-shelf transport at different depths and identified seasonal variability of dominant modes of transport. The impact of wind forcing, tidal forcing, river forcing as well as bathymetric variations and model scales on the transport pathways is investigated.

Numerical Modeling of Sediment Erosion, Deposition, and Transport in the Northern Gulf of Mexico: The Barataria Pass Case Study

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The estuarine and shelf circulation, wind waves, as well as suspended sediment concentration and geomorphological variation, near the Barataria Pass and adjacent inner continental shelf are numerically investigated using a three-dimensional hydrodynamic-wave-sediment coupled modeling system. The modeling system is comprised of the Finite-Volume Coastal Ocean Model (FVCOM), FVCOM-SWAVE (an unstructured-grid variant of the third-generation surface wave model SWAN), and FVCOM-SED (an unstructured-grid sediment model based on the Community Model for Coastal Sediment Transport developed by the USGS and its implementation in ROMS). All three models employ the same finite-volume numerical algorithm and the same unstructured triangular mesh, making them easier to couple without introducing interpolation errors. The numerical model domain extends longitudinally from Mobile Bay, Alabama to west of Galveston Bay, Texas and offshore to ~27°N. Inside the Barataria Basin all major water bodies and intertidal wetlands are covered, including the existing Davis Pond freshwater diversion and proposed mid-Barataria sediment diversion. Near Barataria Pass the model resolutions are ~ 40 m horizontally and ~ 0.1 m over the shoal and ~ 1 m at the thalweg vertically. The model is driven by winds at the surface, tidal and subtidal sea level variations at the open boundary, and freshwater, mud, silt, and sand inflows from various Mississippi River and Atchafalaya River passes, and the Davis Pond Diversion. Numerical simulation results indicate that the exchange of sediment between the Louisiana Bight and the Barataria Bay during April-June 2010 is mainly governed by tidal forcing. The morphological features at the Barataria Pass are one erosion area that is mainly on the shelf-side of the pass and two deposition areas at shelf- and bay-side of the erosion area. The 3-month net suspended sediment flux through the center of the Barataria Pass is bayward due to the transect location being located almost on the northern edge of the erosional area, while the net water flux is seaward during the same period of time. The largest sediment flux into the bay occurs during the prefrontal phase of cold front events.

Wave Patterns and Current Velocity Measurements at a Sharp Front Produced by Runoff from the Mississippi River in the Gulf of Mexico

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Wave refraction measurements near an ocean front are typically collected remotely, either with satellite or airborne observations. In situ measurements of wave refraction patterns or current velocities near an ocean front are sparse. In this field experiment wave and current measurements were recorded in the vicinity of the sharp front caused by Mississippi River runoff in the Gulf of Mexico. Wave and current patterns were measured on both sides of the front using a Lagrangian surface drifter and a wave rider. The measurements were conducted as part of the Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (CARTHE/GoMRI) Submesoscale Processes and Lagrangian Analysis on the Shelf (SPLASH) field campaign in April 2017.The front produced by runoff emanating from the Southwest Pass of the Mississippi River Delta was discovered by synthetic aperture radar (SAR) images. The wave rider and Lagrangian drifter were used for measurements at the sharp front on the northern edge of the jet. A Yost 3-Space accelerometer that measured the components of acceleration was mounted centrally inside the wave drifter. The accelerometer data was then used to calculate directional wave spectra on each side of the front. The Lagrangian surface drifter, used to map the current velocity field in the vicinity of the front, was deployed with one of three different drogue lengths (0.5, 3, 5.5 m). Successive deployments of each drogue length were conducted on each side of the front.

* Student presenter

The experimental design revealed wave and current velocity field differences across the front. The data set from this field experiment may help in planning future experiments with the goal of ground truthing SAR satellite imagery. The data will also help to expand the knowledge of oil spill propagation in areas of high freshwater outflow. Particularly, why some coastal areas were inundated with oil and others were not in the Gulf of Mexico after the Deepwater Horizon Oil Spill.

Estimating Kinematic Quantities of Submesoscale Structures Along Mesoscale Fronts Using Large Drifter Data Sets

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Much of the vertical velocity near the surface of the ocean is thought to be associated with ageostrophic submesoscale phenomena. However, most in-situ observations of submesoscales are made near coastal outflows, while far less is known about how mesoscales and submesoscales interact. The vertical exchange of water associated with these ageostrophic flows plays a critical role in the transport of dissolved nutrients and gases, thus the production and fate of organic matter. Vertical velocities are challenging not only to model accurately, but also to measure because they are very hard to locate in the surface of the ocean. Using a unique massive drifter release during the LAgrangian Submesoscale ExpeRiment (LASER) in the Gulf of Mexico, we observe the generation of submesoscale structures along a mesoscale front separating differing water masses. In order to quantitatively describe the flow sampled by these drifters, we use a novel method to project Lagrangian trajectories to Eulerian velocity fields. This interpolation method uses a squared-exponential covariance function, which characterizes velocity correlations in two-dimensional horizontal space and time, in such a way that the scales of variation are determined by the data itself. from the interpolated velocity fields, we then calculate kinematic properties, including horizontal divergence and vertical relative vorticity, in order to infer the vertical transport occurring within these submesoscale structures. We also compare the drifter data to available SST fields from satellite data and CTD measurements recorded across these strong fronts using a moving vessel profiler. Within the submesoscales, located and tracked by drifters, we find divergence and relative vorticity magnitudes to be on the order of 5f (with f being the planetary vorticity).

Pathways of Hydrocarbons from Future Oil Exploration Sites Around Cuba: Influence of Local and Regional Ocean Dynamics

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Despite great advances in the understanding of Gulf of Mexico (GoM) dynamics, parts of the southeastern GoM have not received much attention. This particularly applies to GoM waters off northwestern Cuba due to lack of accessible in situ observational studies in Cuban waters. We are participating in recent efforts to understand how Loop Current evolution is impacted by oceanographic processes in this region, especially data detected warm-core and cold-core mesoscale eddies, evolving over persistent coastal upwelling. In addition, this is an area of oil exploration; activities in Cuban waters have already taken place and are expected to resume soon. Herein, we present long term simulations over several years of continuous surface spills around Cuba to statistically identify the regions in GoM, Straits of Florida and eastern Florida shelf which are the most likely stranding locations. A fully fledged,

* Student presenter

open source oil drift model (OpenOil) is applied with high resolution hydrodynamic forcing from HYCOM ocean models setups and ECMWF atmospheric and wave models. A recent upgrade to OpenOil is to include bio degradation which is important for long simulations (weeks to months). Significant year to year variability is identified and the importance of regional and local dynamics near northwestern Cuba on ocean oil transport is discussed.

Stressor Impacts on Physical and Biochemical Properties Detected by APEX-EM Floats

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Ten APEX floats with electromagnetic sensors (APEX-EM) developed by Teledyne-Webb were deployed in the Northern Gulf of Mexico in May 2017. In addition to the full suite of temperature, conductivity and current measurements, these floats were equipped with chemical and bio-optical sensors: Aanderaa Optode sensor measuring dissolved oxygen, and the WET Labs ECO puck sensor, which combines measurement of chlorophyll fluorescence (proxy of phytoplankton abundance), measurement of backscatter (proxy of particle concentration) and CDOM fluorescence. The ECO puck sensor was designed to minimize space and power requirements for applications in autonomous measuring platforms, and is rated for sampling to 2000 m depth. Sampling rates can changed by updating mission profiles from continuous to profiling modes between specific depths to once every five to ten days. Data are transmitted over Iridium system including the position when the float reaches the surface allowing for adaptive sample strategies. Here we summarize the measurements from 3000 plus profiles exploring the impacts of current and shear on the biochemical responses under strong forcing conditions including the passages of a cold front and hurricane Nate in 2017. During these events, forced currents in the upper ocean exceeded 0.5 m s^{-1}. Current shear across the base of the ocean mixed layer, defined by both salinity and temperature measurements, forced layer deepening of more than 20 m during a persistent cold front passage. In the case of hurricane Nate, five floats were located along the periphery of a Loop Current warm core eddy and along the northern Gulf of Mexico shelf. In both cases, current transport affected the biochemical response. For example, dissolved oxygen and chlorophyll fluorescence suggest a maximum between 90-100 m. The deep chlorophyll maximum tends to correspond to the oxycline lying between the 24-25 isopycnal in temperature and salinity space. Given the faster sampling rates in continuous mode (~3 hours), this float technology enables investigators to look more closely at the physical-biochemical interactions under differing atmospheric conditions that influences hydrocarbon dispersion.

Hydrodynamic/Water Quality Model for Oyster Restoration in the Western Mississippi Sound

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The BP oil spill caused destructive ecological and economic impacts along the coast of Mississippi. The current study is a part of a broader project that aims to mitigate the risk of further impacts on the area. The development of a hydrodynamic and water quality model for the Western Mississippi Sound is addressed in this paper. The hydrodynamic part of the model simulates flow, salinity, and temperature. The hydrodynamic part of the model is also the driving mechanism for nutrient transport. The water

quality part of the model simulates the physical, chemical, and biological characteristics of Western Mississippi Sound. The model has been developed using the Visual EFDC program that links the hydrodynamic model to the water quality model. A computational grid has been generated consisting of 4 layers, each having 3000 cells. The input data for the hydrodynamic model are: water level, water temperature, salinity, precipitation, solar radiation, wind speed, wind direction, air pressure, and air temperature. The input data for the water quality model are; dissolved oxygen, nutrients (such as carbon, nitrogen, phosphorus and their compounds) and algae. The simulation time period is from Jan 1st, 2009 to Dec 31st, 2017. The model's calibration and validation for the hydrodynamic and water quality results are presented here. The results show that the hydrodynamic model is able to simulate the circulation pattern in the Western Mississippi Sound with a high accuracy, and the water quality model can reproduce the transport processes. The model will be used to identify the most appropriate locations for different species in the Mississippi Sound.

Session 013: Microbial Genomics to Improve Predictive Understanding of Disturbance in the Global Ocean System

The Sub-Chronic Effects of Polycyclic Aromatic Hydrocarbons (PAHs) on the Sheepshead Minnow (*Cyprinodon variegatus*) Gut-Microbiome and Foraging Behavior

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The microbiome plays a key symbiotic role in maintaining host health and aids in acquiring nutrients, supporting development and immune function, and modulating behavior, therefore protecting the host from opportunistic pathogens and other environmental stressors. Microbial communities can vary in species composition and have functionally different roles depending on their location within the host. However, more research is needed to elucidate the potential impact of environmental pollutants on microbial communities and how they can mediate toxicity to the host. Recent studies have shown that contaminants can change the composition and function of vertebrate microbiomes with some evidence showing a shift towards species that are capable of degrading specific chemicals. The Deepwater Horizon disaster that occurred in April 2010 was the second largest oil spill in history and had catastrophic effects on several ecologically important fish species in the Gulf of Mexico. This study aims to determine if exposure to weathered oil will affect the abundance and composition of fish gut-associated microbiomes as well as foraging behavior. We accomplished this by sequencing the gut microbiome of a native Gulf estuarine species, the sheepshead minnow (*Cyprinodon variegatus*). Fish were exposed to oil within HEWAF (High Energy Water Accommodated Fraction) over a 7-day period and whole gastrointestinal tracts were sampled for microbiome analyses. Fish also underwent a foraging behavioral assay to determine feeding efficiency before and after the 7-day exposures. We predict that microbes involved in degrading polycyclic aromatic hydrocarbons (PAHs) will increase in abundance, and that foraging behavior will become less efficient, potentially due to microbiome dysbiosis.

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The Influence of PAH Contaminant Loads and Reef Locations on Eastern Oyster Gut Microbiome Compositions

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The eastern oyster (*Crassostrea virginica*) is an ecologically and economically important organism in the Atlantic and Gulf coastal waters of the U.S., but populations have been on the decline due to overfishing and polluted waters. Oil contamination is prevalent in the Gulf of Mexico coastal regions due to runoff, natural seeps, and oil spills. The most toxic constituents of crude oil are polycyclic aromatic hydrocarbons (PAHs). The goal of this work was to assess the relationship between the levels of PAH contamination in oyster tissue and the composition of the gut microbiome. To this end, oysters were collected from eleven reefs in the Mississippi Sound, including reefs spanning from Bay St. Louis in the west, to the Pascagoula Reef Complex at the mouth of the Pascagoula River in the east. A subset of tissue and shell were homogenized and analyzed for PAHs. Gut samples were dissected from each oyster, then extracted and sequenced using the 16S rRNA gene. Sequences were analyzed using the CLC Genomics Workbench software, and sequences were optimized, assigned OTUs, and aligned with the Greengenes database and relative abundances and alpha and beta diversity indices were calculated. The primary phyla were Proteobacteria, Actinobacteria, Bacteroidetes, and Firmicutes, results that are consistent with other oyster microbiome studies. Proteobacteria and Bacteroidetes are known to break down plant cell wall components, such as cellulose and agar, serving a role in the digestion of food by their host invertebrates. In addition, some Proteobacteria can fix nitrogen within the intestines of other organisms, providing a source of ammonium. Preliminary results demonstrate that location had more influence on microbiome population structure than PAH contamination levels. With these results in mind, future work will investigate the differences in microbiome community of the wild oysters from the Mississippi Sound and oysters grown in an aquaculture facility.

Assessment of Fecal Indicator Bacteria and Potential Pathogens from Multiple Beach Substrates During the BEACHES Project

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As children play at the beach, they are exposed to any contaminants which may be found in sand, water or seaweed. Presence of potentially pathogenic bacteria in the beach environment may pose several risks to individuals, through dermal or mucosal contact, or ingestion. Young children are especially at risk due to certain behaviors such as putting sand or seaweed in their mouth, and their prevalence of dermal abrasions, cuts, and lesions. During the BEACHES project (Beach Exposure And Child Health Study), through the summer of 2018, children were observed and documented while at play on the beach. Concurrent to the study in Miami, samples of water, wet and dry sand, and seaweed were collected at three time points (morning, mid-day, and evening) throughout the day, in the same location as the child behavior observations. The relative abundance of a suite of gene markers for host-specific fecal indicator bacteria and potential pathogens was measured in genomic DNA extracts from these environmental beach samples using molecular microbial source tracking based on quantitative PCR assays for these gene markers. The samples were tested for presence of total general enterococci marker, seagull/seabird marker, dog marker, human markers, and markers for selected potential

* Student presenter

pathogens (including *Vibrio vulnificus*, a known causative agent for necrotizing fasciitis). The abundance of human and bird marker were highly variable, but their presence was observed in many of the samples, while the presence of dog marker was relatively rare in these samples. As dogs are not allowed on either of these beaches, the lack of dog marker is expected. It was beyond the scope of this study to follow up on any reported health outcomes after Beach exposure, but a combination of more risky child behavior plus increased child dermal abrasion/wounds plus increase presence of microbial contaminants would logically suggest an increase in potential exposure risk from at-risk child beach behavior.

Grazing on Prokaryotic Microbes by Nanoplankton in Oil-Polluted Seawater

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Petroleum hydrocarbons are released into the ocean as environmental pollutants through means of routine industrial activities, oil spill incidents and chronic natural seeps. These petroleum pollutants can cause direct and indirect toxic effects to marine organisms. Apart from physical and chemical weathering, a large amount of the petroleum hydrocarbons is metabolized by heterotrophic bacteria sequentially. Nano-size (2-20 µm) marine protists are consumers of bacteria that can substantially alter the abundance and community composition of prokaryotic microbes. Grazing on bacteria by nano-size protozoa can therefore affect the biodegradation on petroleum hydrocarbons and the biogeochemical cycling of carbon and minerals. Experiment was conducted to investigate effect of oil pollution on the bacterivory of nano-size grazers. Natural plankton assemblage < 20 µm was exposed to 5 µL L^{-1} of Light Louisiana Sweet crude oil and 0.25 µL L^{-1} of Corexit 9500A dispersant in incubation containers of dilution experiment. Bacterial abundance (0.2-1.0 µm) of each container before and after incubation was quantified using cell staining technique and epifluorescence microscopy. Grazing coefficient estimated based on bacterial abundance showed reduced bacterivory (0.35 d^{-1}) in chemically dispersed crude oil (DOil) treatment than in control treatment. Interestingly, the bacterivory in crude oil alone treatment (Oil) was 0.91 d^{-1}, higher than that of 0.72 d^{-1} in control treatment. The low bacterivory in DOil treatment implies that heterotrophic bacteria could be released from grazing impact from nano-size grazers and speed up the biodegradation of crude oil in the sea.

Traction Force Measurement of Biofilms Under Laminar Flow

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Bacteria are capable of growing and forming biofilm on biotic and abiotic environments. Bacteria largely exist in sessile communities instead of single-living cells and are embedded in a matrix made of extracellular polymeric substances (EPS) that have a viscoelastic nature. Due to viscoelastic property, biofilm is subject to deformation under external disturbances i.e. fluid sheer stress. In the present study, we have developed a technique to perform in-situ measurement of forces exerted on the bacteria cells causing the deformation of biofilm under different flow velocities. The uniquely designed microfluidic platform contains a flexible mirror embedded in Polydimethylsiloxane (PDMS), that performs as a pressure sensitive substrate, and is bonded to a glass slide with an etched fluidic channel. The flexible mirror is fabricated by sputter deposition of 30 nm aluminum thin film on 0.5 mm of PDMS. The aluminum thin film was topped with 10µm of PDMS. The embedded aluminum thin film is free of wrinkles and cracks in addition to being completely reflective. The distinctive property of the flexible

mirror is the sensitivity to weak forces that can be detected by a digital holographic interferometer (DHI) or an interference reflection microscopy (IRM). The initial experiments are being performed under non-flow condition to examine any elastic deformation. The experiments under continuous flow condition will include a platform that is attached to a chemostat (150 ml flask) and two peristaltic pumps that continuously flow the bacteria suspension in the fluidic setup to facilitate biofilm growth in the fluidics. DHI images will quantify the nano-strain on the thin-film flexible mirror.

Expanding What Is Known About the Marine Methane Biofilter in the Gulf of Mexico Using Combined Sequencing Techniques

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The persistent natural and anthropogenic inputs of hydrocarbons into the northern Gulf of Mexico (nGOM) basin stresses the importance of microbially mediated hydrocarbon oxidation. Methane, a potent greenhouse gas and the primary component of natural gas, was the most abundant hydrocarbon released during the Deepwater Horizon spill. Additionally, microbes in anoxic sediments produce methane that is advected to the upper water column in supersaturated concentrations. High methane concentrations have also been reported in the nGOM hypoxic zone, the second-largest human caused dead zone in the world. To determine which microbes are active in methane oxidation in the shallow water hypoxic zone, 16S rRNA gene, metagenomic, and metatranscriptomic sequencing was carried out on five samples from the 2013 nGOM hypoxic zone. Similar to observations made in the Deepwater Horizon oil spill deep-sea plume, the unassembled metatranscriptomic data showed that particulate methane monooxygenase (*pmoA*) was one of the most highly expressed transcripts. However, analysis of the 16S rRNA data showed low abundance of canonical Proteobacterial methanotrophs. Analyses of metagenome assembled genomes (MAGs) revealed six novel, non-canonical methanotrophs with at least one *pmoA*gene copy. These MAGs were classified as Planctomycetaceae, Verrucomicrobiales, and one unclassified Bacteria, putatively identified as Latescibacteria. These novel MAGs were analyzed with other publicly available genomes and MAGs (e.g. Tara Oceans MAGs) revealing previously unrecognized, active, aerobic, globally distributed marine methanotrophs from the phyla Planctomycetes and Verrucomicrobia, as well as the candidate phylum Poribacteria. The diverse community of active, aerobic, marine methanotrophs in the nGOM suggested that unrecognized methanotrophs may be critical in regulating methane flux from the ocean to the atmosphere.

Session 014: Science to Action: Co-Production of Science to Support Resource Management in the Gulf of Mexico

Incremental Delivery for Exponential Results

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There are significant headwinds to creating nature-based infrastructure such as oyster reefs at meaningful scale. Many of these challenges stem from the fact that public sector ecosystem restoration projects are contracted using processes designed for highways and bridges. After all the careful science, planning and engineering, the project is let for bid and expected to be constructed by the low bidder in one fell swoop. A number of inefficiencies result. Seasonal and interannual variability, combined with unpredictable procurement schedules, create great uncertainty around initial recruitment and growth of shell mass. The coastal engineers compensate for this by increasing the mass and dimensions of the reef components. Consequently, larger equipment is needed, access is more difficult, and costs go up. Changes in the field become much more difficult. If the first year fails to recruit the necessary species, off species may dominate the surface reducing long term success. These all reduce competitiveness of projects to funding agencies. True multi-function success becomes a hit or miss proposition, with lots of hedging and reduced expectations. Our proposal is to treat nature-based infrastructure more like your 401(k) than a bridge, using a concept call Incremental Delivery. The two components of Incremental Delivery are diversified project locations and frequent inputs of small quantities of building material. By defining your project scope to include diverse sites across an ecological gradient (e.g. salinity for oysters), increments are deployed to the location with the best conditions at that time for that initial development. This reduces the uncertainty in recruitment and growth, allowing for smaller reef components. Smaller components can be deployed from smaller vessels, eliminating mobilization charges and allowing the project to be constructed in small increments. Installation, monitoring and maintenance can be performed by the same crew in an ongoing cycle. Using advanced manufacturing techniques, we can adjust the component designs in response to lessons learned. Finally, keeping with the 401(k) analogy, your portfolio literally grows over time as target species generate biomass and calcium carbonate. This presentation will go over a conceptual model, compare to more traditionally constructed restoration and review early results from field trials in Louisiana.

Session 016: Human Health Effects of Oil Spills and Other Disasters: What Do We Know, What Don't We Know, What Do We Need to Know, and How Can We Get There?

Environmental Trauma Response: Risks and Resilience in Cambodian and Laotian Refugee Communities in Coastal Alabama

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Environmental disasters have a profound impact on communities, families, and individuals. Previous research on disaster-prone areas indicates the impact of natural disasters, also known as environmental trauma, on mental health through increased rates of loneliness, depression, and PTSD (Lee *et al*., 2019; Norris *et al*., 1998). Refugee communities may also be at heightened risk in the aftermath environmental disasters due to compounding effects with previous trauma experiences (Lowe, Sampson, Gruebner and Galea, 2015), many of which contributed to migration and increased difficulty navigating resource systems post-disaster. Cambodian and Laotian refugees in coastal Alabama were assessed through qualitative, community-based participatory research (CBPR) and ethnographic, semi-structured interviews (*N*=280) regarding disaster preparedness and response, as well as community problem-solving. Experiences of the Deepwater Horizon oil spill and Hurricane Katrina—both of which

impacted these communities-are examined, with emphasis on individual factors including mental health, as well as familial and community posttraumatic growth. Impacts on the individual level include heightened levels of stress during and after environmental disasters, physical displacement, and vigilance for future disaster preparedness. On the family/community level, the effectiveness of disaster relief organizations and barriers to rebuilding, particularly economically, will be discussed. Furthermore, posttraumatic growth and resilience on individual, family, and community levels will be explored. The importance of capacity-building and connection to resources both within and outside of the community will further be considered (Silka, 2002), including examination of the crucial role of ongoing services that continue beyond the immediate aftermath of environmental trauma (Norris *et al*., 1998). The role of mental health professionals and implications for the therapy

Maternal and Infant Health Needs Among Laotian Families in Mobile County, Alabama

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Many families living and working near the Gulf Coast experience challenges in access to adequate healthcare and preventative health activities. Minority women are at a greater risk for experiencing barriers to breastfeeding than white women. Pilot data we collected from Laotian mothers of small children in Bayou La Batre Alabama suggest that Laotian families do not receive adequate support for sustaining breastfeeding. Moreover, immigrant families from this geographic location (Mobile County and surrounding areas) are more likely to be at or below the federal poverty level and to experience environmental hazards (such as hurricanes, floods, and oil-spills). Food security and safe infant feeding is critical for communities that are vulnerable to disasters and hazards (DeYoung, Suji, & Southall, 2018). Breastfeeding is a fundamental aspect of creating food security and nutrition equity. This is important, especially because Cambodian and Laotian families also experience higher rates of food insecurity, obesity, and hypertension (e.g. Mulasi-Pokhriyal, Smith & Franzen-Castle; 2012; Peterson *et al*., 2010). Additionally, the women in this pilot study indicated that they have very little or no time to engage in maintenance of personal care. Disaster preparedness was not a priority for pregnant or newly postpartum respondents. Some of the respondents also indicated instances of symptoms associated with postpartum mood disorders. This presentation will include a brief overview of maternal and child health (MCH) related to disasters, the state of MCH services for families in the United States Gulf coast, and finally—the gaps in research and outreach for Lao families in coastal communities. Policy implications include pathways for bolstering disaster preparedness and outreach for families with infants and young children.

Analysis of Multidimensional Fluorescence Data Recorded from Benzo[a]pyrene Metabolites in Frozen Matrixes with Machine Learning

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The goal of the present study is to develop screening methodology for the urine analysis of metabolites of polycyclic aromatic hydrocarbons (PAH metabolites). The investigated approach is based on Time-Resolved Laser-Induced Fluorescence Spectroscopy at liquid nitrogen (77K) and liquid helium (4.2K) temperatures. The investigated metabolites include Benzo[a]pyrene-r-7, t-8, t-9, c-10-tetrahydrotetrol (+/-) and Benzo[a]pyrene-r-7, t-8, t-9, t-10-tetrahydrotetrol (+/-). Benzo[a]pyrene is the most toxic PAH

* Student presenter

in the US Environmental Protection Agency list and its concentration alone is often used as a measure of risk. Spectral and lifetime data were recorded from 1-octanol matrixes with the aid of cryogenic fiber optic probes and laser-based instrumentation built in-house. The information content of 77K and 4.2K multidimensional data formats was processed with Machine Learning. Herein, we compare the performance of Mathematical models and Machine Learning for the direct determination of the two metabolites in synthetic mixtures.

Session 017: Application of Remote Sensing to Oil Spill Monitoring and Classification

Mobile Application for Oyster Gape Measurement Study

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This work describes developing mobile application (App) that is currently used to retrieve data from a server and plot a graph for the oyster's gape measurement system developed by our research group. This work aims to help understand the health and spawning season of oysters by using a sensor system App that creates a graph based on the daily activities of the oysters. The App is developed in two major platforms that are the Android and the iOS by using frameworks, programming languages, data viewing systems, libraries and visualization techniques for charts and graphs that are responsive to each platform. This App allows live data visualization for the gape activities. It also allows users to view data for any certain date within a given period. The App includes additional functionality for the users to view data for any specific sensor that is attached to a specific oyster. from the visualization of the data, it is easier to detect the oyster's daily life or normal gaping activities, mortality and spawning events all of which can be helpful to gain deep intuitive understanding and important information in oyster's health and development. In addition, this work paves the way to understand the development of mobile App architecture that can connect and interact with IoT sensor systems for instant data collection and visualization.

Experimental Study of DOA-Based Bubble Sources Localization for Oil Spill Detection

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Since the Deepwater Horizon oil spill in 2010, there has been an increasing demand for a real-time monitoring system that can detect, locate, and assess oil leakages. To this goal, we launched a three-year research project to develop a passive acoustic technique in 2017. The leaked crude oil creates underwater sound through bubble oscillations in an oil spill event. This paper focuses on studying the localization of the bubble-induced wideband sounds sources in an experimental environment conducted in a swimming pool. Hydrophone Uniform Linear Arrays (ULA) are deployed randomly to receive the acoustic signals. Various methods are considered to determine the direction of arrive (DOA). To deal with wideband signals directly, we use generalized cross-correlation with phase transform. In addition, we consider decomposing wideband sources into narrowband bins, and apply spatial spectrum analysis algorithms such as Multiple Signal Classification (MUSIC) at each frequency bin. The multiple 2D angles

* Student presenter

obtained by the linear arrays are further used to localize the leaking position in 3D space. We also investigated the sensitivity of the localization algorithm with respect to variations of physical features such as the cluster of frequency components and noise level. Experiment results were presented and discussed.

Effects of Aerosolized Droplets on Aerodynamic Roughness in the Marine Atmospheric Boundary Layer

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It is computationally expensive and experimentally very challenging to investigate effects of aerosol distribution and concentration on the velocity field within the Marine Atmospheric Boundary Layer (MABL) under a broad range of wind and sea conditions. To provide deeper insight into this topic, a scanning Doppler wind LiDAR was deployed approximately 100 m away from the shore at a site over the coast of the Gulf of Mexico, specifically at the Galveston Island State Park in Texas. This remote sensing instrument has enabled simultaneous and co-located observations of the wind speed and aerosol concentration throughout the ABL height and along the shore-normal direction. While Plan-Position Indicator (PPI) scans showed horizontal variability of the backscatter coefficient of the LiDAR signal, Range-Height Indicator (RHI) scans captured the vertical evolution of aerosol plumes near the surf-zone. Long-duration low-elevation fixed scans in the mean wind direction have enabled investigating the negative correlation between the streamwise velocity and aerosol concentration with a vertical resolution of 1 m and a sampling frequency of 2 Hz. With a field campaign of over 5 months, a large dataset comprising broad variability of wind direction, atmospheric stability regime, turbulence intensity and wave conditions has been collected and processed. Considering the site as an open channel flow with moving boundary has helped us to study the effects of aerosol on the MABL through the Doppler backscatter signal of the LiDAR. A consistently higher backscatter is observed during offshore winds compared to onshore winds. Furthermore, compared to the currently existing roughness models for the MABL, the coupling between aerodynamic roughness and aerosol concentration is characterized. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

Session 018: Impact of Multiple Stressors on Gulf Ecosystems After Oil Spills

Multi-Climate Stressor Effects and Louisiana Sweet Crude Oil Sheen Toxicity in Larval Eastern Oysters (*Crassostrea virginica*)

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Crassostrea virginica is an important commercial bivalve species which also has numerous ecological roles from biogeochemical cycling, providing habitat for larval fish and crustaceans, and reducing the impacts of coastal storms. Oil may pose a threat to oyster larvae swimming in the water column, leading to potential negative effects on growth and development. Oil toxicity may be further enhanced by chemical changes in the presence of sunlight, and may vary with temperature and salinity. This study

examined the toxicity of thin oil sheens with and without ultraviolet (UV) light. Larval *C. virginica* were exposed to four different oil sheen thicknesses and either no UV or 2-hour UV light exposure for 24 hrs. Following the exposure larvae were transferred to clean seawater at either the same or lower salinity and incubated at either the same or higher temperature to determine the compounding toxic effects of a previous oil exposure and climate stressor.

The presence of a 2-hour UV light exposure increased oyster mortality for all oil sheen thicknesses. Concurrently, a low salinity shock and a high temperature shock following an oil sheen exposure increased oyster mortality over the course of 96 hours. Median lethal concentrations (LC_{50}) were determined. The LC_{50} for a 24-hour exposure without UV was 1.94 µm while a 2-hour UV exposure increased oil toxicity two-fold (LC_{50} = 0.98 µm). This study provides new data for thin oil sheens and larval life stages under variable environmental conditions. The results of this study will be used to inform oil spill response and restoration decisions.

Impacts of Oil Exposure, Low Oxygen, and Temperature on Aerobic Performance of Red Drum (*Sciaenops ocellatus*)

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Aerobic scope, the difference between an animal's minimum aerobic metabolic requirements and their maximum metabolic capacity, is an important metric influencing ecological success in fishes. Crude oil exposure can impair cardiorespiratory performance in fishes, which reduces maximum metabolic rate, aerobic scope, and likely impairs ecological performance. However, oil is not the only stressor that can impact aerobic scope, especially in areas affected by crude oil spills (e.g. the Gulf of Mexico). Hypoxia (low dissolved oxygen) is known to constrain maximum metabolic rate in fishes, while high temperature raises minimum metabolic costs and constrains maximum metabolic rate. Despite this knowledge, there has been little effort to determine how these environmental factors may influence metabolic injury following oil exposure. Therefore, the goal of this study was to investigate the effects of acute oil exposure, hypoxia, and temperature on the metabolic performance of a fish common to the Gulf of Mexico - red drum (*Sciaenops ocellatus*). Here, red drum were acclimated to a series of 3wk temperature acclimations before a subset of individuals were exposed to crude oil for a 24h period. Following exposure, aerobic scope, post-exercise oxygen consumption, and hypoxia tolerance were quantified before each individual was assessed for a suite of physiological characteristics that could drive differences in aerobic performance (e.g. hematocrit and blood binding affinity). Our results show that temperature significantly impacts aerobic scope by raising standard metabolic rate and constraining maximum metabolic rate. Oil exposure also significantly impacted maximum metabolic rate, although the cold temperature mitigated the negative impacts of oil. High temperature also significantly lowered hypoxia tolerance among individuals. These results suggest that acclimation to lower temperatures may mediate the insult of injury to metabolic performance following exposure to crude oil.

Toxicity Assessment of Novel Oil Dispersant Based on Silica Nanoparticle: An Update Testing Different Chemical Composition and Endpoints

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The current strategy to remediate oil spill accidents is based on mechanical removal of the oil or its dispersion. The latter approach uses chemical dispersant, such as Corexit®, facilitating the breakdown of the oil slick, thus preventing the coating of oil on animals and the slick on the surface of the water and catalyzing bacterial degradation of oil. However, several studies point out that such methodology makes toxic compounds in crude oil more bio-available to the aquatic biota, increasing the adverse effects of oil exposure in the water column. In this project, a different approach has been applied, using Nanotechnology to make a more environmentally friendly dispersant without toxic effects with the capability to uptake the oil components efficiently. Previously, we have presented the efficacy and safety of a novel silica-based nanoparticle (NP) with amphiphilic chemical branches (i.e. hyperbranched poly-glycidol -SiO2-HPG-). We assessed its toxicity to embryos and juveniles of the freshwater species fathead minnow (FHM), and as an indirect measurement of oil uptake efficacy, the expression of the gene *cyp1a*. Our results suggest that SiO2-HPG is not acutely toxic to early life stages of FHM after 96 h of exposure to NP. Furthermore, the induction of *cyp1a* gene was diminished when fishes were co-exposed with the water accommodated fraction of the oil (WAF) plus NP. In this prospective abstract, our aim is to further test a new version of synthesized NPs optimized after adjusting specific design parameters, adding more endpoints to confirm the efficacy and safety of this novel compound. Among the added endpoints are alterations of lipid expression, energy metabolism, and heart development. In addition, a saltwater species silverside minnow will be used for the toxicity assessment. Our expectation is to have a more efficient oil dispersant using Nanotechnology without the adverse effects of chemical dispersants and to have a better understanding of the physiology of fish exposed to crude oil components.

Oil, Mercury Levels, and Stable Isotopes in Seaside Sparrows and Marsh Rice Rats Across the Mississippi River Plume

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Variation in levels of mercury (Hg) for Gulf of Mexico ecosystems is largely unknown for waters and wildlife alike. Compounding this uncertainty, a large input of organic matter from the 2010 Deepwater Horizon oil spill created reducing conditions that potentially increased Hg methylation and its bioavailability. Higher Hg concentrations could then have toxic effects on organisms and populations, alone or by interacting with hydrocarbon exposure from the spill. To characterize variation in wildlife Hg exposure, we quantified circulating blood total mercury (THg) concentrations in seaside sparrows (*Ammospiza maritima*) and marsh rice rats (*Oryzomys palustris*) from locations west and east of the Mississippi River plume (MRP). Further, we tested for differences in THg concentrations in wildlife from oil-contaminated and un-oiled sites. To address the potential confounding effect of diet variation on Hg transfer, we also measured stable isotope values of blood in both species, using δ15N and δ13C as indicators of trophic position and the source of primary production. Our results did not support elevated Hg exposure in sites oiled by the spill. Instead THg concentrations in both species were higher east of the MRP compared to either control or oiled sites to the west. THg was also higher in adult sparrows compared to juveniles. Stable isotope values (δ15N) showed very different trophic structures for communities on the two sides of the Mississippi River. In seaside sparrows, but not in marsh rice rats, THg was positively correlated with trophic position, suggesting biomagnification of mercury, driven by birds east of the MRP. This is the first report of fine-scale geographic variation in mercury

* Student presenter

concentrations in marsh resident species in the Gulf of Mexico. The documented differences are consistent with known hydrological differences between the two sides of the MRP. They also have implications for human exposure to Hg via consumption of fish from the two areas.

Role of Nutrient Availability on the Diatom *Phaeodactylum tricornutum* in the Presence of Oil

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The Deepwater Horizon oil spill released 4.3 million of barrels of crude oil into the Gulf of Mexico (GoM). In the coastal zone of the GoM, phytoplankton are known to be nitrogen limited for most of the year, including the post spill period. Little is known about the phytoplankton response to nutrient availability in the presence of oil. Previous studies show that the diatom *Phaeodactylum tricornutum* (Pt) is resilient in the presence of oil and it is hypothesized to be an effect of its protective silica frustule. The purpose of this study was to test if nitrate and silica limitation affect the response of Pt in the presence of oil. Diatom cultures were grown in four different f/2 media nutrient treatments for a year: replete, -Si, ¼ N, and combination -Si and ¼ N. Each culture was subsequently inoculated into a control and water accommodated fraction of oil (WAF) treatment for 4 days. Samples were taken daily to monitor photosynthetic efficiency using fluorescence induction and relaxation and PhytoPAM, changes in cell densities, concentration of oil in the growth medium, and intracellular and extracellular macromolecular composition were also determined. Results showed that photosynthetic efficiency and growth rates were more affected by nitrogen limitation than the presence of oil. Extracellular macromolecular composition showed higher carbohydrate to protein ratios in the nitrogen limited treatments as well. In addition, Pt showed morphological variability with cells linking together in “chains” when Si and N limited for prolonged periods. This study could help us better predict how the GoM phytoplankton may respond to any future oil spills when affected by nutrient stress.

The Gulf of Mexico Hypoxic Zone and Its Effect on the Gonadal Structure of Protogynous *Centropristis philadelphica*

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Hypoxia in the Northern Gulf of Mexico (GOMEX) is a growing issue that has intrigued scientists for decades, but studies of the long-term implications of hypoxia on fish reproduction are few and far between. Thomas and Rahman (2011) found that hypoxia suppresses the enzyme aromatase, inducing the production of male tissue in female *Micropogonias undulatus* individuals, but information on only one species does not tell the entire story of how hypoxia might affect the complex GOMEX ecosystem. *Centropristis philadelphica* is a species of seabass in the Northern GOMEX and is a protogynous hermaphrodite, meaning individuals begin life as females and undergo a sex change at a certain stage during development. These individuals undergo aromatase suppression naturally at a certain stage during life history, facilitating the transition from female to male. Here we look at the gonadal structure of hypoxia-dwelling *C. philadelphica* to determine the effects of hypoxia on their reproductive development. By comparing the ratio of male-to-female gonadal tissue in specimens sampled at hypoxic sites with those sampled at normoxic sites, we look for individuals that have developed male tissue prematurely, showing a disruption in the reproductive norm. Nutrient pollution from agricultural run-off

is the most widely-known contributor to hypoxia in the GOMEX. Nutrient run-off recruits large algal masses, and their subsequent decay recruits aerobic bacteria that deplete the ocean of dissolved oxygen. However, oil exploitation has been shown to play a role in hypoxia as well. In response to oil spills, bioremediation strategies using hydrocarbon-degrading bacteria have become increasingly popular. Bacteria use dissolved oxygen in the water to break down the hydrocarbons, giving this remedial strategy the potential to further deplete the GOMEX of dissolved oxygen. Continued oil exploitation in the GOMEX has the potential to exacerbate the scope of hypoxia and may have severe impacts on fish populations and the greater ecosystem. In order to determine these large-scale effects, though, we must first consider the effects of hypoxia on a population level. Histological studies like this one allow us to gain a larger understanding of the impacts of hypoxic zones on fish populations and reproductive development.

Microbial Symbionts of *Spartina alterniflora* and the Plant Genetic Response in an Oiled Environment

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After the Deepwater Horizon oil spill, much attention was paid to the potential benefits of microbial biodegradation of oil. New technologies allowed for unprecedented, high-resolution profiling of microbial communities. Most of this work examined how the microbial community composition changed in coastal ecosystems, like saltmarshes, and whether or not changes corresponded to prevalence of oil in the environment. However, recent research emphasizes the complex symbioses between microbes and macro-organisms. While the morphology and physiology of the foundational salt-marsh grass, *Spartina alterniflora*, was carefully monitored after the oil spill, little research was conducted examining the more cryptic responses of the plant - namely its genetic response to an oiled environment and how genetic expression related to changes in the microbiome of the grass. Some grass species have been shown to have strong relationships with microbial symbionts that allow them to exist in stressful environments, like volcanic soils or saline environments. However, microbes have also been known to take advantage of stressed plants, as was seen in the marsh dieback that plagued the southeastern United States at the turn of the millennium. To tease apart the interactions of the *S. alterniflora* and its microbiome in an oiled environment, we ran a four-month long growth chamber experiment in which we examined the degree to which oil homogenized the soil microbial community and the root transcriptome of *S. alterniflora*. We report how differential genetic expression relates to bacterial soil community composition and the importance of the initial microbial community composition in shaping the community trajectory after oiling. We also discuss how interactions may be both enhancing and exacerbating the plant stress response and the potential use for these results in restoration of oiled salt marshes.

The Effects of Photo-Oxidized Oil and Increased Nutrient Availability on Marine Phytoplankton Communities

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Oil spills can pollute aquatic ecosystems and have harmful effects on marine organisms. Phytoplankton serve a crucial role as the main primary producers of marine environments, fixing inorganic carbon and

producing oxygen. Previous studies have shown that oil can have negative effects on marine phytoplankton. However, these studies have used higher concentrations of oil than are typically found in marine oil spills and often these studies are conducted with select species of phytoplankton. Photo oxidation of oil and its effect on marine phytoplankton has not been explored in detail in previous studies and is an inevitable process during weathering of oil at the surface of the ocean. Fresh water inflows also bring essential nutrients like carbon and nitrogen marine ecosystems during oil spill scenarios. There is variable knowledge about the real time effects of oil spills and nutrient amendments on marine phytoplankton. The aim of this experiment was to test the effects of weathered oil and nutrient supplementation on a natural marine phytoplankton community. Treatments of natural Atlantic Ocean phytoplankton communities were exposed to different concentrations of weathered and non-weathered oil, and additions of nitrogen, in the form of ammonium chloride, and carbon and nitrogen, in the form of glutamine. Results showed that photo oxidized oil had a negative effect on phytoplankton abundance and addition of nutrients in the form of glutamine had a positive effect on phytoplankton health. Photophysiological measurements indicated that addition of nutrients lead to increased photosynthetic efficiency by decreasing light harvesting antennae size among the phytoplankton community. Future studies could be dedicated to the effects of increased nutrient addition on the recovery of ecosystems affected severely by oil spills.

Oiling Impacts on Salt Marsh Ecosystem Processes: Insights from a Large-Scale Marsh Mesocosm Experiment

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Coastal wetlands straddle the land/ocean interface, providing myriad ecosystem services yet are also especially vulnerable to disturbances across a range of time and space scales. Most disturbance studies rely on either large-scale comparisons between disturbed and undisturbed sites that may have other uncontrolled, underlying differences or on small-scale manipulations of individual processes in isolation from other relevant processes. Here we report results from a large-scale experiment using a salt marsh mesocosm facility capable of testing the impact of disturbances on intertwined ecosystem-scale processes against a backdrop of controlled and uniform environmental conditions. The facility consists of 12, hydrologically independent *Spartina alterniflora* marsh mesocosms (3m diameter) each with its own paired tidal surge tank capable of generating tidal cycles with ranges up to 50cm via an automated water control system of blowers and airlifts. Specifically, we report results on how oiling impacts salt marsh plant dynamics; soil biogeochemistry; and microbial abundances and composition by assigning three marsh tanks to each of four treatments: control plus light, moderate and heavy oiling levels scaled to the SCAT categories observed following the DWH spill. Measurements were made every 1-2 months beginning over one year prior to oiling in July 2019 and extending through 6 months post-oiling. Water level, temperature, and salinity and soil temperature and redox potential are logged continuously. Other regular baseline measurements include: 1) soil physical and chemical properties; 2) porewater chemistry; 3) oil characterizations; and 4) faunal abundances. This yearlong pre-oiling time series in a large-scale, highly monitored and controlled experiment provides a baseline against which we will track short- and long-term responses of marsh ecosystem processes to a gradient of oil exposure.

* Student presenter

Effects of Crude Oil Vapors on the Cardiovascular Flow of Embryonic Gulf Killifish

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Crude oil exposure from oil spills is known to cause serious health effects in humans and animals. These effects include developmental and cardiac defects, which have been studied extensively in exposed fishes. While previous studies have focused primarily on the effect of direct crude oil contact, our project attempts to study the effect of airborne exposure to volatile organic compounds released from crude oil. We do this using Gulf Killifish (*Fundulus grandis*) embryos, a unique Gulf of Mexico teleost model which can develop outside the water. In this study, these embryos were exposed to vapors produced by crude oil samples taken from the Deepwater Horizon oil spill riser. Oil-exposed killifish embryos had reduced hatching success and those that hatched normally were used for imaging. High speed videos of blood flowing through an intersegmental artery were taken from the hatchlings, and particle image velocimetry was used to measure blood flow parameters. Results show that oil-exposed killifish hatchlings had significantly reduced blood flow speed, flow rate, evidence of reduced cardiac contractility, and increased pulse rate compared to control killifish hatchlings. Also, hematocrit was slightly higher in oil-exposed killifish hatchlings than control killifish hatchlings. These results suggest that normal-appearing oil-exposed killifish hatchlings had reduced cardiovascular performance in comparison to control killifish hatchlings. Further, this study demonstrates the potential for non-traditional physiological measurement techniques to probe the sub-lethal effects of oil exposure and demonstrates the usefulness of the Gulf killifish as a unique teleost model for studying the effects of exposure to aerial toxicants such as crude oil vapors.

Session 019: Fate of Dispersed Oil

Biodegradation of Oil and Gas in Seawater at Oxygen-Reduced and -Saturated Conditions

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Dissolved oxygen (DO) in deep-sea waters may be renewed very slowly in several of the world's oceans, resulting in reduced DO concentrations. This may create naturally occurring areas of deep-sea hypoxia (DO levels less than 2.0 mg/L) or anoxia. In this study, we examined DO consumption and biotransformation of oil compounds and natural gas (NG) in DO-reduced and -saturated natural seawater (SW). Separate experiments in SW with a paraffinic oil were performed with low energy water-accommodated fractions (LE-WAFs; ~1.5 mg/L VOC), or oil films immobilized to hydrophobic adsorbents (Fluortex fabics; ~10 mg/L TEOM), and with a synthetic mixture of NG included in both systems (~88 vol% methane; ~8vol% ethane, ~4vol% propane; ~1.8 mM NG). DO concentrations were reduced in the SW by using a reducing agent and N2-bubbling. The DO-reduction procedures reduced the oxygen concentrations by 1 to 3 mg/L lower than saturated SW. The flasks were incubated static without headspace at 5°C for up to 64 days. During this period DO was reduced by 50-67% in the flasks, resulting in lower DO concentrations in originally DO-reduced than DO-saturated samples. Gas analyses showed that methane was poorly depleted in both DO-reduced and -saturated samples. Propane was depleted in DO-saturated, but not in DO-reduced samples, both in LE-WAFs and oil-immobilized samples, but

ethane only in DO-saturated oil. VOC compounds in the LE-WAFs, including BTEXs, were also depleted slower in the DO-reduced than -saturated SW. However, measured semivolatile compounds (naphthalenes, 2- to 5-ring PAHs, decalines) were reduced less differently in the DO-reduced and -saturated SW in samples with immobilized oil. These data indicate some influences of reduced DO levels on biodegradation of soluble oil and gas compounds, although the results should be confirmed in real SW samples from relevant deep-sea basins and with realistic oil and gas concentrations.

Computational Fluid Dynamics and the Prediction of Droplet Sizes

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The fate and final location of spilt oil is determined by the droplet size that will form. Large droplets will rise rapidly to the surface, while small droplets can become trapped in subsea inversion layers. Where they can either fall to the seafloor as marine snow or be consumed by microscopic marine life. Experimental determination of droplet size distributions is hampered by the necessary size of the equipment to produce results with turbulence of the order seen at the Macondo Event. As droplet breakup in turbulent flows will occur in the universal region of the energy cascade, autoclaves provide the ability to study the fundamental nature of droplet breakup with a desktop apparatus. Additional to this is the ability to use Computational Fluid Dynamics (CFD) to simulate the nature of turbulent flows and using parameters from a single-phase system predict the droplet sizes observed in experiments. This works shows that it is possible to use single-phase simulations to predict droplet sizes observed in a dispersed system. This is important to the application of dispersants as, at some point, the local turbulence will be enough to breakup oil up sufficiently to sequester it in the deep-sea without the application of dispersants. The level of turbulence required to do this can be investigated with autoclaves and CFD.

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

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The current and primary methodology for oil spill remediation involves the use of small molecule surfactants that facilitate the formation of oil microdroplets. This thermodynamically unstable process requires constant energy input to emulsify the oil droplets. Furthermore, this route only slows down the coalescence of oil, it does not prevent it. These small molecule surfactants also contain charged particles that retard bioremediation and exhibit a severe dependence on concentration and environmental conditions. Due to these factors, they show no long-term stability. Amphiphilic grafted nanoparticles (AGNs) show promise as a more efficient platform both from an economical and a toxicological standpoint. Our general design is to use a silica nanoparticle as the core substrate, poly(caprolactone) (PCL) as the oil-soluble polymer, and hyperbranched poly(glycidol) (HBPG) as the hydrophilic polymer to provide steric stabilization. By varying the amount and density of polymer grafted from the nanoparticle, tunability in oil uptake and water stability can be achieved. Previously, it was shown that the AGNs composed of PCL and HBPG display limited solubility. As a result, poly(ethylene glycol) was added to the copolymer as an additional hydrophilic component to improve water solubility, which showed

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significantly improved water solubility. Additionally, the synthesis for the PCL-HBPG copolymer has recently been optimized further and shows significantly improved water solubility. Now, there are several routes available to achieving water soluble AGNs with control over grafting density and grafted polymer composition.

Nanoparticle-Micelle Oil Dispersants from SiO_2-poly(caprolactone)-*b*-poly(oligo ethylene glycol methyl methacrylate) Amphiphilic Grafted Nanoparticles

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Using common polymerization techniques, amphiphilic grafted nanoparticles (AGNs) can be synthesized for use as commercial oil dispersants. Following previous work in the literature, it is the goal of this research to use less tedious steps to make these AGNs with greater effectiveness at dispersing oil from inherent architectural design. The primary focus of this route is to use well-established techniques with room temperature reaction conditions easily scalable to industry requirements. Surface-initiated ring opening polymerization (SI-ROP) and atom transfer radical polymerization (SI-ATRP) will be utilized to sequentially graft amphiphilic linear-bottlebrush polymers from the surface of the silica nanoparticles. Multiple repetitions of these reactions allow the ratio of hydrophobic to hydrophilic character to be tuned, resulting in increased water dispersibility, shelf life, and oil uptake. Through collaborations we are checking both the biocompatibility and eco-friendliness of these particles from the oil uptake efficiency data, as well as toxicology results from embryo and juvenile fish populations. These combined efforts afford a more comprehensive picture at the effectiveness of these particles to ultimately aid or replace commercially used Corexit®.

Session 020: The Deep Gulf of Mexico: Knowns and Unknowns After the Deepwater Horizon Spill

Bacterial Degradation of Crude Oil and Methane at Elevated Pressure

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After the Deepwater Horizon oil spill, crude oil and methane gas leaked into the world's largest habitat, the deep-sea. A number of different factors determine the fate of the leaked hydrocarbons into the environment and the enrichment of indigenous petroleum-degrading microbial communities in the oil plume, responsible for the degradation of the oil and the gas released, were monitored. It was found that biodegradation plays an important role in the degradation of hydrocarbons in the ocean (1), however the mechanisms are not well understood. As deep-sea drilling for crude oil is expanding, the understanding in the biodegradation of crude oil under deep-sea conditions is crucial. To investigate the biodegradation of hydrocarbons under deep-sea conditions, special steel reactors which can withstand pressure up to 400 bar, were designed and equipped with oxygen sensors and partly with NIR-measurement for methane concentration determination. The dynamic of microbial communities as well as growth and activities of hydrocarbon-degrading bacteria growing on crude oil, methane and

* Student presenter

dispersant under the influence of different pressures and temperatures were investigated. The investigations revealed that hydrostatic pressures of the deep-sea influences biodegradation of oil and gas and that it is an important factor determining the fate of hydrocarbons in deep-sea environments.

(1) Hazen *et al*. 2010, Deep-Sea Oil Plume Enriches Indigenous Oil-Degrading Bacteria. *Science* 330 (6001):204-208. doi:10.1126/science.1195979

Near-Inertial Currents in the Deep Gulf of Mexico

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Near-inertial oscillations in the deep ocean are important in many ways, such as transporting biogeochemical particles and providing energy for deep-ocean mixing. Spatial and temporal variations of near-inertial oscillations in the deep Gulf of Mexico (GoM) are rarely reported. In this study, a collection of moored current observations is used to describe the characteristics of near-inertial currents in the GoM. The observed velocity shows an energy peak around the local inertial frequency (about 1 cycle per day, which is close to the diurnal tidal frequency) in most current records. The energy density at the near-inertial frequency generally decreases from the surface to about 1200 m and then remains a relatively small value below. In the Loop Current region and the northeastern GOM, however, high near-inertial energy appears in both the upper (above 800 m depth) and the bottom ocean (below 1000 m depth and within 200 m above the bottom). Although downward energy propagation from the upper layer to the deep ocean is common, upward propagation in the deep ocean is also observed, consistent with bottom generation of near-inertial oscillations. To explore possible relationships between the low-frequency variations of near-inertial currents and the subinertial bottom currents, we also calculate and compare the low-frequency modulation of near-inertial currents with the bottom subinertial currents. Moreover, since surface and bottom current coupling exists in some regions of the GoM, we also compare the modulation of bottom near-inertial currents with local and remote surface currents, which provide potential ways to predict modulation of deep-ocean near-inertial currents by examining surface observed features.

Annual- to Decadal-Scale Sedimentation Patterns off Northwest Cuba over the Past 100 Years

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Sediment cores collected off Northwest Cuba were analyzed for sediment texture, composition and geochronology to investigate annual to decade scale environmental changes over the past 100 years. Mineral composition, determined by XRD, of the core collected off Havana, showed sediments consist primarily of aragonite and calcite, with subordinate Mg-calcite and quartz. The core shows a significant change in sedimentation patterns over the past 10 years, while remaining relatively stable over the previous 90 years. This pattern reflects a potential increase of coastal tun-off of island-derived

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sediments over the past 10 years. Although still a work in progress, sediments to the west of Havana continue to reflect a more marine influence with no detectable recent increase in island run-off.

Factors Influencing $^{210}Pb_{xs}$ Inventories in Northeast Gulf of Mexico Bottom Sediments

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Excess ^{210}Pb ($^{210}Pb_{xs}$) geochronology is a method of age and depositional rate estimation in marine sediments, that is based on the radioactive decay of ^{210}Pb derived from ^{222}Rn. These calculations rely on the measurement of the $^{210}Pb_{xs}$ in the sediment column, which is defined as ^{210}Pb produced by the decay of ^{222}Rn in the atmosphere, as opposed to supported ^{210}Pb, which is part of the ^{238}U decay series in rocks and sediment grains. As the series is in secular equilibrium, the supported ^{210}Pb activity is generally constant and equal to other radioisotopes in the series. The $^{210}Pb_{xs}$ inventory is the summation of all present $^{210}Pb_{xs}$ in a core and is integral to the calculations necessary for determining sediment age and depositional rates using the CRS ^{210}Pb dating method. Sediment cores were collected in the Northern Gulf of Mexico following the Deepwater Horizon oil spill in 2010, with collection sites spanning two sedimentological provinces. Specifically carbonate sediments dominate east of the DeSoto Canyon, and siliciclastic sediments dominate west of the canyon. Each core was analyzed for texture, composition, and $^{210}Pb_{xs}$ inventory. The $^{210}Pb_{xs}$ inventories were compared to sediment texture (average % grain size), composition (average % carbonate and average % siliciclastic), water depth, and location, in order to isolate any relationships among factors and $^{210}Pb_{xs}$ inventories, and furthermore, to help determine what factors have the strongest influence on $^{210}Pb_{xs}$ inventories. A strong relationship was found in which fine-grained, siliciclastic sediments correlate to higher $^{210}Pb_{xs}$ inventories. In cores from west of the DeSoto Canyon, grain size was found to be the most influential factor on $^{210}Pb_{xs}$ inventories; while in cores to the east, neither grain size, composition, nor water depth were shown to have strong influences on $^{210}Pb_{xs}$ inventories. Water depth was shown to have little influence on $^{210}Pb_{xs}$ inventories.

The Chemical Legacy of Oil Spills in the Gulf of Mexico: Lessons Learned from Organic Geochemical Analyses of Sediment Samples

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The two largest accidental oil spills in history occurred beneath the ocean's surface in the Gulf of Mexico (GoM). The Deepwater Horizon oil spill (DWHOS) in the northern GoM occurred in 2010, 31-years after the Ixtoc-1 oil spill (IOS) in the southern GoM. Multiple studies have shown that the pelagic and benthic habitats from coastal to offshore environments were affected by both spills. In the northern GoM, sediment cores from 2010-2011 revealed extensive deposition (~110,000 km2) of oil-residues on the seafloor. To better understand the long-term preservation of oil residues from the IOS spill, we analyzed sediment samples collected in 2015-2016. Our chemical analyses showed buried-weathered oil from the IOS in offshore and coastal environments after more than 3-decades of the spill. Higher concentrations of oil-derived hydrocarbons were observed in mangrove forests relative to offshore sediments, but in all environments, toxic compounds like PAHs (polycyclic aromatic hydrocarbons) were low. The application

of a new analytical approach in the coastal samples indicates that transformation products are present at levels above concentrations of concern in the environment with high toxicity/mutagenesis risk. In the northern GoM, analysis of sediments collected in 2018, showed oil residues beyond the spatial range where it was previously shown to have been impacted by the DWHOS. Redistribution of weathered oil residues after initial deposition occurred and is attributed to sediment resuspension and its subsequent downslope redeposition following seafloor topography. Altogether these Gulf-wide studies demonstrate that long-term preservation of weathered oil residues occurs on the coast and at depth. Studies are needed to better understand the long-term fate and impact of transformation products in deep-sea sediments.

Elemental Composition in JS-0815 Southern Gulf of Mexico Cores

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Sediment cores were collected in the southern Gulf of Mexico (SGoM) near the site of the 1979 IXTOC-1 Oil spill. Cores were analyzed for elemental composition and magnetic susceptibility (MAGSUS) using an XRF Core Scanner. Elemental ratios and percentages were analyzed for Al, Si, S, K, Ca, Ti, Mn, Fe, Zn, Rb, Sr, and Ba to isolate possible volcanic signatures of the El Chichón volcanic eruption of 1983 in Chiapas, Mexico. The purpose of this project was to use the volcaniclastic material from the El Chichón eruption in the sedimentological record as an independent age dating tool to correlate and verify Pb-210 dating. Core scan data, analyzed by XRF, from El Chichón Ash samples showed high percentages of Al, Si, and K, as well as Ca, Fe, and Zn. Elevation in Al, Si, and K, between 40-115mm down core, suggest that these elevations could be indicators of a high input of siliciclastic sediments in the form of volcaniclastic material. Although analysis of core scan data is still a work in progress, there appears to be a relationship between the elevated levels of siliciclastic indicators and the elemental composition of volcanic ash samples.

Organic Carbon Burial Rates and Efficiency in Sediment Cores from the Gulf of Mexico

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The burial and preservation of sedimentary organic carbon (C_{org}) have a key role in controlling atmospheric carbon dioxide concentrations, and consequent effects on global climate at geologic time scales. However, on shorter time scales, anthropogenic disturbances of the marine environment, such as those related to offshore oil production and land use changes may alter C_{org} exchange between continental and oceanic domains, elevate petrocarbon ($C_{p\text{-}org}$) deposition and enhance marine C_{org} production, all having unknown effects on C_{org} cycling. In this work, we present preliminary results of an ongoing assessment of the spatial and temporal variability of centennial C_{org} burial rates and efficiencies in the Gulf of Mexico. We focused on the historical development of the oil industry, including the two major spills occurred in the GoM (i.e. Ixtoc-1 in 1979 and DWH in 2010), through the study of sediment

* Student presenter

profiles, collected during the 2010 and 2017 C-IMAGE sampling expeditions, using ^{210}Pb as a radiotracer to evaluate the sediment accumulation rates. This quantitative assessment of C_{org} burial rates will elucidate the role of the Gulf of Mexico as a carbon sink, and the potential consequences of the offshore industry development in the region on C_{org} cycling over the past century.

Deployable, Networked Ammonium-Nitrate Sensors to Enable Monitoring of Deep-Water Nitrogen

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Although investigations into effects of oil spills on microbiota have primarily focused on carbon-degrading organisms, hydrocarbons can also affect nitrogen cycling microbes. The varying timescales of nitrifier, denitrifier, and anammox growth, metabolism, and nutrient availability, which is compounded by seasonal eutrophication in the Gulf of Mexico, demand high spatiotemporal resolution. To separate these effects, we propose sensors that resolve inorganic nitrogen speciation with high spatial and temporal resolution. Current solutions require large investments of personnel, cost, and energy. Passive sensors with polymer-derived or paper-based materials face rapid fouling, and optical methods that use fluorescence of analyses require high responsivity photodetectors and complex microfluidics along with constant human supervision. Thus, there is a strong need for energy-efficient and long-lasting water sensors that can be deployed over large areas for ammonia monitoring. The proposed system adapts electrochemical stripping, a novel treatment process, to selectively sense ammonia and nitrate. This two-membrane, three-chamber process uses water electrolysis to provide electrons at the anode that are matched by transmembrane transport of ammonium, where cathodic pH increases convert ammonium into ammonia, a volatile species that crosses a gas-permeable membrane to an acidic trap chamber. Nitrate reduction can also be performed at varying potentials to differentiate nitrate from ammonia. The system can be remotely controlled by wireless networks because electricity replaces chemicals as the major input. We will detail relative rates of nitrogen reactions and transport in varying reactor geometries to maximize sensitivity and selectivity. This framework includes effects of temperature, membrane properties, and ambient nitrogen concentrations. Based on a 3-year battery life, these sensors could be applied in long-term campaigns that elucidate deep-water nitrogen dynamics.

Benthic Foraminifera Before and After the Ixtoc 1 Oil Spill in the Southern Gulf of Mexico

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The Campeche Sound (Southern Gulf of Mexico) is the main offshore oil producing area of Mexico, as well as an area of natural oil seeps. In order to evaluate the oil exposure influence in the benthic environment, we have studied the foraminifera, as representatives of the benthic microfauna, from over 100 surface and subsurface sediment samples. Benthic Foraminifera (BF) are known indicators of environmental health, and their recovery and resilience have been monitored in the northern gulf after the DWH blowout. However, no such studies were made in the Campeche Sound after the IXTOX - 1 oil spill (1979-1980), nor were there baseline studies of BF from pre-industrial times. Due to preservation of the foraminiferal shells in the sediments, the average environmental conditions at the time when they

were living can be reconstructed in accurately dated sediment cores. We present here a compilation of our studies from the last 15 years in the Campeche Sound and give examples of BF faunal characteristics from the IXTOC - 1 horizon, the present time and pre-industrial times. Overall, BF populations decrease in abundance and diversity at the IXTOC-1 horizon and recover towards present time. BF responses are complex and depend on the geomorphologic and oceanographic settings, water depth and distance to either natural or anthropogenic oil exposure; however, highest diversities are recorded at pre-industrial times, suggesting return to pristine conditions have not been reached.

Assessing the Presence of Oil Residues in Marine Sponges from the Gulf of Mexico

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Accidents related to intense petroleum related activities such as the Deepwater Horizon Oil spill (DWHOS), can release polycyclic aromatic hydrocarbons (PAH) and derivatives that are known to cause mutagenic, genotoxic and carcinogenic effects in organisms. Marine sponges (Porifera Phylum) have a higher capability to accumulate PAHs from both the dissolved and particulate phase and have been suggested as an alternative bioindicator to mussels. However, few studies have tested sponges in the Gulf of Mexico (GoM). In this study, we evaluated the presence of PAHs in different species of sponge samples (*Agelas* sp., *Aphrocallistes* sp., *Aplysina* sp., *Ircinia* spp. *Niphates* spp. and *Xestospongia muta*) from locations east of the Deepwater Horizon located at 3 to 497m depth. Samples were collected by an FAU-Harbor Branch Scientific Cruise in July 2010. We used a single-step lipid extraction and purification procedure (ultra-sonification) coupled with a highly sensitive chromatographic technique (GC/MS/MS-MRM) for the identification and quantification of PAHs (2-6 ring and homologues). Results will be presented for each species and compared spatially to better understand exposure, uptake, and storage trends of oil-residues in sponges residing on the continental-shelf of the northeastern GoM.

Session 021: Outcomes from Large-Scale Fishery Monitoring Projects Following the Deepwater Horizon Oil Spill: What Have We Learned, and Where Do We Go from Here?

Differences in Habitat Use by Female Red Snapper: Comparison of Mature and Immature Fish

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This study compared age, fork length and occurrence of immature and mature female Red Snapper (*Lutjanus campechans*) off the coast of Mississippi in 2016-2018 at different artificial structure types (artificial reef, oil platforms, rigs-to-reef) and depths (shallow, 0-20m; mid, 20-50m; deep, 50-100m) to determine differences in habitat use. There was a significant difference in distribution of immature versus mature fish by depth (χ^2, $p<0.001$). Mature fish being more common in deep water both overall and when only platforms were considered. In addition, immature fish were less common at rigs-to-reef structures than functionally mature fish ($p=0.002$) but not physiologically mature fish ($p=0.356$). For

mature fish, a 2-way ANOVA showed there was no significant difference in fork length (FL) for depth and structure, but K-W tests showed a significant difference in age for both depth and structure ($p<0.001$). There was a significant difference for FL by depth, but not structure type for immature fish ($p=0.047$), but there was a significant interaction between depth and structure ($p=0.01$). There was no significant difference in age of immature fish across depths, but they were significantly more common at artificial reefs than platforms (K-W, $p<0.001$). Immature fish were significantly smaller and younger at shallow and mid depths compared to mature fish (K-W, $p<0.001$), but there was no difference in FL or age in deep water by maturity. Immature fish were also smaller at platforms and artificial reefs than mature fish (K-W, $p<0.001$), but younger at platforms and rigs-to-reefs than mature fish (K-W, $p\leq0.034$). Our results suggest that larger and older females are found at deeper depths where fishing pressure is lower, while smaller, immature fish are most often found in shallow, reef-based areas where pressure is highest. These spatial differences in maturity can help inform management regulations for the species.

Combining Multibeam Sonar and Towed Camera Technologies for Habitat Mapping and Reef Fish Assessments in the Eastern Gulf of Mexico

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When environmental disasters occur and damage assessment begins, the importance of baseline data inevitably rises to the forefront of discussions on “lessons-learned.” It also quickly becomes obvious where gaps in the data exist which make truly assessing the damages difficult. When the Deepwater Horizon spill occurred in 2010, the eastern Gulf of Mexico (GoM) was relatively spared, but this event nonetheless emphasized the need for more baseline data pending future disasters. The West Florida Shelf, in particular, possesses several management categories that are “data poor”. As such, the Continental Shelf Characterization, Assessment and Mapping Project (C-SCAMP) began in 2015 via grant funds from penalties incurred by BP and Transocean that were awarded via the National Fish and Wildlife’s (NFWF) Gulf Environmental Benefit Fund (GEBF). The project’s aim was to begin filling in some baseline data gaps which exist for benthic habitat and living marine resources. The C-SCAMP group focuses on mapping new areas of potential high-quality benthic habitat for GoM reef fishes using multibeam sonar, then assessing habitat quality and reef fish densities using a towed camera system and water column echosounder. The overall project approach will be presented along with summarized results from C-SCAMP’s sub-projects including sea turtle habitat use, development of fish auto-recognition software, large-scale habitat mapping, and pairing fisheries echosounders with towed camera video to better estimate reef fish densities within a study area.

Characterization of Sea Turtle Habitat Use on the West Florida Shelf Using Benthic Mapping Techniques

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The use of offshore marine benthic habitats by sea turtles is poorly characterized due to the difficulty of obtaining *in-situ* data. Understanding benthic habitat use that is important to the species’ reproduction, foraging or migrations is critical for guiding management decisions. Multibeam bathymetry and

backscatter mapping techniques coupled with a towed camera-based assessment survey system (C-BASS) equipped with environmental sensors was used to characterize sea turtles in their benthic habitats on the West Florida Shelf (WFS) from 2015 to 2019. As a result of a grant from the National Fish and Wildlife Foundation's Gulf Environmental Benefits Fund (GBEF) critical sea turtle data was collected which included; spatiotemporal, species identification, life stage, habitat use, behavior and environmental parameters. In total, 79 sea turtles were observed during 97 transects of approximately 2,700 km which was recorded on 380 hours of video. Several sea turtle species were observed throughout the WFS, including loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*) and green turtles (*Chelonia mydas*). The sea turtles were observed most frequently along the Gulfstream natural gas pipeline where they were seen most commonly resting on the seafloor. This combined video-mapping technique can provide crucial insight into the benthic habitats used by sea turtles and demonstrates a monitoring technique capable of collecting valuable information for sea turtle conservation and management efforts.

Spatial Dynamics of the Quantity and Quality of Natural and Artificial Reef Habitats in the Eastern Gulf of Mexico

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Since 2010, the Florida Fish and Wildlife Research Institute has conducted habitat mapping to support reef fish survey efforts in the eastern Gulf of Mexico. Through 2018, more than 4,400 randomly-selected surveys (each approximately two km^2) have mapped more than 7,700 km^2 of seafloor using side scan sonar. Following standardized protocols, side scan sonar imagery was processed prior to manually identifying and delineating polygons encompassing individual reef features. To date, 33 unique habitat classes have been identified, including a wide diversity of natural and anthropogenic reef types. Overall, 97.1% of the total area mapped was comprised of non-reef, unconsolidated sediments. Of the 222.4 km^2 of reef habitat classified, 60.7% (134.9 km^2) was comprised of flat hard bottom, characterized by generally low-relief (less than 0.1m), hard substrate often colonized by attached biota. Unidentified artificial reef habitat was the most common anthropogenic reef type delineated (greater than 2,700 polygons totaling 0.2 km^2). Over 67% of all artificial reef features identified were located within the Florida Panhandle. While the primary objective of mapping efforts is to inform habitat-based reef fish surveys, the randomized design employed represents the largest scale habitat mapping effort conducted in the eastern Gulf of Mexico to date and allows for broad-scale inferences into reef habitat composition and coverage throughout the region.

NOAA/NFWF Deepwater Horizon Oceanic Fish Restoration Project Lessons Learned

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The NOAA/NFWF Deepwater Horizon Oceanic Fish Restoration Project is voluntary, temporary and non-regulatory restoration project that aims to restore pelagic fish that were injured by the 2010 Deepwater Horizon oil spill by reducing fishing mortality during a repose period each year. This first of its kind open ocean fish restoration project was developed by working with the pelagic longline fishing community in the Gulf of Mexico. The project includes two separate, but complementary components: (1) a repose

period, and (2) use of alternative fishing gear. This presentation highlights the challenges and opportunities that NOAA Fisheries experienced during project development and implementation.

A Hydroacoustic Spatial Evaluation of the Effective Area Sampled by Baited Underwater Camera Surveys in the Eastern Gulf of Mexico

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Stereo baited remote underwater video arrays (S-BRUVs) provide fisheries-independent, multi-species relative-abundance and length-frequency data for stock assessments and ecological studies. The Florida Fish and Wildlife Research Institute (FWRI) and other organizations worldwide have used S-BRUVs to quantify aquatic organisms associated with a range of habitats for decades. Despite the increasing popularity of S-BRUVs, more information regarding the area and total biomass sampled are needed to assess whether absolute abundance estimates can be generated from S-BRUV data. As an initial step towards addressing these information gaps and increasing the utility of data provided by S-BRUV surveys in the eastern Gulf of Mexico, we evaluated the fish re-distribution in relation to S-BRUV presence. A vessel-mounted hydroacoustic array equipped with split-beam 38 and 120 kHz Simrad Ek80 transducers was used to survey 41 375 x 375 m transects centered around sampling sites before and during camera deployments at multiple natural and artificial habitat types in waters 10-91 m depth. Mean volume backscatter and target strength estimates were used to calculate fish densities within 5-m horizontal intervals along the survey track for the lower and upper water column. The lower water column extended to 5 m immediately overlying the seafloor, reflecting the height viewed by the S-BRUV at the outer range at which fishes could be identified on video, while the upper water column extended from > 5 m above the seafloor to 6 m below the sea surface. Fish density data were then interpolated, and raster calculations were applied to quantify the spatially-explicit change in density and estimate the area sampled with the S-BRUV. Analysis of these data will provide insight regarding the feasibility of providing absolute abundance estimates from S-BRUV survey data.

Disentangling the Role of Time, Space, and Environmental Conditions in Structuring West Florida Shelf Demersal Fish Communities

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Bottom trawl surveys are an important component to fisheries assessment and management as they provide substantial data on the distribution, abundance, and life history of fishes and macroinvertebrates. The Southeast Area Monitoring and Assessment Program (SEAMAP) groundfish trawl survey was initiated in the western Gulf of Mexico (GOM) in the early 1980's on an annual basis. In 2008, The Florida Fish and Wildlife Research Institute's Fisheries-Independent Monitoring Program in collaboration with the National Marine Fisheries Service expanded this survey eastward to include the West Florida Shelf (WFS). Assessment and management of fisheries in the GOM has historically focused on single-species approaches, and WFS SEAMAP surveys have provided essential data used for single-species assessments. However, the most-recent reauthorization of the Magnuson-Stevens Fisheries Conservation and Management Act emphasized the need for incorporating ecosystem based/multispecies modeling into the decision-making process. Recent work by Matheson *et al*. (2017)

used a multispecies approach with WFS SEAMAP data to better understand the importance of space and time of day in structuring demersal fish assemblages. Their findings showed that time of day played a significant role in the structuring of demersal fish communities. Although their results highlight a strong need to incorporate diel period into ecosystem models (which is generally lacking), they did not test the influence of season in explaining variations in assemblage structure. Here we use a similar multi-species/variate approach described in Matheson *et al*. (2017) to examine the role of season in explaining variation in fish assemblage structure among other time, space, and environmental variables. Our results will provide a further understanding of the potential mechanisms structuring demersal fishes in the GOM and offer additional insights to improve ecosystem/multispecies based modeling approaches.

Evaluating the Usefulness of GoPro Cameras Deployed in Conjunction with Fisheries Independent Hooked Gear Sampling Along the West Florida Shelf

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Between 2014 and 2018 the Florida Fish and Wildlife Conservation Commission (FWC) conducted fisheries-independent hooked gear sampling along the West Florida Shelf to provide data on the abundance, size composition, and life history of managed reef fishes. In 2016, FWC began deploying GoPro cameras at hooked-gear sampling locations to provide a detailed description of the habitat sampled. Over 96% of GoPro camera deployments in 2016-2017 (*n* = 814) resulted in identifiable bottom habitat. The habitat information was then compared with a prior habitat classification (geoform) derived from the interpretation of side scan sonar data. Habitat classifications from GoPro footage and side scan sonar were in full agreement 43.8% of the time, possible agreement 31.9 % of the time and in disagreement 24.3% of the time. Almost half of the disagreements between GoPro habitats and side scan geoforms were the result of no habitat being visible within the GoPro footage (sand bottom). The side scan geoforms most likely to be unconfirmed by GoPro footage were small-scale isolated features (reef modules/boulders), were difficult to identify on GoPros (ledges/escarpments) or both (fractures). Habitat descriptions provided by the GoPro cameras were also used to model the probability of catching two highly desirable reef fish species, Red Snapper (*Lutjanus campechanus*) and Red Grouper (*Epinephelus morio*), via hooked gear. The probability of catching a Red Snapper was not influenced by any of the habitat variables provided by GoPro footage but the species was more likely to be caught in 2017 along the Florida panhandle with increasing depth. Red Grouper were more likely to be caught on natural habitats with higher percentages of soft coral in peninsular Florida. In conclusion, the deployment of GoPro cameras in conjunction with hooked gear sampling was useful for corroborating side scan habitat data, while also providing insight into habitat use of select reef fishes.

Improved Understanding of the Spatial and Habitat Dynamics of the Size Composition of Reef Fishes Using Stereo-Baited Remote Underwater Video

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The accurate characterization of size/age composition is critical to the assessment of managed reef fishes, especially as it relates to the estimation of overall stock productivity. In the eastern Gulf of Mexico, information on reef fish size composition is being increasingly generated from stereo-baited

remote underwater video (S-BRUV) surveys, which utilize stereo imaging technology to provide in situ size measurements. Data from S-BRUV surveys are especially valuable because these surveys are much less size- or species-selective than traditional capture gears. However, until recently, survey efforts were limited in spatial extent and were only conducted on natural reef habitats, so important questions remained as to how representative data were of true population size composition. To address this, the Fish and Wildlife Research Institute expanded S-BRUV survey efforts through funding provided by the National Fish and Wildlife Foundation through the Gulf Environmental Benefit Fund. Beginning in 2014, sampling was expanded to include natural and artificial reef habitats in the Florida Panhandle, and subsequently, the remainder of unsampled areas and habitats along the West Florida Shelf (WFS). from 2014 - 2018, over 30,000 individual fish measurements were obtained for 107 reef fish taxa over a variety of natural and artificial habitat types. This presentation will highlight notable examples of spatial and habitat-associated differences in size composition of managed reef fishes and how these data can be integrated to more accurately estimate population-level size composition in support of improved assessment and management in the region.

Gag Grouper Ontogenetic Movement on the West Florida Shelf

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The ontogenetic migration of Gulf of Mexico gag grouper on the West Florida Shelf takes them from their larval spawning grounds to juvenile estuarine nurseries, then to mid-shelf reefs as adults. After maturity, most female gag undertake a migration to shelf-edge reefs during the spawning period, and return to mid-shelf reefs afterward; however, the topic of how female gag grouper spend the rest of the year is relatively unstudied. Using data from NFWF funded Gulf Reef Fish Survey and At-Sea Observer projects sampling recreational private and for-hire fisheries, this study will characterize the locations, seasons and depths where the relevant fisheries interact with female gag grouper.

Mapping Benthic Habitat on the West Florida Shelf Using Multibeam Acoustics and Towed Underwater Video to Improve Fisheries Science and Management

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The West Florida Shelf (WFS) is an extremely important area for both commercial and recreational fisheries. However, the lack of habitat maps in this area makes planning fisheries independent monitoring surveys difficult and hinders the ability to manage and monitor fish stocks and ecosystems over time. As of 2015, only 5% of the WFS had been mapped in high resolution using a multibeam echosounder with little effort expended to infer and verify habitat type. After the Deepwater Horizon oil spill in 2010, the importance and paucity of critical baseline data such as these became extremely apparent. In 2015, The Continental Shelf Characterization, Assessment, and Mapping Project (C-SCAMP) began using a multibeam echosounder and towed underwater video to map benthic habitats and improve our understanding of fish-habitat relationships on the WFS. For this study, high resolution multibeam bathymetry and co-registered backscatter data were collected and processed. A portion of

these areas were then “ground-truthed” using towed video transects to assess habitat type and identify fish. Habitat maps were created using a statistical classification model that predicts benthic habitat type based on the acoustic signature. Progress towards a unified habitat map of the West Florida Shelf will be presented including habitat interpretation of multibeam surfaces collected by other groups prior to this project, particularly focusing on those within Marine Protected Areas. Applications of the resultant habitat maps for fisheries management will be demonstrated and discussed.

Seasonal Dietary Shifts of Red Snapper (*Lutjanus campechanus*) from Northern Gulf of Mexico Waters off of Mississippi

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Over the last several decades Red Snapper (*Lutjanus campechanus*) diets have been studied extensively with little consensus on feeding behaviors. Those studies were based on gut content analysis and were spatially and temporally restricted, leading to assumptions that seasonal dietary patterns are indicative of year-round behavior. We studied the diets of Red Snapper collected from the northern Gulf of Mexico (NGOM) off Mississippi each month between April and October of 2016 and 2017, sampling three oil/gas platforms, two non-structure controls, and three rigs to reef (or two rigs to reef and one fish haven) sites in each of three depth strata (shallow, <20m, Mid, 20-49m, and Deep, 50-100m). 1492 Red Snapper and their associated prey items were analyzed. Gut content was visually identified and DNA barcoded where possible. Fish muscle tissue and prey from the gut content were then analyzed for carbon and nitrogen stable isotope values. Both classic gut content analysis and stable isotope mixing models show a shift in the prey community of Red Snapper seasonally. This shift is coincident with periods of high riverine outflow that significantly alters the salinity regime and nutrient inputs into the NGOM. Correlation between environmental parameters and Red Snapper diet may therefore be useful in determining what prey species will be available to Red Snapper under different hydrological regimes caused by freshwater input from rivers and flood control structures, as well as with seasonal changes. Furthermore, this study suggests that comprehensive seasonal sampling is necessary for highly dynamic systems such as the NGOM in order to determine the diets of reef fish with high site fidelity.

Foraminiferal Biomonitoring as an Effective Tool for Investigating the Dispersion of Bio-Deposits from a Cage Culture Farm in the Persian Gulf

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Large-scale and intensive mariculture of finfish is inevitable in the Persian Gulf, while this activity at the proposed sites poses a serious threat to the environmental integrity of this important body of water and marine ecosystems. The negative impact to the benthic community is largely due to over enriching the sediments beneath the aquaculture site because of excessive bio-deposits. We report here on bio-monitoring observations of biodeposit dispersion at a relatively deep-water cage culture farm in the northern Persian Gulf. Benthic foraminifera are well-known environmental bio-indicators because of their short lifespan and quick response to environmental changes. These bio-indicators are abundant in bed sediments of the Persian Gulf. Foraminiferal assemblages also can be used as excellent indicators for environmental changes caused by floating fish farms. This study tests foraminferal bio-monitoring

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

Session 023: Understanding Processes Associated with Sub-Surface Oil and Gas Releases, with Special Focus on the MC20 Site in the Northern Gulf of Mexico

Visual Quantification of Oil and Gas Bubbles from MC20

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Persistent oil slicks have been observed within Mississippi Canyon lease block 20 (MC20), near the toppled Taylor Energy well jacket, following Hurricane Ivan's passage through the Gulf of Mexico in 2004. Acoustic surveys have observed prominent plumes of gas and oil rising from near the well jacket to the surface. The objective of this research was to qualitatively evaluate these plumes and to quantify the density and size frequency of bubbles. An oil and gas bubble collecting and imaging device (bubblometer) was constructed. Its components include a calibrated visualization chamber, transparent collection tube, and four sample cylinders. The bubblometer was mounted on the lower platform (skid) of a Comanche ROV. In its retracted position, the lower opening of chamber was closed; a hydraulic actuator extended the bubblometer beyond the skid so that the chamber was open at the bottom. Location of the plumes was determined by a NOAA acoustician, allowing the ROV operator to navigate to the site and position the bubblometer within the plumes. Video of bubbles passing through the bubblometer visualization chamber and entering the collection tube was recorded with an HD video camera calibrated to resolve 4 pixels/mm. Video frames were analyzed with a Matlab based machine learning algorithm to count, classify, and measure gas and oil bubbles to provide an estimate of oil flux at the MC20 site. A total of 12,139 bubbles were counted (5,881 gas-oil mixture and 6,258 oil) and were typically 5-10 mm or greater. Mixed bubbles contained 35.6% oil by volume.

Session 024: To Disperse or Not to Disperse? That Is the Question

An Interpretation of Factors Accounting for Deep Oil Plumes Following Deepwater Horizon

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* Student presenter

The experimental use of the sub-surface dispersant injection (SSDI) strategy for Deepwater Horizon (DWH) was done ostensibly for two reasons: (1) to reduce the quantity of volatile organic compounds (VOCs) entering the atmosphere around workers above the blowout, and (2) to more efficiently treat the large volumes of oil escaping from the well, compared to traditional surface application with aircraft (which was also done). Since DWH, the oil industry has invested in new technologies for delivering dispersants to BOPs and has stockpiled dispersants with the expectation that SSDI will be used as a primary response strategy for the next "ultra-deep" (i.e., ≥1,500 m) blowout. Despite extensive research on the topic, a number of essential questions remain unanswered, including: *How effective was the use of SSDI in reducing the quantity of oil and VOCs eventually reaching the surface?* Answering this question has enormous practical and economic consequences, as the marine oil industry both in the Gulf of Mexico and globally is increasingly reliant on ultra-deep production. However, current uncertainty in the fundamental mechanisms involving deep sea blowouts and the efficacy of SSDI as a response countermeasure remain. Thus, there remains a fundamental dilemma for oil spill responders: to disperse at depth or not. In this paper we discuss processes and information which argue that the creation of deep oil plumes at 1,100 m water depth as a result of DWH were in part created by a variety of physical and chemical processes other than SSDI. Further we consider scientific approaches to help resolve the dilemma for oil spill responders regarding the use of SSDI for the next deep blowout.

Assessing the Genotoxicity and Tumorigenic Potential of Crude Oil and Dispersants in Mice

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To assess the lung toxicity of oil and dispersants, we exposed wild-type C57BL6 (B6) male and female mice (*n*=3 of each sex per treatment) by oropharyngeal aspiration to 0.1 WAF of crude oil, Corexit 9500, Corexit 9527, 9500+oil and 9527+oil and saline (as control). On day 14, total lung RNA was isolated from the left lung for RNA-seq analyses and the right lung was fixed by perfusion with formalin for histological evaluation. Lung tissue sections from the exposed mice revealed modest lung injury and inflammation due to the dispersants. Analyses of RNA-seq data by KEGG-pathway-based differential expression revealed that Corexit 9527 treatment of male mice elicited the largest changes with upregulation of 21 KEGG pathways at an FDR <0.10. Among the top of upregulated pathways were p53 signaling (mmu04115) (p=5.41e-5), a well-described response to DNA damage, three DNA repair pathways (mmu03460 Fanconi anemia pathway, mmu03430 Mismatch repair, mmu03410 Base excision repair) as well as Cell cycle (mmu04110) and DNA replication (mmu03030) pathways. Most of the above pathways were also upregulated in female mice treated with Corexit 9527, e.g., p53 signaling (p=2.84e-3), mismatch repair (p=2.10e-3), Fanconi anemia pathway (p=6.39e-4), DNA replication (p=1.37e-5) and cell cycle (p=5.03e-6). Similar results were achieved through DAVID enrichment analyses of genes upregulated (at p<0.05) by Corexit 9527, where functional terms of "DNA damage" and "DNA repair" achieved enrichment p values of 5.68e-11 and 2.37e-10, respectively, in male mice and 9.13e-5 and 1.85e-4, respectively, in female mice. Overall, our RNA-seq results are consistent with the hypothesis that dispersant Corexit 9527 promotes lung injury and inflammation by inducing DNA damage, leading to secondary DNA repair and replication responses, which may contribute to lung carcinogenesis.

* Student presenter

Interfacial Phenomena of Natural Dispersants for Crude Oil Spills

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The purpose of this study is to simulate the dispersion process of crude oil into water by using a nature dispersant system, which includes a nature surfactant (non-gelling extract, NE), a food-grade solvent (d-limonene, DL), and silica nanoparticles (SiNPs). This functional surfactant was extracted from the mucilage of the *Opuntia ficus-indica* cactus leaves. It was found that surface tension values of water were decreased with the application of NE, and they followed a linear relationship with respect to the natural logarithm of the concentrations of NE. We found that the application of NE in the water phase led to decreasing oil-water surface and interfacial tensions. Surface tension measurement, baffled flask test, shaking turbidity test, and droplet size measurement were performed with crude oil to study the synergistic effect of DL and SiNPs on NE as a dispersant system. It was found that the oil-in-water (O/W) emulsion had a lower surface tension due to the application of DL, which can push the emulsion balance actively from W/O emulsion towards dispersion. Furthermore, the addition of the SiNPs increased the stability of O/W emulsion. The baffled flask test showed that the dispersion effectiveness of NE had been significantly improved with the synergy of both DL and SiNPs. The ratio of NE/DL/SiNPs has also been optimized through the baffled flask test. The average droplets size of O/W emulsion was smaller in the systems with NE+DL+SiNPs when compared with the systems using the conventional dispersant COREXIT® EC9500A by droplet size analysis via optical microscope. The smaller droplets size implies that NE+DL+SiNPs would provide better stability to O/W emulsion. The shaking turbidity test confirmed that NE+DL+SiNPs maintained the highest stability throughout the 12-hour experiment.

Aerogels: Improving Oil Spill Response with Advanced Materials

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There has been nearly no innovation on shoreline oil spill response technologies last two decades. Here, we explore the use of two types of aerogels, Cabot™ Thermal Wrap® (TW) and Spaceloft® (SL), which can be autofactured in a continuous fabric geometry, rolled out as protective barriers, and subsequently reclaimed with minimal human intervention. Our results showed that these aerogel composites offer several advantages: (1) nearly twice as high oil uptake as similar polypropylene and polyurethane foam (PUF) devices without significant water uptake, (2) excellent reusability (10 cycles), (3) high oil recovery (40-60%) following mechanical pressing with modest force (40 N). Findings from a life cycle assessment model demonstrated that these materials are competitive from a cost and environmental sustainability perspective when compared to state-of-the-art PUF sorbents. In particular, when SL aerogels are burned for energy recovery in waste-to-energy facilities, aerogels could generate approximately 8×10^3 MJ/ m^3 oil in single and multiuse scenarios. SL aerogels with reusability advantages offered energy and materials savings even when used once and disposed via landfill. In contrast, used PUF sorbents take up a large amount of water with oil, and they generally are landfilled as a result. Finally, we will discuss the design efforts to oil recovery device for aerogels, which could automate shoreline response.

* Student presenter

Evaluating the Relative Sensitivity of Atlantic Scleractinian Corals to Oil and Dispersed Oil to Better Inform Spill Response Decision Making

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Coral reefs are frequently at risk of exposure to petroleum from a range of sources and are one of the highest valued natural resources for protection in oil spill response management. A significant challenge in evaluation of spill response decisions is the frequent lack of reliable organismal toxicity data for qualitative and quantitative comparisons of differential resource impacts. This research uses metrics that emphasize sublethal indicators of effect, which may be more representative of actual exposures, in order to support effective decision-making and response should a spill occur near coral reefs. The sensitivity of the Atlantic scleractinian coral species *Acropora cervicornis, Porites astreoides, Siderastrea siderea, Stephanocoenia intersepta,* and *Solenastrea bournoni* to hydrocarbon exposure was assessed with 48-h assays using 1-methylnaphthalene, phenanthrene, toluene, MC252 crude oil and chemically dispersed crude oil (Corexit 9500). Single compound acute and subacute endpoints were used for species sensitivity comparisons, and to determine the target lipid body burdens for each coral. Results indicated that the most sensitive coral tested (*A. cervicornis*) is more resilient to hydrocarbon exposure than 60% of the species with similar effect data, possibly due to the lipid-rich nature of coral tissue and their ability to secrete mucus. This predicted resiliency was examined using MC252 crude oil and chemically dispersed crude oil assays. Detailed hydrocarbon exposure characterization and subacute/acute affects were used in a toxic unit approach to assess toxicity and evaluate the potential impacts of dispersant use on these coral species. The results of this study provide a framework for the prediction of oil impacts and impact thresholds on the coral animal and related habitats, improving Net Environmental Benefit Analysis (NEBA) of response options in coral reef environments.

Development of an Oil Dispersant Using Biosurfactants for Oil Spill Treatment in North Atlantic Ocean

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Environmentally friendly biosurfactants (i.e., lipopeptides and rhamnolipids) were investigated as an alternative to chemical surfactants being applied in dispersants. Mixed with conventional surfactants (i.e., Span 80, Tween 80, DOSS), biosurfactant-surfactant mixtures were prepared. The mixtures were preliminary screened based on the oil-water interfacial tension reduction, emulsion capacity, and HLB value. The synergistic interaction of the selected mixtures was also evaluated based on micellar composition and micellar interaction. The selected surfactant mixture was further mixed with solvents and evaluated for their dispersion efficiency of heavy oil (i.e., Bunker C) and medium oil (ANS) at 25°C and 4°C respectively, using the seawater collected from North Atlantic Ocean. The distribution of the dispersed oil droplets was determined, and the toxicity of dispersed oil droplet was also investigated. The droplet size decreased with increasing dispersant-to-oil ratio. The toxicity test also proved that the mixture can be classified as low-toxic and thus can be considered as a potential alternative to conventional oil-spill dispersants.

* Student presenter

Exploring a Novel Adsorption Material for Decanting Water Treatment

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In a marine oil spill accident, skimming is one of the most commonly used response technologies to recover spilled oil from sea surface. Skimmer operation, however, recovers a large amount of water in the form of emulsion or free water. Decanting the recovered water thus becomes a critical process as it could greatly increase storage capacity and save the time for oily water transportation. Therefore, a more efficient oil/ water separation technology is urgently needed to treat the recovered mixture to an acceptable level and overall to improve the marine oil spill response efficiency. In this work, graphene oxide (GO), was evaluated as a rapid and effective adsorbent under ambient temperature and seawater conditions. GO was prepared by commercially available graphite using modified Hummers method. The prepared GO was characterized by X-Ray diffraction, UV-Vis, Scanning Electric Microscope (SEM) and Fourier-transform infrared spectroscopy (FTIR). The typical GO peak was found in XRD result and the specific absorbance peak of UV-Vis was also observed. FTIR indicated the existence of -OH, -COOH and aromatic functional groups. The prepared GO was dispersed in distilled water and added into emulsified oil and seawater. After adsorption of oil, the decanted water was further filtered to remove the floating particles before oil and GO residue analysis. In this study, the removal rate of n-alkanes reaches over 99%, meanwhile 16 PAHs were not detectable in the decanted water. Droplets, in the range of 0.3 nm to 1 µm, were not detectable in this study. The GO particles were not detectable in this treated water. Given the amphiphilic of GO, it has the characteristics as a surfactant. The nonpolar graphene tends to attract nonpolar fractions of crude oil. The polar part of GO attacks asphaltenes and resins of crude oil. This work presents a promising onsite separation technology, which can efficiently separate oil from emulsion during decanting process.

Session 025: Large Marine Vertebrates in the Northern Gulf of Mexico Ten Years After the Spill: New Findings, Synergies, Collaborations, and Opportunities

Bottlenose Dolphins and Red Tide Harmful Algal Blooms: Are Patterns of Dolphin Responses Emerging from Repeated Events?

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Bottlenose dolphins exhibit strong site fidelity to many Gulf of Mexico bays that experience red tide harmful algal blooms. Blooms vary in spatial coverage, duration, and severity, but can cause direct dolphin mortality from brevetoxins, as well as lagged ecological impacts from prey fish mortalities. A severe red tide along the central west coast of Florida in 2005-06 was associated with temporary changes in dolphin habitat use, declines in body condition, and increased adverse human interactions, including deaths of 2% of resident Sarasota Bay dolphins from recreational fishing gear ingestion. Fish surveys documented a decline of 75% for the dolphins' primary prey fish, suggesting a reason for increased interest in anglers' bait and catch. Fish numbers did not return to pre-bloom levels for two years, and dolphins continued to exhibit elevated levels of human interactions. Were the changes

observed in association with the 2005-06 severe red tide a model for what may happen as blooms are expected to increase in severity and frequency with climate change, and if so, what can be done to reduce human impacts to dolphins? A severe red tide in 2018-19 is providing an opportunity to look for patterns of changes. We have documented the loss of 88% of dolphin primary prey fish, and initial findings indicate changes in dolphin behavior, trophic level at which they are feeding, body condition, and occurrence of skin lesions. Our passive acoustic monitoring network is documenting dramatic ecosystem changes. Within a 3-week period, we disentangled two 2-yr-old calves from recreational fishing line in areas affected by the bloom. Continuing research is focused on determining whether we can predict circumstances under which increased adverse human interactions might be expected to occur, allowing us to proactively target outreach efforts to try to reduce anthropogenic impacts, and in assessing the resilience of the ecosystem to severe red tide events.

Developing a Novel Remote Tag Attachment Technique to Better Understand Small Cetacean Movement Patterns in the Northern Gulf of Mexico

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The National Marine Fisheries Service manages one species of small cetacean in Gulf of Mexico coastal waters and an additional seven species in continental shelf waters. Movements between and among habitats of these species are relatively unknown, which limits the ability of management agencies to develop strategies for assessing anthropogenic impacts. Following the Deepwater Horizon oil spill, the Natural Resource Damage Assessment estimated that 38% of coastal bottlenose dolphins and 4% of continental shelf small cetaceans were killed as a result of DWH oiling, and that these stocks are a priority for management and conservation efforts. As restoration efforts are implemented in the Gulf of Mexico, it is essential to monitor the status of these stocks. New methodologies to safely and efficiently collect data and assess threats to coastal and continental shelf small cetaceans are essential as these species continue to be exposed to numerous anthropogenic stressors. The objectives of this project are (1) to develop a new and innovative tool to remotely attach telemetry devices to monitor movement patterns and habitat use of small cetaceans; and (2) to deploy satellite tags remotely on free-swimming small cetaceans in the coastal and continental shelf waters of the Gulf of Mexico to facilitate safe collection of data on movements and critical habitats for these species that can be used to inform management agencies on appropriate management and restoration strategies. Over the past two years, scientists and engineers have worked together on Objective 1 to develop a prototype for remote tag attachment. During October 2019, an in-field feasibility assessment of this prototype occurred along the coastal waters of Panama City, Florida. Additional testing on stranded carcasses is ongoing to refine the remote tagging methodology before moving on to Objective 2, in which remote tag deployments are planned for Spring/Fall 2020.

* Student presenter

Assessment of Sublethal Cardiac Injury in Bottlenose Dolphins (*Tursiops truncatus*) in the Gulf of Mexico Following Exposure to Deepwater Horizon Oil-Associated Chemicals

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Health studies conducted in the wake of the Deepwater Horizon (DWH) oil spill represented significant progress in characterizing oil-associated effects on cetaceans; however, some critical questions remained unanswered. In 2016, an increased prevalence of systolic heart murmurs was noted in dolphins from heavily-impacted Barataria Bay, LA (BB) relative to those in Sarasota Bay, FL (SB), outside the oil spill footprint. Due to limited cardiac diagnostics in field protocols, the effects of oil on cardiac health have not been fully evaluated. To address this need, innovative field-ready techniques for cardiac evaluation were developed with U.S. Navy dolphins and then applied to free-ranging BB and SB dolphins during comprehensive health assessments (2017- 2018). Systematic cardiac auscultation detected fixed or dynamic murmurs in the majority of animals regardless of oil-exposure history, and most murmurs (95%) were due to benign elevation of flow velocity through one or both cardiac outflow tracts. Telemetric 6-lead electrocardiography detected arrhythmias in more BB dolphins (43%) than in SB dolphins (29%), with all animals having an underlying normal sinus arrhythmia. Arrhythmias were considered low to moderate risk for adverse cardiac events and included atrial and ventricular premature beats, sinus tachycardia, and 2nd degree atrioventricular block. Echocardiography showed the mean interventricular septal wall (IVS) thickness was less ($p=0.0031$) in BB adult males (meanIVS = 0.32 cm ± 0.05 SD) compared to SB adult males (meanIVS = 0.42 cm ± 0.07 SD). However, it is currently unclear if this difference is an indication of cardiac disease or physiologic differences. Potential mechanisms for cardiac injury were evaluated by retrospectively examining histologic lesions in tissues of dead, stranded dolphins. Dolphins within the oil spill footprint had a higher prevalence of cardiac fibrosis than control animals stranding outside the spill area (44% vs 19%, $p=0.002$).

Estimation of Long-Term Regional Density Variations of Sperm Whales in the Mississippi Canyon Area of the Gulf of Mexico from Acoustic Recordings

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Passive acoustic monitoring is a critical tool to study deep-diving marine mammals, such as sperm whales. The Littoral Acoustic Demonstration Center-Gulf Ecological Monitoring and Modeling (LADC-GEMM) consortium collected broadband acoustic data in the Mississippi Canyon area near the vicinity of the 2010 oil spill site between 2001 and 2017. These data allow inference of short-term and long-term variations in regional abundance of sperm whales. Potential sperm whale clicks were detected by using a band-energy-based method to search for acoustic events above a user defined threshold in the click's production band (3-20 KHz). The probability of detection to convert acoustic activity to density estimates was determined by two different approaches: by currently broadly utilized Monte Carlo simulation and by localizing detected calls. The results show that the sperm whales are present in the region throughout the year but have lower density during winter months. The habitat preference shift was observed after the 2010 oil spill with activities higher at the sites further away from the spill site. The results indicate the importance of long-term spatially distributed acoustic monitoring in

* Student presenter

understanding how environmental disasters affect marine mammal population and their habitat. [This research was made possible in part by a grant from The Gulf of Mexico Research Initiative].

Changes in Bottlenose Dolphin Immune Functions Associated with the Deepwater Horizon Oil Spill in the Northern Gulf of Mexico—A Recurrence?

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The explosion of the Deepwater Horizon platform in 2010 resulted in an unprecedented release of oil in the Gulf of Mexico. Comprehensive capture-release health assessments were conducted on bottlenose dolphins in Barataria Bay, LA (BB) in 2011-2018, to assess potential health effects resulting from exposure to oil. Results were compared to those for Sarasota Bay, FL (SB) dolphins not exposed to oil. We previously reported significant increases in T lymphocyte proliferation, as well as lower Th1 cytokines, higher Th2 cytokine IL-4, and lower Treg cytokine IL-10 in BB 2011 compared to SB, with values returning to "normal" between 2013-2016. These changes in immune functions were generally similar to those in other species upon exposure to oil or PAHs, and consistent in time and space with exposure to oil from DWH. Interestingly, results from health assessments in BB 2017-2018 showed a recurrence of increased T cell proliferation and a cytokine balance tilt towards a Th2, rather than Th1 or Treg response, as was observed in 2011. In 2018, BB dolphins had significantly more circulating Treg cells than SB dolphins. *In-vitro* stimulation resulted in greater Th2 responsiveness in BB compared to SB dolphins, and *in-vitro* exposure of SB dolphin cells to oil also resulted in enhanced Th2 responsiveness. Further exploration showed that dolphins born after the spill appeared to exacerbate the trend in BB dolphins' cytokine balance, suggesting the possibility that dolphins born after the spill also suffered negative health consequences of exposure to oil, or were potentially exposed to other stressors in 2016 and later. Mice we experimentally exposed to oil had a significant increase in T lymphocyte proliferation and in circulating Treg cell number, as observed in BB dolphins, but multi-generational effects were not observed. Our study highlights the need for assessing subtle, sub-clinical aspects of health to understand potential ongoing and future consequences of exposure to oil spills, and demonstrates the value of using both *in-vivo* and *in-vitro* laboratory studies to better understand the strength of the link between oil exposure and effects observed in field studies.

Sparse Representation-Based Classification of Sperm Whale and Beaked Whale Clicks from the Gulf of Mexico

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Sperm whales (*Physeter macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*), and Gervais' beaked whale (*Mesoplodon europaeus*) are known to produce high frequency echolocation clicks, which distinguish them in passive acoustic records. High frequency (up to 65 kHz) implies high sampling rates that lead quickly to a large amount of data to be processed for long-term surveys (months to year). As a result, the development of efficient and robust automatic detection and classification methods is

needed to analyze this growing amount of acoustic data. Moreover, these methods should be suitable to real-time applications. We propose a general method of detecting and classifying multiple echolocation clicks. The proposed approach relies on the sparse framework recently developed in signal processing and machine learning. Sparse representations express a given signal as a linear combination of base elements in which many of the coefficients are zero. Such representations can capture the click variability and can be automatically learned from the time series of the digitized acoustic signals, without requiring prior transforms such as spectrograms, wavelets, or cepstrums. Rejection of any "unwanted classes" or false alarm is achieved without feature learning. The proposed method is modular. Other classes can be appended to or removed from the classifier without requiring retraining. The classifier is easy to design since it relies on few "easy-to-tune" parameters. The method is applied to passive acoustic data collected in the Gulf of Mexico in 2017. It allows to automatically identify beaked whale and sperm whale clicks in real time from continuous stream of acoustic data after the clicks dictionary is learned. [This research was made possible by a grant from The Gulf of Mexico Research Initiative.]

Population Modelling to Predict Recovery Trajectories of Marine Mammal Stocks Impacted by the Deepwater Horizon Oil Spill

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The Deepwater Horizon oil spill impacted many stocks of marine mammals in the Gulf of Mexico. As part of the Natural Resources Damage Assessment (NRDA), population models were constructed, based on existing data as well as data collected post-spill as part of the NRDA, and were used to assess the extent of population declines and predict recovery trajectories. Age-structured models were considered for Bay, Sound and Estuary (BSE) and coastal bottlenose dolphin (*Tursiops truncatus*) stocks, and stage-structured models for all the other stocks and taxa. The NRDA models forecast that significant decline would continue in many stocks over the decade following the spill, primarily due to sublethal but chronic health effects continuing to affect survival and reproductive rates. We present ongoing work to update these models, undertaken by members of the Consortium for Advanced Research on Marine Mammal Health Assessment (CARMMHA). Additional information to use as model inputs was generated by CARMMHA thematic and field projects, which has improved our understanding of the ongoing cardiac, immune and indirect (prey-related) effects of the oil spill on BSE bottlenose dolphins, as well as the Northern Coastal Stock. This information formed part of formal expert elicitation exercises which considered the time taken for exposed individuals to recover to baseline levels of vital rates, and on population parameters related to density dependence. Both considered the transferability of information gained by field studies of BSE and coastal bottlenose dolphin stocks to offshore stocks and other species (e.g. deep diving species like sperm whales). This updated assessment comes at a crucial time, when the original NRDA models predicted the impact (in terms of reduction in population size) would be most severe.

* Student presenter

Distribution Patterns of Sperm Whale and Oceanic Dolphin Sightings from Vessel Surveys Conducted Before and After the Deepwater Horizon Spill

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Between 2003 and 2009, the NOAA Fisheries, SEFSC conducted three line-transect vessel surveys (historical dataset) to assess the distribution and abundance of cetaceans in the oceanic waters of the northern Gulf. In 2017 and 2018, as part of the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS dataset), three additional surveys were conducted. Eighteen different species of cetaceans were documented, including sperm whales and oceanic dolphins (Stenellids and unidentified dolphins sighted beyond the continental shelf). During the historical surveys, 733 cetacean sightings were recorded, including 137 sightings of sperm whales and 291 of oceanic dolphins in over 18,700 kilometers of effort. For the GoMMAPPS surveys, 451 sightings were recorded, including 111 of sperm whales and 153 of oceanic dolphins in 18,900 kilometers of effort. Mapping the sperm whale sightings indicated a potential shift from the east (historical) to the western Gulf (GoMMAPPS); whereas, the distribution of oceanic dolphins appeared generally similar in both datasets. Surveyed waters of the Gulf were divided into eastern (longitudes 81°W to 86°W), central (87°W to 92°W), and western (93°W to 96°W) and the number of sightings of sperm whales and oceanic dolphins were calculated per km of effort beyond the continental shelf in each area for both the historical and GoMMAPPS datasets. For sperm whales there was a 4.5-fold increase in the number of sightings per km of effort during the GoMMAPPS surveys in the western Gulf and the same decrease in the east, while numbers remained similar in the central Gulf. Sightings per km of effort of oceanic dolphins remained somewhat similar in the eastern and western Gulf while in the central Gulf there was a 2.6-fold decrease during the GoMMAPPS surveys. In addition to visual sightings, acoustic detections of sperm whales from towed array will be evaluated for evidence of a potential western shift in distribution.

Health and Behavioral Responses of Common Bottlenose Dolphins (*Tursiops truncatus*) in Low Salinity Waters Within the Barataria Basin in Louisiana

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More than 3,000 common bottlenose dolphins (*Tursiops truncatus*) are estimated to inhabit Barataria Basin (BB), Louisiana. It is unclear how BB dolphins respond to fluctuating salinity, which in some areas declines to 0 parts per thousand (ppt) at times. In 2017, we temporarily caught and attached satellite-linked tags to 17 BB dolphins (10 females; 7 males) to evaluate movements relative to modeled salinity trends. We also collected biological samples and conducted physical examination, pulmonary and reproductive ultrasound, and skin assessment. We compared dolphin locations to mean daily salinity estimates provided by the Water Institute of the Gulf from a Delft3D model. Despite extremely low-salinity conditions, most dolphins maintained a limited range (averaging 3.4 km net movement per day within 10-20 km of their capture locations). One dolphin spent at least 49 consecutive days in waters estimated to be under 7.5 ppt salinity. Two dolphins had unusually broad movement patterns across the BB (averaging 7.6 km net movement per day). However, despite the broader ranges, their movements

* Student presenter

were not associated with salinity gradient. Across our analyses, we found no evidence that any of the dolphins moved in response to seasonal salinity changes. We identified a high prevalence of skin lesions, as well as abnormalities in serum biochemical markers and urine:serum osmolality ratios for dolphins sampled in lower salinity portions of the basin. A standardized analysis of health records assisted in the determination of the potential long-term impacts of low salinity exposure in natural events (e.g., extreme weather) and anthropogenic events (e.g. flood control, sediment diversions). This study provides information on potential health effects and behavioral responses of dolphins and can inform study designs to monitor associated health impacts from low salinity exposure.

Developing an Operational Sea Turtle Stranding Analysis System to Improve Understanding of Sea Turtle Mortality in the Gulf of Mexico

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All species of sea turtles are listed as threatened or endangered under the Endangered Species Act. Five of the world's seven species of sea turtles are found within the Gulf of Mexico (GOMX) and are subject to both natural and anthropogenic sources of mortality. Understanding factors contributing to sea turtle mortality is a primary focus of the Gulf of Mexico Sea Turtle Early Restoration Project. For this purpose, a sea turtle stranding analysis tools system was developed with the goal to estimate the probable at-sea locations of origin of stranded sea turtles (i.e., the source of mortality) and predict the influence of environmental conditions on animal drift and dispersal. This system consists of a user-friendly web interface and two sea turtle mortality analysis tools: Backcasting Analysis and Mortality Mapping (BAMM) and Beaching Probability Index Tool (BPI). Both tools conduct ocean physical model-based drift analysis using winds, current and ocean conditions from physical numerical models. BAMM incorporates drift analysis with the sea turtle stranding records provided by the National Sea Turtle Stranding and Salvage Network to estimate likely mortality site. BPI is a stranding probability prediction tool, which allows users to ascertain likelihood of floating carcasses stranding on GOMX beaches and to inform stranding surveillance efforts. This information will provide valuable insight for resource managers and allow stranding networks to better respond to and plan for sea turtle stranding emergencies.

Transcriptomic Analyses of Bottlenose Dolphin Blood and Skin to Identify Additional Biomarkers and Pathways to Inform Cetacean Health Assessment

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In the wake of the Deepwater Horizon oil spill numerous adverse health impacts have been observed in bottlenose dolphins, including compromised reproductive, pulmonary, cardiac, immune and adrenal functions. Veterinary assessments of these systems in wild animals can be difficult and costly. However, samples for -omics based analyses can be obtained with minimal stress to the animal and methodologies are increasingly cost-effective. Transcriptomic based approaches allow for a robust analysis of the molecular mechanisms involved in disease and stress response and may allow for earlier detection of changes in health. The blood transcriptome contains a broad range of transcripts and markers have

been identified in many species, whereas the skin transcriptome generally exhibits lesser transcript diversity but is easily sampled in cetaceans via remote biopsy. This study is leveraging the wealth of data that has been obtained from bottlenose dolphin health assessments in the northern Gulf of Mexico (NGoM) since 2013 to explore changes in the blood or skin transcriptome that are associated with observed disease states, biochemical or physiological measurements, or environmental factors. Transcriptome profiling by RNA-seq of 76 blood samples from Barataria Bay, LA or Sarasota Bay, FL and 28 skin samples from Barataria Bay, LA is complete and bioinformatic analyses are ongoing. Weighted gene co-expression network analysis, principal component analysis, pathway mapping, and differential expression analysis will be used to identify genes or networks that are associated with various stressors or health parameters of importance to dolphin populations in the NGoM. Interrogation of the transcriptomic data in the context of the broad health assessment data set will enhance wildlife veterinarians' abilities to characterize and identify stress-related disease and improve the extrapolation of molecular level diagnostic tools to ecologically relevant individual or population levels.

Spatial, Temporal, and Individual-Level Variation in Northern Gulf of Mexico Common Bottlenose Dolphin Diet

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Ecological factors that change over spatial and temporal scales may drive dietary variation of generalist foragers at both population and individual levels. Using stable isotopes from skin samples, we examined the diets of common bottlenose dolphins (*Tursiops truncatus*) captured in 2018 at two field sites in the northern Gulf of Mexico: Mobile Bay, Alabama (MB) and Barataria Bay, Louisiana (BB). We examined in detail temporal (2011 - 2018) and individual-level dietary variation in Mobile Bay using isotopes from liver, muscle, and skin. To provide further insight into individual-level variation in isotopic signatures, we also satellite-tracked 18 tagged dolphins in MB in 2018. In 2018, dolphins from both field sites fed primarily on fish (MB 74%; BB 95%), with smaller amounts of decapods (MB 18%; BB 5%) and, in MB only, cephalopods (9%). In 2011, dolphins in MB fed primarily on cephalopods (liver 67%, muscle 48%, and skin 55%), particularly in weeks prior to sampling. Fish were the dominant prey group in all other years, while cephalopods likely comprised < 20% of dolphin diets in those years. The difference in diets between 2011 and other years suggests potential interannual variation in the availability of prey groups, particularly squid. We found considerable among-individual variation in carbon isotope values despite diet similarity, suggesting different foraging habitats rather than prey groups. Data from the satellite-tracked dolphins confirm that among-individual variation in diet maybe related to fine-scale movement patterns in MB dolphins. By comparing long-term stable isotope data from common bottlenose dolphins, and incorporating movement data, we found that dolphins are capable of considerable dietary flexibility while maintaining relatively small ranges.

* Student presenter

Session 026: Modeling Oil Spills from Small to Large-Scales: Recent Research Results and Synthesis Toward Improving Oil Spill Response

SOSim: A Probabilistic Bayesian Model for Submerged Oil Tracking

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The deep depth and broad breadth characteristics of submerged oil found in the deep oceans during Deepwater Horizon (DWH) well blowout made the oil difficult to locate and track. Further, current models are limited in their accuracy to project oil movement in time, given the uncertainties and constraints typical of emergency response scenarios. Therefore, SOSim (Subsurface Oil Simulator) was developed to assist the operational response by exploiting limited field observations of oil concentrations in time and space, accounting for uncertainties and making time-updated predictions. SOSim uses probabilistic Bayesian inferential methods coupled with field observations and prior datasets from other oil trajectory models, such as SINTEF's Oil Spill Contingency And Response (OSCAR) model, to predict submerged oil trajectories with uncertainty bounds on the potential polluted areas. These prediction results represent distributions of the probability of finding submerged oil mass as a function of space and time. Results are plotted on a map with depth contours, to provide oil spill responders with a ground-truthed indication of the extent of polluted areas. In addition, SOSim can assist oil responders in developing field sampling plans, and updating them as new field observations become available, to support efficient choices of sampling locations in space. New data can then be input to SOSim to generate time-updated oil trajectory predictions, iteratively. These methods have been demonstrated versus historical data on the DWH spill. Current work includes the development of SOSim's capability for modeling fate processes and developing sampling strategies for operational response and natural resource damage assessment.

Effects of Diluted Bitumen Oil Products with Sediment on Benthic Organisms

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Diluted bitumen (dilbit) oil products are transported through pipelines across aquatic habitats and have the potential to impact freshwater and marine species, including benthic organisms. To understand better the effects on sediment dwelling organisms, 10-day bedded sediment tests using two different dilbit oil products, Cold Lake Blend and Western Canadian Select, were performed on two amphipod species, *Hyallela azteca* (freshwater) and *Leptocheirus plumulosus* (saltwater). The results showed EC25 value ranges of 3.39-6.69 g/Kg based on growth and survival, and LC50 values between 0.58 and 0.70 g/Kg based on survival for *H. azteca* and *L. plumulosus*, respectively. This study is the first to report the toxicity of sediment associated dilbit and is a step in the process to improve our understanding of the effects dilbit oil spills can have on often overlooked, yet extremely valuable, freshwater and marine benthic habitats.

* Student presenter

Impact of Bubble Size on the Budget of Turbulent Kinetic Energy and Mean Flow Structure in a Bubble Plume

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Bubble plume as a surrogate of oil spill plume has been extensively studied. However, the impact of sizes of particles (e.g., bubbles, droplets) on the mean characteristics and turbulent fluctuations of velocity, flux of volume and momentum, and kinetic energy in these multiphase flows are not well understood. Here we present an experiment with detailed analysis of budget equations for turbulent kinetic energy (TKE) in bubble plumes. We used two types of diffusers (i.e., an air stone and a single-hole orifice) to generate air bubbles with two different size distributions (median diameter of 2.5 and 5.5 mm for air-stone and single-orifice, respectively). Flow rates of 0.25 and 1.25 liter/min were used for each diffuser to expand data in the non-dimensional space. The velocity field was measured using a two-dimensional particle image velocimetry system. The profiles of mean and turbulent parameters in both radial and vertical directions were quantified and the impact of bubble sizes was investigated. Through the budget analysis, we found unbalanced TKE among shear production, advection from the mean flow, turbulent diffusion, and dissipation. The residual term in the TKE budget is likely associated with the direct energy production from bubbles, and we found the bubble production is correlated to the bubble sizes. The influence of bubble sizes on the turbulence in turn affects the mean flow velocities in the bubble plume, resulting in different behaviors of plume structures.

Use of Chemical Concentration Changes in Coastal Sediments to Compute Oil Impact Dates and Regions

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Oil spills can result in changes in chemical contaminant concentrations along coastlines. When concentrations are measured over time, this information can be used to evaluate the impact regions and dates. The objective of this research was to evaluate the oil impact dates for different regions. The results were based on the computation of oil spill chemical (OSC) concentration changes (CCC) within sediments in coastal zones after oil spills. By comparing the results from the CCC method with the results from models and remote sensing images during an active oil spill, it could be used to improve the accuracy of models and provide information useful for assessing human health risks and for decision-making. The CCC method was based on separating the target coastal zone into segments and then documenting the timing of large increases in concentration for specific OSCs within each segment. The dataset from the Deep-Water Horizon (DWH) oil spill was used to illustrate the application of the method. There are some differences in impact dates from different methods. Oceanographic information suggests that these differences may be caused by the impacts of river-induced fronts on OSC distributions that influence oil transport in the nearshore. Differences may also be due to the possible influence of submerged oil or from mixing within the freshwater and seawater interface that is unaccounted for by oil spill trajectories.

* Student presenter

Formation and Fate of Oil Particle Aggregates in the Gulf of Mexico Continental Shelf: Numerical Modeling

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Observations from the Deepwater Horizon event in the Gulf of Mexico showed that oil droplets, marine snow, and mineral grains combined and formed aggregates having a wide range of transport characteristics, which modified the dispersal and fate of oil. One type of these, Oil Particle Aggregates (OPAs), were composed primarily of a mixture of oil and mineral sediment. Though the Gulf of Mexico has some very turbid waters, to date, few numerical models have accounted for the range of aggregation processes likely to form OPAs. However, interactions between oil and mineral aggregates may be represented using techniques recently developed to account for sediment flocculation. As part of CSOMIO (Consortium for Simulation of Oil Microbial Interactions in the Ocean), we modified an existing, population dynamics-based flocculation model (FLOCMOD) to account for the formation of OPAs. The formation of OPAs changes the vertical transport of both the oil and the mineral grains; modifying sediment settling, while increasing deposition of oil to the bed. The new module, OPAMOD, is used for investigations into how interactions between oil droplets and sediment impact their vertical transport, including settling of oil to the Gulf of Mexico seafloor. A one-dimensional (vertical) version of this water column model has been implemented in the Regional Ocean Modeling System (ROMS) and used to represent various scenarios from the Gulf of Mexico continental shelf including oil spills during energetic storms, or within turbid river plumes. Parameterizations gained from the one-dimensional (vertical) model will be directly transferrable to a three-dimensional coupled oil-sediment-microbial model being developed by CSOMIO.

Simulation of Hypothetical Oil Blowout in Walker Ridge Field (Gulf of Mexico Region)

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The oil exploration associated with water bodies is worrisome due to the risk of spills, with harmful consequences for the population, economy, and environment. Numerical models can be employed to simulate the transport and fate of spilled oil in the ocean, becoming an important tool for mitigation and response operations. A simulation for a hypothetical blowout in a region located in ultra-deep waters (2913.88 m) in Walker Ridge Field (26.44927°N / 90.78335°W), Gulf of Mexico, was performed using a system of Lagrangian numerical models to determine the oil trajectories along the water column and the surface. This system is composed by three modules: Plume Dynamic Module, for the near-field; Advection-Diffusion Module, modelling the far-field; and Surface Module, modelling the oil slick on the surface. The simulation lasted for 30 days starting in January 01, 2019, with the blowout occurring along the 24 hours of the first day, releasing 8709 oil barrels. The ocean and wind datasets used as ambient conditions are respectively from Mercator Ocean and ERA5-ECMWF. The results indicate the great control of both subsurface and surface plumes by the complex system of currents, meanders and eddies in study region. Along the water column, in the first days the oil was displaced towards Southeast from the bottom to 500 m below the surface, changing the direction to Northeast at the top 500 m. The first oil droplets reached the surface approximately 3.5 h after the blowout. After 10 days, all subsurface oil was situated at the top 1000 m, with the droplets reaching the surface 100 km to the East and 75 km to the South from the blowout site. At the surface, the oil slick transport was controlled by an anticyclonic

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eddy centered around 25.5°N / 91°W, with part of the slick entering a meander associated with the eddy and transported towards the coast of Mexico. After 30 days none of the oil particles reached the coast and all oil had risen to the surface.

A Multi-Agent Based Multi-Objective Particle Swarm Optimization (MMPSO) for the Optimal Planning of Offshore Oil Decanting System

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The decanting system is usually used in a combination with oil skimmers. It ensures a portion of oily water to be separated from the recovered oil and returned to the ocean after proper treatments. How sound efficiency of the decanting system highly affects the total cost and time of the oil spill cleanup process. This paper presents a developed multi-objective particle swarm optimization with multi-agent system approach (MMPSO). The MMPSO method was evaluated by 6 traditional multi-objective functions. The results showed MMPSO can reduce 25% population size and 33.3% generations to achieve the same convergence as multi-agent particle swarm optimization. The MMPSO was further applied for a hypothetical case study of marine on-site decanting and wastewater treatment system. The optimal designs emphasized to select the types of physical separation technologies (i.e., gravity, hydrocyclone and coalescene separator), types of demusifier (i.e., Alcopol O 60%, Alcopol PG 70, BASF A, BASF B and Biodemusifier), disposal time of demusifier, and parameters of on-site advanced oxygen process wastewater treatment (e.g., flowrate, retention time, etc.). Multiple designs were provided under different required scenarios with the optimal response time and cost. The results showed a strong capability of the proposed approach in facilitating multiple processes in on-site oil decanting by recommending optimal management of sources. **Keywords**: multi-objective optimization, decanting system, multi-agent system, particle swarm optimization

Developing a Tool for Generating the Conditional Oil Spill Probabilities for Beaufort Sea Planning Area

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The Bureau of Ocean Energy Management (BOEM) oversees and administrates the oil and gas leasing, exploration and development plans in the U.S. Outer Continental Shelf (OCS). As oil spills may occur associated with these activities, BOEM conducts an oil spill risk analysis (OSRA) to estimate the oil spill statistics for the contingency planning in these areas. The OSRA first identifies an area where the offshore oil and gas exploration may occur and also the environmental resources in or near the OCS that could be potentially impacted by the oil spill before computing the spill contact statistics from the hypothetical spill locations to the environmental resources. Because the leasing area and environmental resources are pre-determined prior to the OSRA model run, a new OSRA run needs to be conducted if any changes are made later. To improve the efficiency of this process, a prototype tool is currently under development for the U.S. Arctic OCS, allowing the subject matter experts in BOEM to select any hypothetical leasing areas and assess the spill contact probability from these areas to the environmental resources of any kinds without a rerun of the OSRA model. The approach is based on millions of trajectories generated in the Chukchi and Beaufort Sea planning areas using a 20-year coupled ocean

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and ice model output along with the modelled surface wind data. The spill contacts to a set of rectangular grid cells (i.e. with spacing larger than the OSRA model grid but much smaller than the smallest environmental resource) covering the entire OSRA model domain will be archived in a database and analyzed later to derive the spill contact probability from a specific leasing scenario to a particular environmental resource. Users will get the oil spill statistics by providing the information on the leasing area and environmental resources.

Vertical Dispersion of Oil Droplets Induced by Langmuir Supercells in the Coastal Ocean

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Interaction between the wind-driven shear and the wave-induced Stokes drift in the upper ocean leads to Langmuir cells consisting of wind-aligned counter-rotating vortices. In inner-shelf regions undergoing strong wind and wave forcing during storms, Langmuir cells can reach the bottom of the water column while increasing in intensity and coherency. These full-depth Langmuir cells have been denoted as Langmuir supercells or LSCs because they provide a dominant mechanism for sediment resuspension and subsequent lateral transport by the current. LSCs have been discovered through their resuspension of sediments along the upwelling limbs of the cells. In the presence of oil broken up into droplets at the surface of the sea, LSCs also serve to entrain the droplets along the downwelling limbs of the cells. Lagrangian particle tracking simulations will be presented demonstrating the oil droplet entrainment dynamics induced by LSCs. The methodology consists of a steady-state Reynolds averaged solution of the flow resolving the LSCs with particle tracking based on a discrete phase model using a random walk method to account for the turbulence. Distributions of oil droplets induced by LSCs as functions of LSC structure and strength will be investigated. It is found that for weaker LSC, the droplets tend to accumulate primarily along the downwelling limbs underneath the surface convergence zones of the cells leading to the so-called Stommel retention zones (SRZs). Meanwhile, stronger, more coherent LSC lead to less pronounced SRZs and greater dispersion of the droplets within the upwelling limbs of the cells.

Large-Eddy Simulations of Oil Aerosol Plume Dispersion in Marine Atmospheric Boundary Layer

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In the aftermath of an offshore oil spill accident, oil droplet aerosol can be emitted into the air due to impacts of various physical processes on the surface oil slicks at the air-water interface, such as surface wave breaking, bubble bursting, and tearing by high wind. The subsequent airborne transport of oil aerosol by the wind turbulence in the marine atmospheric boundary layer (MABL) plays a crucial role for further spreading the environmental impact of the offshore oil spill accident. This airborne transport process is highly affected by the complex interactions between wind turbulence, sea-surface waves, and the atmospheric thermal stability in the MABL. In this study, we use a wave-phase-resolved large-eddy simulation model to simulate the oil aerosol plume dispersion in the MABL. This research was made possible by a grant from The Gulf of Mexico Research Initiative.

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Fluorescence Spectroscopy of Oil-Impacted Waters in the Gulf of Mexico: Enhancing Detection with a Microfluidic Platform Using Solid Phase Extraction

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The Deepwater Horizon (DWH) oil spill impacted various ecosystems and water bodies (offshore, coastal and wetlands) in the northern Gulf of Mexico (NGoM), with some regions showing longer-term effects. Polycyclic aromatic hydrocarbons (PAHs), a component of crude oil exhibit fluorescent properties that can be detected using fluorescence spectroscopy. Many studies that have reported on the use of excitation/emission matrix (EEM) fluorescence spectroscopy to detect fluorescence signatures linked to PAHs in Gulf waters during and after the DWH spill were mainly conducted in the more offshore waters. In the river-influenced coastal waters and wetlands, high abundance of colored dissolved organic matter (CDOM) due to terrestrial inputs and higher productivity can potentially mask the fluorescence signatures associated with the PAHs in the seawater. In this study, we first describe results of an earlier study that documented the fluorescence EEMs of dissolved organic matter combined with parallel factor (PARAFAC) analysis that characterized the fluorescence of seawater in the coastal and offshore waters during and after the DWH oil spill. We then describe fluorescence characteristics of coastal seawater samples combined in different oil-water mixtures using a 3D centrifugal microfluidic platform for spilled oil enrichment and detection based on solid phase extraction (SPE). This sensor can be used as a portable device for real-time detection and monitoring of PAHs in coastal waters. A comparison of fluorescence results using the traditional EEMs spectroscopy with fluorescence from the portable microfluidic platform will be presented.

Sinking POC from Sediment Traps in the Northern Gulf: The Rest of the Story

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We have previously reported isotopic results (^{14}C, ^{13}C and ^{34}S) for sinking particulate organic carbon in the northern Gulf of Mexico from sediment traps deployed from 2010 through March 2015 (Yan *et al*., 2016; Chanton *et al*., 2018; Giering *et al*., 2018). In this presentation we will update those results for the period of September 2015 through July 2018 for our DWH or OC-26 site at 29.6666 N and 88.3600 W. Traps were located 120 m above the sea floor. Over this period the $\Delta^{14}C$ values of the collected particulate organic matter averaged -44 ± 51‰, the $\delta^{13}C$ values averaged -21.8 ± 0.4‰, and $\delta^{34}S$ values averaged 17.3 ± 3.0‰. Previous background post spill values (from July 2013 to March 2015 had been -3 ± 31‰, -21.9± 0.5‰ and 16.9 ± 2.0‰ for $\Delta^{14}C$, $\delta^{13}C$ and $\delta^{34}S$ respectively. These new values are somewhat ^{14}C depleted relative to the previous record but are within error, and they extend our time series of background Gulf post-spill collections from 2 years to 5 years. We also collected material in sediment traps deployed at 30 m above the sea floor. These values were $\delta^{13}C$ -22.2 ± 0.6‰ and for $\delta^{34}S$, 16.8 ± 2.9‰, suggesting that little resuspension affected the deeper trap as its sulfur isotope values was indicative of water column production not reduced sulfur, and it was not different from traps further off

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the seafloor. Radiocarbon values for these samples are pending and should be available by the meeting. Limited samples were collected at 625 m above the seafloor, and ^{13}C values were -22.4± 0.6‰ while sulfur was 17.0 ±3.0‰, again indicative of marine production, and similar to the other traps. We observed little change in the isotopic composition of sinking POC across depths from 625 to 30 meters above the sea floor.

Dissolved Trace Metals in Surface Waters of the Texas-Louisiana Shelf: Pollutant Transport and Potential Water Mass Tracers

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Trace metals can serve as essential nutrients for phytoplankton production, as toxins arising from anthropogenic pollution, and/or as useful chemical tracers of oceanographic processes. The Gulf of Mexico is an ideal model system for studying trace metal cycling in marginal seas, given its abundant continental shelves, multiple river inputs with varying anthropogenic influence, dust and sediment fluxes, and massive gradients in primary production from the shelf to the oligotrophic waters offshore. However, despite these exciting biogeochemical gradients and features, almost no trace metal data exist in the Gulf of Mexico literature, likely because of previous sampling contamination issues. Here, we present surface water dissolved Fe, Mn, Zn, Cu, Cd, Ni, and Pb concentrations from three cruises to the Texas Louisiana Shelf: a 2017 nearshore transect along the West Texas Shelf following Hurricane Harvey, and 2018 and 2019 occupations of a triangular cruise transect connecting the Atchafalaya River to Galveston Bay to the Flower Garden Banks. First, we evaluated all observed metal concentrations against toxicity thresholds and find toxicity to be low. Then, we analyzed distributions for transport and biogeochemical process gradients. Following Hurricane Harvey in 2017, most metals had linear relationships with salinity along the shelf, consistent with a strong influence of hurricane floodwaters on surface metal distributions. Comparison of these distributions to metal:salinity relationships in local bays and estuaries such as Galveston Bay helped reveal the source of freshwaters to the Gulf. In contrast, in the 2018-2019 cruises the metal:salinity relationships break down and instead point to local metal-specific transformations. We use metal:metal relationships, spatiotemporal comparisons, and correlations to other hydrographic parameters to distinguish influences of humans, dust, sediments, mixing, and biology on these trace metal distributions.

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