Gulf of Mexico Shipwreck Corrosion, Hydrocarbon Exposure, Microbiology, and Archaeology Project (GOM-SCHEMA)

Reporting Timeframe: October 1, 2016 to September 30, 2017

Leila J. Hamdan
University of Southern Mississippi
Phone: (228) 818-8011 Email: leila.hamdan@usm.edu

PROJECT INFORMATION

Co-PI(s) Name(s): Melanie Damour
Institution: Bureau of Ocean Energy Management
Phone: (504) 736-2783
Email: Melanie.damour@boem.gov

Co-PI(s) Name(s): Lisa A. Fitzgerald
Institution: Naval Research Laboratory
Phone: (202) 404-2553
Email: lisa.fitzgerald@nrl.navy.mil

Co-PI(s) Name(s): Christopher Horrell
Institution: Bureau of Safety and Environmental Enforcement
Phone: (504) 736-2796
Email: Christopher.horrell@bsee.gov

Co-PI(s) Name(s): Robert Church
Institution: Oceaneering Inc.
Phone: (338) 210-0000
Email: rchurch@oceaneering.com

Co-PI(s) Name(s): Daniel Warren
Institution: P&C Scientific, LLC
Phone: (713) 201-2663
Email: Daniel.warren@pandcscientific.com

Co-PI(s) Name(s): Sheli Smith
Institution: The PAST Foundation
Phone: (614) 340-1208
Email: sheli@pastfoundation.cor

Federal Program Officer Name: Melanie Damour

Institution: Bureau of Ocean Energy Management
Phone: (504) 736-2783
Email: Melanie.damour@boem.gov

Award Number:
Bureau of Safety and Environmental Enforcement - E14PG00044 – Hamdan - PI
Bureau of Ocean Energy Management - M13AC00015 – Hamdan – PI
Bureau of Ocean Energy Management- M13PG00020 – Fitzgerald – PI
Bureau of Ocean Energy Management – MP13PC00021 – Church, Warren, Smith - PI
Period of Performance: September, 2013 to May, 2017

Project Website: https://hamdanlab.com/gom-schema/

LONG-TERM GOALS

This project monitored the impacts of the *Deepwater Horizon* (DWH) Spill of 2010 on historic shipwrecks and their associated microbiomes from 2014-2017. Section 106 of the National Historic Preservation Act requires Federal agencies to consider the potential effects of permitted activities on cultural resources such as shipwrecks before issuing permits or providing funding for projects. However, the impacts resulting from the DWH spill to shipwrecks in the northern Gulf of Mexico were not addressed by the Natural Resource Damage Assessment process and would have remained unknown unless this work was carried out. The study's long-term goal is to continue to monitor impacts from the spill on microbial communities that play a role in shipwreck preservation, habitability, and degradation, and recovery. Deep-water shipwrecks provide a valuable location for identifying and tracking the spill's residual impacts from the microscale to the macrostructure of the artificial reef. We also endeavor to utilize deep-sea shipwrecks as a focal point for studies of microbial biogeography, and evolution in the deep sea, through future research projects that have their scientific basis in findings from this work. The team has several proposals in review to execute this continuing scientific goal.

OBJECTIVES

The scientific objectives of the study were to (1) monitor whole microbial communities at shipwreck sites to assess their current condition (2) determine if sites were exposed to oil/dispersant through geochemical and geological evaluations of sediment (3) Identify genes associated with corrosion activities at each shipwreck site to evaluate temporal changes over time as well as any changes related to the oil spill (4) Update archaeological site plans (5) image shipwrecks to provide information on structural impacts, and (6) train new scientists in deep sea research.

APPROACH

Study partners addressed impacts from the 2010 oil spill at one or more scales (e.g. micro-, meso-, or macroscale). Microbiologists and chemists examined microscale impacts on shipwreck surfaces, biofilms and sediments. This was accomplished using a molecular biological approach that incorporated 4 years of sediment profiles to identify community composition and metabolic function, in situ. The microbiological study also utilized seafloor landers and laboratory experiments to identify compositional and functional impacts to biofilm forming communities after being challenged with spill contaminants. This element of the work included microbiologists and chemists at three institutions, and the contributions of students at two universities.

Geologists and bio- and geochemists examined meso-scale seafloor impacts, by studying sediment biogeochemistry, physical dynamics, and tracking rates of sedimentation. The latter analysis provided the most definitive evidence of impacts at one of our sites. This work incorporated the input of senior scientists at five institutions. Marine archaeologists at three institutions used innovative 3D laser/3D sonar scans and high-resolution imagery to reveal macroscale impacts to historic shipwrecks. This produced an image library that will be used in the future to quantitatively monitor effects at the meso-scale.

WORK COMPLETED

The project was completed in May 2017, with the final reports of findings submitted to BOEM.

RESULTS

The study provided evidence that the fallout plume of the DWH spill reached at least one historic shipwreck (*U-166*), and impacted sediment communities at three sites closest to the Macondo well. Specifically, microbiological, chemical and physical evidence at *U-166*, Mardi Gras, and *Anona* experienced exposure from the spill, which resulted in anomalously high sedimentation rates, deposition of oil snow, and microbiological responses. Microbiological responses include an increase in hydrocarbon degraders and genes at these sites, that were still evident four years after the spill.

Laboratory experiments revealed that oil exposure increases the rate of metal loss from steel experimental surfaces, concurrent with increased population abundance of hydrocarbon degrading bacteria, and genes which result in the production of corrosive metabolites. Biofilms on steel disks exposed to chemical dispersants had a sustained reduction of biodiversity, and expression of genes indicative of biofilm function collapse.

Study results also show that presence of a shipwreck on the seafloor impacts the composition of microbiomes in the surrounding sediment, providing the first evidence of an 'artificial reef effect" for seafloor microbes. This is an important finding, as it identifies the impact of the "built" environment in the deep sea. This area of results is the basis for research projects aimed at understanding how the contemporary environment is shaping life on the seafloor.

The work also documented macro-scale impacts to shipwreck hulls, potentially as a result of spill exposure. The video, photo and 3D surveys also provided information to help update site plans, and provide further information about the provenance of 19th century shipwrecks.

All participants bridged knowledge gaps across disciplines, provided information on the impacts of the spill, predicted effects on the preservation of shipwrecks, and built a foundation for new discovery and hypothesis driven research. This activity provided a means to deeply engaged students (K-12, undergraduate, graduate) and the public in outreach, education and research.

DELIVERABLES/DATA TRANSMISSIONS

1. **National Security - NA**

2. **Economic Development (e.g., new product lines, businesses, practices, increased efficiency, new manufacturing techniques) - NA**

3. **Quality of Life (e.g., public health, ecosystem health, coastal resource management)**

The study provided information on the ecosystem health status of deep-sea artificial reefs, and the condition of cultural resources. Such information is vital to protecting and understanding resources in the deep-biosphere.

4. **Science Education and Communication –**

This project positively influenced education through outreach and STEM components. Four graduate students and five undergraduate students conducted research under this project. Using the web-based "Basecamp," teachers and K–12 classrooms across the U.S. participated engaged with scientists during the March 2014 cruise. Students asked questions of shipboard scientists in real time, and were tasked with finding solutions to real challenges faced by the team. The PAST Foundation developed a ROV competition for high school students, where teams of students designed, built, and "flew" ROVs in a test tank at the Center of Science and Industry in Columbus, Ohio. As part of the ROV Challenge, teams collected archaeological, biological, and geological "samples" at a scaled replica shipwreck model using techniques similar to those employed during GOM-SCHEMA's cruises. Students field-tested their engineering designs and performed biological, physical, and archaeological sampling at a "shipwreck." Information about the ROV Challenge, is at https://pastinnovationlab.org/ultimate-rov-challenge-was-amazing and https://pastinnovationlab.org/2015-rov-design-challenge-ranger-class-a-big-success.

Dissemination of results to scientists, stakeholders, and the public was achieved in part through press releases and media interviews. PIs have been interviewed by scientific and mainstream outlets including The Washington Post, Newsweek, Scientific American, Live Science, BBC Earth, and Südwestdeutscher Rundfunk (German public radio station SWR2). Other outlets republished articles in scientific (ex. Archaeology Magazine), traditional (Chicago Tribune), international (International Business Times, ABC Sociedad) and industry- and technology-related media (ex. Marine Technology News, Paint Square, Work Boat). The project and lead PI will also be featured in a Mississippi Public Broadcasting documentary in winter 2018. The diversity of media outlets sharing information about the project demonstrates reach and significance the research to ocean science, education, industry, technology and public sectors. A list of media engagements is found at: https://hamdanlab.com/schema-in-the-news/.

IMPACTS AND APPLICATIONS

1. **National Security –**

2. **Economic Development (e.g., new product lines, businesses, practices, increased efficiency, new manufacturing techniques) - NA**

3. **Quality of Life (e.g., public health, ecosystem health, coastal resource management)**

The project provided important baseline data in the form of biological, chemical, physical and

archaeological evidence to evaluate future impacts to ecosystem health and the management of coastal resources.

4. **Science Education and Communication –**

The GOM-SCHEMA project provided a foundation for long-term monitoring to document impacts from the 2010 Deepwater Horizon oil spill on historic shipwrecks, and examine ecosystem recovery in sensitive deep-water habitats. This will result in future research projects by students in PI laboratories, development of curriculum on deep-sea ecosystems and cultural resources, and the publication of results.

RELATED PROJECTS

The GOM-SCHEMA project provided a foundation for long-term monitoring to document impacts from the 2010 Deepwater Horizon oil spill on historic shipwrecks, and examine ecosystem recovery in sensitive deep-water habitats. The project also provided the basis for novel work. NRL's Platform Support Program is funding GOM-SCHEMA research through FY 2018, more than a year beyond the project period. NRL also supported four cruises beyond the scope of GOM-SCHEMA, to extend the temporal reach and scientific impact of the work. BOEM is considering a continuation of this project (GOM-SCHEMA II) through partnerships, cost share, and funds leveraging. Co-PI Fitzgerald successfully used project data to develop a Navy research program on deep-sea carbon fixation. Co-PIs Hamdan and Damour are seeking funding for aspects of continued work through a FY 2018 NOAA OER grant proposal, a NSF Center for Dark Energy Biosphere Investigations seed proposal, a NSF Biological Oceanography proposal, and a DARPA BAA. Each of the partners has committed to continuing the important work this study started.

PUBLICATIONS

In Review:

Hamdan, LJ, Salerno, LJ, Reed, A, Joye, SB, Damour, M. The impact of the *Deepwater Horizon* blowout on historic shipwreck–associated sediment microbiomes in the northern Gulf of Mexico. Nature Scientific Reports

Salerno, JL, Little, BA, Lee, J, **Hamdan, LJ**. Impacts of crude oil and chemical dispersant exposure on marine microbial biofilm formation and steel corrosion. Frontiers in Marine Science

Haridas, D, Biffinger, JC, Boyd, TJ, Fulmer, PA, **Hamdan, LJ**, Fitzgerald, LA. Laboratory growth of denitrifying microbial consortia from shipwreck sites in the Gulf of Mexico. F1000

Published:

Damour, M, Church, R, Warren, D, Horrell, C, **Hamdan, LJ**. 2016. Gulf of Mexico–Shipwreck Corrosion, Hydrocarbon Exposure, Microbiology, and Archaeology (GOM–SCHEMA) Project: Studying the Effects of a Major Oil Spill on Submerged Cultural Resources. In Marco Meniketti (ed.) ACUA Underwater Archaeology Proceedings of the 2015 Annual Meeting of the Society for Historical Archaeology, Seattle, WA, pgs. 51–61. **(30%; NA)**

In Preparation:

Hamdan, LJ, Salerno, JL, Brock, ML*, Damour, M. Microbial Stowaways: The influence of historic shipwrecks on seafloor microbiome dispersal.

Brock, ML*, Mugge, RL*, Salerno, JL, Damour, **Hamdan, LJ.** Source, composition, and function of biofilm microbiomes near deep–sea shipwrecks impacted by the *Deepwater Horizon* spill.

Salerno, JL., Blackwell, C*, Peters, E, Damour, M, **Hamdan, LJ**. Characterization of *Lophelia pertusa* microbiomes across coral microhabitats.

PATENTS

Not Applicable

WORK PLAN

Not Applicable – Project completed in May 2017.

OUTREACH MATERIALS

The video found at this link: https://youtu.be/Y6FFA1IMCRI was produced by the American Geophysical Union, in collaboration with Project PIs Hamdan and Damour in 2016. This was accompanied with a press release that included photos from the project. These materials provide a comprehensive understanding of the project, it's results, and our cross disciplinary goals.

https://news.agu.org/press-release/gulf-of-mexico-historic-shipwrecks-help-scientists-unlock-mysteries-of-deep-sea-ecosystems/

GoM-SCHEMA blogs were posted regularly on www.hamdanlab.com
All photos and short videos from GoM-SCHEMA can be found on the Flickr libraries provided below:
July 2014 Cruise
July 2014 Continued
April/May 2015 Cruise
May 2016 Cruise
June 2017