UNIVERSITY OF FLORIDA: BIODEGRADATION OF THE DEEPWATER HORIZON OIL IN FLORIDA MARSH ECOSYSTEMS AND EXPLORATION OF NOVEL PASSIVE REMEDIATION STRATEGIES

Andrew R. Zimmerman and Brian S. Silliman

SCIENCE ACTIVITIES

1) General Summary

1) Measure natural DH oil degradation rates in an oil-impacted salt marsh.
2) Assess the ecosystem impacts of DH oil contamination in an oil-impacted salt marsh and how these vary over time (and with oil degradation).
3) Examine the effect of enhanced soil aeration on DH oil degradation rate and ecosystem health in an oil-impacted salt *Narrative (1 pages maximum): Please provide a brief overview of the project and goals **supported** during the conduct of this project. Be sure to highlight any 'lessons learned' that could be applied to other/future oil spill related projects (e.g., management, data support, logistics, etc.). Listing accomplishments against project activities, objectives and milestones in bulleted form is acceptable.*

The project is focused on examining the biodegradation of the Deepwater Horizon (DH) oil and associated parameters of ecosystem health in an affected Gulf Coast marsh setting, Barataria Bay, Louisiana. It also examined the efficacy of two novel passive remediation methods for enhancing rates of oil degradation; 1) chemical oxidation, and 2) biochar amendment (adding charcoal adsorbent). Specific goals were as follows:

marsh.
4) Examine the effect biochar addition on DH oil degradation rate and ecosystem health in an oil-impacted salt marsh.

The following activities were accomplished in support of the above goals of the project:

- October 2010: Initial survey of oil coverage and marsh plant die-off on Barataria Bay, LA shorelines made. At this time, 14 sampling sites were established to monitor oil degradation, plant coverage and shoreline erosion (3 die-off + 4 non-die-off sites, 3 m and 15 m from the marsh edge at each site).
- October 2010: Three caged oiled and three non-oiled field sites were established in Barataria Bay, LA with treatments; a) control, b) oxidant - Mg peroxide, c) biochar - pyrolyzed pine wood, d) oxidant and biochar.
- All samples have now been collected. In time following the spill; time 5 months (October 2010), 6 month (November 2010), 11 months (April 2011), and 18 months (Oct. 2011), and 21 months (Jan 2012). Ecological data such as live and dead plants, rhizomes, mollusks, crabs, etc. were collected at each site at each time.
-Experiments were conducted to determine the extent of oil coverage on plant blade needed to cause death of plant.
-Poles were installed to measure erosion rates at each of the sites including oiled sites and non-impacted control sites.

-Samples have been sent to FSU high mag. lab for ultra-hi-res FTIR-MS analysis to examine in more detail, the chemical composition of the degraded oil/sediment organic matter mixtures at oiled and non-oiled survey sites.
-Sediment cores were collected to examine downcore sediment oil distributions.
-Marsh sediment samples were collected by a student from McMaster University to investigate the response of all three microbial domains to petroleum contamination and correlating this to the potential for biodegradation.
-Wind field and wave modeling of Bataria Bay was conducted to evaluate the relative erosion susceptibility of each site.

2) Results and scientific highlights

Narrative (2 pages maximum): This should be a summary of significant results (positive and negative) and conclusions during the conduct of this project. Listing science results and highlights in bulleted form is acceptable. In each case, please explain the impact of the result.

1) Measure natural DH oil degradation rates in an oil-impacted salt marsh.
- After one year, oil concentrations (total alkane and PAHs) in oil-impacted Barataria Bay marsh sediments returned to those indistinguishable from those present at sites not impacted sites.
- Some compounds were more refractory than others.
- The average half-life of oil-derived compounds was about 6 months.

These results suggest that natural unassisted biodegradation may be best in natural marsh settings rather than chemical or physical treatments including washing or physical removal

2) Assess the ecosystem impacts of DH oil contamination in an oil-impacted salt marsh and how these vary over time (and with oil degradation).
-oil coverage was primarily concentrated on the seaward edge of marshes
-there were clear thresholds of oil coverage that determined the severity of salt marsh damage, with heavy oiling leading to complete plant mortality and absence of macro-invertebrates
-oil-driven plant death on the edges of these marshes more than doubled rates of shoreline erosion, further driving marsh platform loss that is likely to be permanent
- after 18 months, marsh grasses have fully recovered into non-eroded areas and, subsequently, the elevated shoreline erosion rates observed at oiled sites have decreased to levels at control marsh sites.

These findings warns of the enhanced vulnerability of already degraded marshes to heavy oil coverage and provides a clear example of how multiple human-induced stressors can interact to hasten ecosystem decline. They suggest that recovery efforts may be better focused on erosion prevention during the period of sea grass denudation rather than oil removal.

3) Microbial impacts.
- Microbial biomass does not change with presence of petroleum
- Distinct microbial communities at impacted and reference sites
- Evidence of petroleum used as microbial carbon source at impacted sites in Oct 2010, however minor inputs of petroleum to microbial communities at all time points

These findings link DWH oil disappearance to microbial biodegradation and serve as preliminary data for more in-depth study.

4) Examine the effect of enhanced soil aeration and biochar addition on DH oil degradation rate and ecosystem health in an oil-impacted salt marsh.

-this data is still being evaluated but preliminary finding suggest that that treatment with a chemical oxidant did hasten the degradation of oil-derived compounds by 30-50% without altering the recovery of marsh plant and snail populations to pre-oiling levels.

-this data is still being evaluated but preliminary finding suggest that that treatment with a chemical oxidant did hasten the degradation of oil-derived compounds by 10-60% without altering the recovery of marsh plant and snail populations to pre-oiling levels.

These findings show encouraging preliminary evidence of the positive benefit of these passive remediation approaches. However, definitive answers will likely not be available due to the natural variation both within and between treatment sites. Thus, they suggest that more controlled-condition and replicable mesocosm studies are called for.

Overall

Our ecological results suggest that there are reasons for both optimism and concern about the impact of this oil spill on Gulf Coast salt marshes. On one hand, our results reveal that marsh vegetation displays remarkable resilience to oil spills by concentrating and containing the effects of oil on the marsh edge, recovering fully in non-eroding areas after ~1.5 yrs., and suppressing, through this re-colonization, future accelerated erosion rates along the shoreline. The lack of oil on the marsh surface or on grasses at distances greater than 15 m from the shoreline at any site suggests that incoming oil sheens were contained and prevented from moving into interior marshes. However, this resistance comes at a high cost for the impacted areas because marsh grass die-off and subsequent sediment exposure to waves results in a more than doubling of the rate of erosion that hastened destruction of the intertidal platform needed for salt marsh vegetation to persist.

Our bioremediation results are still preliminary, yet suggest that there is potential to these two passive remediation approaches; chemical oxidant and biochar amendment. While the benefit derived may not be large, given the relatively rapid natural loss of oil compounds, there was not apparent detriment to ecological recovery. Thus, these treatment approached might be tuned, in the future, to operate more quickly or more effectively, speeding marsh recovery. This may be of particular importance in light of the permanent loss of marsh platform surface observed to occur during prior to plant re-colonization.

3) Cruises & field expeditions

October 2010), 1 month (November 2010), 3 months (January 2011) and 6 months (March 2011), and 12 months (Oct. 2011). An additional sampling trip in Jan. 2012

Ship or Platform Name	**Class** (if applicable)	**Chief Scientist**	**Objectives**	**Dates**
Small Charter Boat		Zimmerman	Survey, Establish treatment plots, Sample collection	10.18.10
Small Charter Boat		Silliman	Sample collection	11.09.10
Small Charter Boat		Silliman	Sample collection	12.10.10
Small Charter Boat		Silliman	Sample collection	04.13-11
Small Charter Boat		Zimmerman	Sample collection	10.14.11
Small Charter Boat		Silliman	Sample collection	01.8.12

4) Peer-reviewed publications, if planned (Note: a special section will focus on student and post-doctoral publications)
    a. Published, peer-reviewed bibliography (Copies of the papers are requested)
    b. Manuscripts submitted or in preparation (Please note target journal, and anticipated date of publication or submission)

Silliman, B. R., J. Diller, M. W. McCoy, G. Kasozi, K. Earl, J. van de Koppel, A. R. Zimmerman. (2012). Degradation and Resilience in Louisiana Salt Marshes after the BP-DWH Oil Spill. *Proceeding of the National Academy of Science*. 109: 11234-11239.

Kasozi, G., Zimmerman, A.R., Mitra, S. and B. R. Silliman. Natural degradation of BP-DWH Oil Spill alkanes and PAHs in Gulf Coast salt marsh sediments, Barataria Bay, LA, U.S.A. (in preparation for *Environmental Science & Technology*).

Mahmoudi, N., Fulthorpe, R. F., Zimmerman, A.R., B. R. Silliman & G.F. Slater. Temporal trends in microbial abundance and biodegradation in Louisiana salt marshes following the Deepwater Horizon oil spill (in preparation for *Environmental Science & Technology*).

Zimmerman, A.R., G. Kasozi, Mitra, S. and B. R. Silliman. Natural and passive treatment-enhanced degradation of BP-DWH Oil Spill in Gulf Coast salt marsh sediments, Barataria Bay, LA, U.S.A. (in preparation for *Environmental Science & Technology*).

5) Presentations and posters, if planned (Please provide copies of each) (Note: a special section will focus on student presentations)

Title	Presenter	Authors	Meeting or Audience	Abstract published (Y/N)	Date
Oil spill driven saltmarsh die-off in Barataria Bay	Silliman	Silliman, B. R., J. L. Diller, K. Earl, G. N. Kasozi, A. R. Zimmerman	International Marine Conservation Congress	N	May 14, 2011
Oil spill driven saltmarsh die-off in Barataria Bay	Silliman	Silliman, B. R., J. L. Diller, K. Earl, G. N. Kasozi, A. R. Zimmerman	American Association for the Advancement of Science, 2012 Annual Meeting	N	Feb. 18, 201

6) Other products or deliverables
Please list (for example: maps, models, tools) and indicate where they can be located/obtained.

7) Data
Please provide a spreadsheet indicating the metadata and ancillary information on the location and status of the archived samples. Also, indicate if there are any issues with respect to data archiving

schedule and plan. If you have a lot of metadata, representative samples will suffice. This will all be incorporated into the GoMRI database at some point in the future.

Data will be released in each of the present and planned publications, including Supplemental data sections.

PARTICIPANTS AND COLLABORATORS

8) Project participants

Please list the participants of your project, their role(s) and contact information. No personal information will be released.* ***Note: Student/educational information will be collected elsewhere in this report****.*

** We understand one person may fulfill more than one role; please list all applicable roles using the following standardized titles: Principal Investigator, Co-Principal Investigator, Scientific Participant, Technician, Lab Assistant, Administrative Support.*

First Name	Last Name	Role in Project	Institution	Email
Andrew R.	Zimmerman	P.I.	University of Florida, Dept Geological Sciences	azimmer@ufl.edu
Brian S.	Silliman	Co-P.I.	University of Florida, Biology Dept	brs@ufl.edu
Jessica	Diller	*Technician*	University of Florida, Biology Dept	jessicadiller@gmail.com
Kamala	Earl	*Technician*	University of Florida, Biology Dept	brs@ufl.edu
Stephanie	Buhler	*Technician*	University of Florida, Biology Dept	buhler88@ufl.edu
Greg	Slater	collaborator	McMaster University	gslater@mcmaster.ca

MENTORING AND TRAINING

9) Student and post-doctoral participants

Please list the student participants of your project, their educational role, and other information. No personal information will be released.

First Name	Last Name	Post-doc / PhD / MS / BS	Thesis or research topic	Institution	Supervisor	Expected Completion year
Gabriel	Kasozi	Post-doc	Sediment chemistry	University of Florida, Dept Geological	Andrew Zimmerman	2012

				Sciences		
Michael	McCoy	Post-doc	Ecology	University of Florida, Biology Dept	Brian Silliman	
Cong	Zhang	PhD	Distribution of oil in a Gulf Coast estuary following DWH spill	University of Florida, Dept Geological Sci.	Andrew Zimmerman	2016
Nagissa	Mahmoudi	PhD	Microbial biodegradation of oil	McMaster University	Greg Slater	2013

10) Student and post-doctoral publications, if planned
    a. Published, peer-reviewed bibliography (Copies of the papers are requested)
    b. Manuscripts submitted or in preparation (Please note target journal, and anticipated date of submission or publication)

11) Student and post-doctoral presentations and posters, if planned (Please provide copies of each)

Title	**Presenter**	**Authors**	**Meeting or Audience**	**Abstract published (Y/N)**	**Date**
Temporal trends in microbial abundance and biodegradation in Louisiana salt marshes following the Deepwater Horizon oil spill	Mahmoudi	Mahmoudi, N., Fulthorpe, R. F., Zimmerman, A.R., B. R. Silliman & G.F. Slater	American Geophysical Union, Fall Meeting 2012	N	Dec. 9, 2012

12) Images
Please attach high-resolution images and provide details including a description of the image, location, credit, date, etc. Of note: Image may be used in FIO or GoMRI promotions, so please make sure you have rights to use the image.

13) Continuing Research
If you are continuing this research under another grant, please include granting authority and title of award and a very brief synopsis (2-3 sentences).