

**ASSESSING THE IMPACT OF THE DEEPWATER HORIZON OIL SPILL  
ON SEDIMENTS AND BENTHIC COMMUNITIES ON THE WEST  
FLORIDA SHELF AND SLOPE**

David J. Hollander and Patrick T. Schwing  
University of South Florida, College of Marine Science  
St. Petersburg, FL

## SCIENCE ACTIVITIES

### 1) General Summary

*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.*

We proposed to assess the impact of Deepwater Horizon oil on sediments and benthic communities on the West Florida Shelf and Slope and identify possible mechanisms including the “bathtub rings” caused by subsurface oil and gas intrusions impinging on the shelf and slope and the results of enhanced flocculation and oil sediment deposition “the dirty blizzard” in the Northern Gulf of Mexico . The outcomes are related to the goals below:

1. To assess the distribution and extent of subsurface oil by examining sediments along depth transects across the Florida Shelf and Slope.
  - Two transects (PCB and DSH) were sampled during three cruises: November 2010 (10 sites collected), December 2010 (7 sites collected), and February 2011 (11 sites collected). Up to eight sediment cores were collected at each site with some overlap between the December and February sites for a time-series study.
  - Grain size, total organic material (TOM), and carbonate content were determined for each sample in the three time series sites (DSH08, DSH10, and PCB06) along with several of the other cores from the PCB transect.
  - Short-lived radionuclide (SLR) geochronologies ( $^{210}\text{Pb}$ ,  $^{234}\text{Th}$ ) were produced for the three time series sites as well as the entire PCB transect. Using the bulk density of each sample and the constant rate of supply model, mass accumulation rates (MAR) were calculated for each site over time.
2. To measure sediment concentrations of hydrocarbons specific to the Deepwater Horizon oil spill and evaluate potential toxicity.
  - Organic geochemical analysis was focused on the three time-series sites (DSH08, DSH10, and PCB06). All three of these sites were sampled in December and February. Total organic carbon, total aliphatic fraction, and polycyclic aromatic hydrocarbon (PAH) concentration was determined for each sample. A health index was constructed for PAH toxicity.
3. To measure sediment concentrations of vanadium and nickel (high concentrations in crude oil) and assess their toxicity.
  - ICP-MS analysis of each sediment sample from DSH10 and DSH08 determined the vanadium and nickel concentration of the surface sediments (oiled) and down-core samples (natural baseline).
4. To quantify benthic foraminiferal assemblages and shell abnormalities from contaminated vs. non-contaminated sites and horizons to document any impact on benthic communities.
  - Benthic foraminifera were picked, identified to genus, and in some cases species, and counted. Samples from DSH08 (December and February), PCB06 (December and

February), and DSH10 (February) were used for benthic assemblage/abundance analysis. Several other cores from the PCB transect were sampled to determine whether there was an increase in shell abnormalities at suspected intrusion depths (400 and 1400 m).

5. To assess potential uptake of hydrocarbons by benthic foraminifera based on stable and radiocarbon isotope geochemistry.  
-Benthic foraminifera (*Uvigerina peregrina*, *Cibicidoides wuellerstorfi*, *Cibicidoides kullenbergi*) and Planktonic foraminifera (*Globigerinoides ruber*) were isolated from the surface samples of DSH10 and DSH09 and analyzed for both stable and radio-carbon.
6. To establish pre-impact conditions for sediment geochemistry and benthic foraminiferal assemblages as a baseline for future monitoring studies of benthic habitats.  
-The down-core portions of each sediment record have provided an excellent background or baseline for sedimentology, accumulations rates, benthic foraminifera assemblages/abundance, and PAH concentrations/toxicity.

Lessons Learned:

The high-resolution sampling (2mm in the surface section) of these sediment cores was vital to the success of this project. The combination of accumulation rates (SLR dating), PAH toxicity, and benthic foraminifera abundance analysis has proven to be a powerful tool in documenting the effect of the Deepwater Horizon oil spill on the benthic habitat.

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.

Results presented by each goal are:

1. To assess the distribution and extent of subsurface oil by examining sediments along depth transects across the Florida Shelf and Slope.  
-A 2-10 times increase in mass accumulation rate was observed in late 2010 and early 2011 at all sampling sites relative to the mass accumulation rate down-core (e.g. 0.05 g/cm<sup>2</sup>/yr down-core to 0.50 g/cm<sup>2</sup>/yr in 2010). This increase in MAR is now referred to as the “flocculent blizzard”  
-The carbonate content and the TOM did not change dramatically during the pulse of sedimentation.  
-Fine-grain material (silts and clays) increased during the pulse
2. To measure sediment concentrations of hydrocarbons specific to the Deepwater Horizon oil spill and evaluate potential toxicity.  
-The TOC accumulation rate increased from down-core rates of ~1.5 g/m<sup>2</sup>/month to ~15 g/m<sup>2</sup>/month in 2010 and early 2011.  
-The PAH accumulation rate increased from down-core rates of ~10 µg/m<sup>2</sup>/month to ~300 µg/m<sup>2</sup>/month in 2010 and early 2011.

-The low molecular weight (LMW) PAH concentrations also increased from down-core (~5 µg/g OC) to 2010/2011 (~15 µg/g OC).

-A health index (HI) was calculated for the sedimentary PAH concentrations, where values higher than 1 are considered detrimental to biological processes (e.g. respiration, reproduction). In the sediments deposited in 2010 and 2011, the HI value was between 9 and 25.

3. To measure sediment concentrations of vanadium and nickel (high concentrations in crude oil) and assess their toxicity.
  - There was no significant increase in vanadium or nickel from the baseline values in the down-core section to the surface samples deposited in 2010 and early 2011 in any of the sites sampled.
4. To quantify benthic foraminiferal assemblages and shell abnormalities from contaminated vs. non-contaminated sites and horizons to document any impact on benthic communities.
  - A benthic foraminifera mortality event was documented in the December 2010 records using both abundance (concentration) and also benthic foraminifera mass accumulation rates (BFMAR). The concentration of benthic foraminifera in the surface section (2010, ~0.5 f/cm<sup>3</sup>) of both PCB06 and DSH08 decreases dramatically with respect to the concentration down-core (~10 f/cm<sup>3</sup>).
  - There is a marked increase in the concentration of benthic forams in the surface of DSH08 from February 2011, which is indicative of a recovery.
  - There is a continued decrease in the concentration of benthic forams in the surface of PCB06 from February 2011, which is indicative of a continued mortality event.
  - There is no significant increase over time in shell deformity or abnormality in the benthic foram communities that were sampled (PCB transect)
5. To assess potential uptake of hydrocarbons by benthic foraminifera based on stable and radiocarbon isotope geochemistry.
  - Preliminary radiocarbon results ( $\Delta^{14}\text{C}$ ) from benthic foraminiferal tests from DSH10 are lower (-107) than the dissolved inorganic carbon in the sediments of the gulf (~-100), which suggest the metabolization of petrogenic carbon
6. To establish pre-impact conditions for sediment geochemistry and benthic foraminiferal assemblages as a baseline for future monitoring studies of benthic habitats. (noted above in each objective)

The two hypotheses tested by this project were:

1. Organic compounds and inorganic metals specific to oil are enriched in sediments at about 400 and 1400 m along the impacted transect off of northwestern Florida. The null hypothesis is no enrichment above natural background levels.

Result: Organic compounds (PAH) are enriched in sediments from ~1000-1200 m throughout the DeSoto canyon area.

2. Benthic foraminiferal assemblages reveal significant differences in community structure, geochemistry, and shell abnormalities at about 400 and 1400 m along the impacted transect off of northwestern Florida. The null hypothesis is no differences from natural background levels as measured below the oiled horizon and at unoiled sites.

Result: There is a significant difference in community structure, abundance, and preliminarily shell structure during and after the Deepwater Horizon event at sites located from 100-1200 m in the Desoto Canyon, but no significant increase in shell abnormalities in and of the PCB transect records.

**Conclusions**

- Sediment mass accumulation rates increased by up to an order of magnitude in late 2010 and early 2011 related to the Deepwater Horizon oil spill (flocculent blizzard).
- A benthic foraminifera mortality event has been documented in late 2010 and early 2011 that occurs synchronously with the increase in sedimentation as well as an increase in PAH concentration and toxicity.
- There is no direct sedimentary or organic geochemical evidence of bathtub rings occurring at ~400 and 12000 m. However, the carbon isotopes of benthic foraminiferal tests may be the only lasting record of direct hydrocarbon contact with the sediments through ingestion of oil byproducts. More work is needed to quantify the duration and concentration of oil and gas impinging on the continental slope.

3) Cruises & field expeditions

Ship or Platform Name	Class (if applicable)	Chief Scientist	Objectives	Dates
Weatherbird II		Ben Flower	Collect sediment core samples and water samples along the PCB transect and at the 400 m isobath	November 2010
Weatherbird II		David Hollander	Collect sediment core samples and water samples along the DSH and PCB transects	December 2010
Weatherbird II		David Hollander	Collect sediment core samples and water samples along the PCB and DSH transects	February 2011

- 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)

Sediment Pulse in the NE Gulf of Mexico Following the 2010 DWH Blowout. Brooks, G. R., Larson, R. A., Flower, B., Hollander, D., Schwing, P. T., Romero, I., Moore, C., Reichart, G-J., Jilbert, T., Chanton, J., Hastings, D. (Submitted). Deep Sea Research

Effects of the Deepwater Horizon Oil Blowout on Deep Sea Benthic Foraminifera in the Northeastern Gulf of Mexico, Schwing, P.T.: Flower, B.P.<sup>A</sup>, Romero, I.C., Brooks, G.R., Larson, R.A., Hollander, D.J. (Submitted). Deep Sea Research

Hydrocarbons in deep-sea sediments following the 2010 Deepwater Horizon Blowout in the Northeast Gulf of Mexico, Romero, I.C, Schwing, P. Brooks, G.R., Larson R.A., Flower, B; Goddard, E.A<sup>1</sup>, Hollander, D.J. (Submitted). Deep Sea Research

Hollander, D.J., R. Larson, I. Romero, P. Schwing, K. Watson, N. Zenzola; D.W., Brooks, G., Hastings, J. Chanton, J. Kostka. W. Overholt, Mechanisms of Sedimentary Oil Deposition in Deep-Sea in the aftermath of the Deepwater Horizon Blowout Event, to be submitted to Science, May 2013

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

<b>Title</b>	<b>Presenter</b>	<b>Authors</b>	<b>Meeting or Audience</b>	<b>Abstract published (Y/N)</b>	<b>Date</b>
Assessing the impact of Deepwater Horizon oil spill on sediments and benthic communities on the West Florida Shelf and Slope.	Flower, B.P.	Flower, B. P., G. R. Brooks, L. Collins, D. W. Hastings, D. Hollander, P. Hallock-Muller	FIO BP Principal Investigators meeting	N	May 2011
Rapid Increase in Accumulation Rate and Shift in Sedimentary Regime in the NE Gulf of Mexico Following the 2010 BP Blowout Event.	Brooks, G.R.	Brooks, G. R., D. Hollander, B. P. Flower, D. W. Hastings, A. Valente, K. Hill, C. Moore, I Romero.	Ocean Sciences Meeting	Y	February 2012
Changes in the redox state of sediments following the 2010 BP blowout	Hastings, D.W.	Hastings, D. W., G. R. Brooks, D. J. Hollander, R. Larson, J.	Chemical Oceanography workshop, "From the Sediments to the Air-Sea Interface, University of Washington	N	November 2012

		Morford, I. Romero, S. Hammaker*, A. Hogan, T. Roeder*			
Changes in the redox state of sediments following the 2010 BP blowout.	Hastings, D.W	Hastings, D. W., G. R. Brooks, D. J. Hollander, R. Larson, J. Morford, I. Romero, S. Hammaker*, A. Hogan, T. Roeder*	American Geophysical Union Fall Meeting	Y	December 2012
Using short-lived radionuclide inventories and geochronology to quantify benthic foraminifera response to the BP oil blowout.	Schwing, P.	Schwing, P.T., Flower, B.F., Brooks, G.R., Larson, R.A., Romero, I., Hollander, D.J.,	Gulf of Mexico Oil Spill & Ecosystem Science Conference	Y	January 2013
Shift in sedimentation patterns and increased mass accumulation rates following the BP blowout event: NE Gulf of Mexico,	Larson, R.	Larson, R.A., Brooks, G.R., Schwing, P., Hollander, D., Romero, I., Moore, C., Matsunaga, A., Hill, K.	Gulf of Mexico Oil Spill & Ecosystem Science Conference	Y	January 2013
Changes in the redox state in pore water and marine sediments following the 2010 BP blowout.	Hastings, D.	Hastings D. W., G. R. Brooks, D. J. Hollander, R. Larson, J. Morford, I. Romero, S. Hammaker, A. Hogan, T. Roeder, T. Bartlett.	Gulf of Mexico Oil Spill & Ecosystem Science Conference	Y	January 2013
Testing the Mechanisms of Sedimentary Oil	Hollander, D.J.	Hollander, D.J., G. R. Brooks, D. J. Hollander, R.	Gulf of Mexico Oil Spill & Ecosystem Science Conference	Y	January 2013

Deposition in Deep-Sea.		Larson, I. Romero, P. Schwing, K. Watson, N. Zenzola; D.W., Hastings, J. Chanton, J. Kostka. W. Overholt,			
Radiocarbon analysis of the Gulf Oil Spill	Chanton, J.	Chanton, J., J. Cherrier, J. Sarkodeeadoo, W.M. Graham, S. Joye, D. Hollander, C. Brunner,	Gulf of Mexico Oil Spill & Ecosystem Science Conference	Y	January 2013

6) Other products or deliverables

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

(Sampling site map attached)

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.

(Sediment core allotment attached)

**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
David	Hollander	PI, organic and	USF	davidh@marine.usf.edu



		inorganic geochemistry		
Laurel	Collins	Slope foraminiferal assemblages	FIU	collinsl@fiu.edu
David	Hastings	Trace metal sediment geochemistry	Eckerd College	hastindw@eckerd.edu
Gregg	Brooks	Sedimentology/radio. Geochronology	Eckerd College	brooksg@eckerd.edu
Pamela	Hallock Muller	Shelf foraminiferal assemblages	USF	pmuller@usf.edu
Jeff	Chanton	Radiocarbon Analyses	FSU	jchanton@FSU.edu
Joel	Kostka	Genetics-Microbial Ecology/Community Structure	Georgia Tech	Joel Kostka <joel.kostka@biology.gatech.edu>

### 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
Patrick	Schwing	Post-doc	Radio. Geochron./foram assemblages/isotope geochem.	USF	Hollander	2014
Lauren	Reilly	BS	Foram assemblage/isotope geochem.	USF	Hollander	2013
Nicola	Zenzola	BS	Organic geochem.	Eckerd	Hollander	2012
Larson	Rebekka	PhD	Radio geochron/Sedimentology	USF/Eckerd	Hollander	2015
Roeder	Tara	BS	Trace Metals	Eckerd	Hastings	2012

- 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)

Schwing, P.T., Flower, B.P., Romero, I.C., Brooks, G.R., Larson, R.A., Hollander, D.J. (Submitted). Effects of the Deepwater Horizon Oil Blowout on Deep Sea Benthic Foraminifera in the Northeastern Gulf of Mexico. Submitted to Deep Sea Research

- 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
Using short-lived radionuclide geochronology to quantify benthic foraminifera response to the BP oil blowout	Schwing, P.T.	Schwing, P.T., Flower, B.P., Brooks, G.R., Larson, R.A.	Geological Society of America Annual Meeting	Y	11/5/12
Utilizing <sup>234</sup> TH and <sup>210</sup> PB Geochronologies to detect increased sediment mass accumulation following the BP Blowout Event: NE Gulf of Mexico	Larson, R.A.	Larson, R.A., Brooks, G.R., Hollander, D.J., Schwing, P.T., Hill, K., Moore, C., Matsunaga, A.	Geological Society of America	Y	11/5/12
Assessing the Fate and Impact of the BP Oil on Deep-Sea Sedimentary Environments and Benthic Communities: NE Gulf of Mexico	Larson, R.A.	Larson, R. A., G. R. Brooks, B. P. Flower, D. Hollander, D. W. Hastings, I. Romero, A. Valente, K. Hill, C. Moore	Ocean Sciences Meeting	Y	February 2012
Where Has All the Oil Gone? The use of trace metals as potential indicators	Roeder, T.K.	T. K. Roeder*, D. W. Hastings, C. Holzinger*, E. Playle*, G R.	American Geophysical Union Fall Meeting,	Y	December 2011

of oil contamination in marine sediments and beach sands		Brooks, M. Huettel, J. Kostka, R. A. Larson, B. P. Flower.			

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.

(Synthesis figure attached)

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).

Continuing research on this project is being supported by the Gulf of Mexico Research Initiative (GOMRI) through the Center for Integrated Modeling and Analysis of the Gulf Ecosystem (C-IMAGE) and the Deep Sea to Coast Connectivity in the Eastern Gulf of Mexico (Deep-C) consortia. The focus of the sediment group within these consortia is to further define and quantify the physical, chemical, geological, and biological effects of the flocculent blizzard and its effects on benthic habitats in the northern Gulf of Mexico.