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BEFORE THE U.S. SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

HEARING: "Five Years After Deepwater Horizon: Improvements and Challenges in Prevention and Response"

April 29, 2015

Good morning Chairman Thune, Ranking Member Nelson, and members of Committee. Thank you for giving me the opportunity to provide testimony regarding the lessons learned and long term environmental impacts of the Deepwater Horizon (DWH) / Macondo oil well blowout (hereafter Macondo Blowout), which devastated the Gulf of Mexico ecosystem beginning in April 2010. My name is Samantha Joye and I am a Distinguished Professor at the University of Georgia. My research examines the naturally-occurring microbial processes that mediate oil and gas cycling in the Gulf of Mexico and Arctic Ocean, two areas where natural seepage of hydrocarbons is widespread. I have published over 120 peer-reviewed papers on these and related subjects. I have worked in the Gulf of Mexico ecosystem for 20 years and continue to do so.

For this hearing, I was asked to discuss what the scientific community has learned in the past five years in the wake of the Macondo Blowout, the lingering environmental impacts, as well as my thoughts on how to move forward so that we are better prepared as a research community and as a response community for the next incident. My comments represent the not only my opinions, but those of my colleagues within the consortium that I direct, and of the broader scientific community working in the Gulf system, of which I am an active participant. The topic of this hearing could not be more timely. Recently, John Amos summarized the number and location of hazardous material spills in the Gulf since the 2010 DWH disaster: 10,000 spills of various sizes have occurred in the past five years. Clearly, it is not a matter of if, but rather when, the next large accidental offshore marine oil discharge occurs in the Gulf of Mexico.

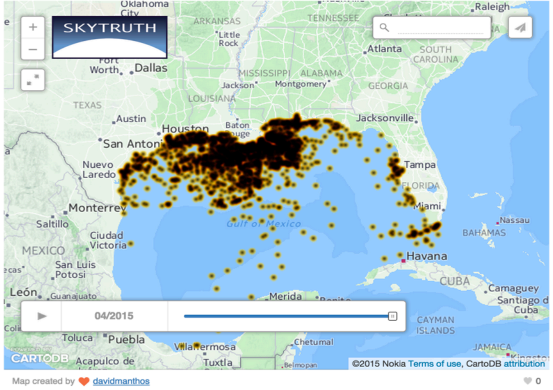

Figure showing the locations of hazardous material spills in the Gulf since 2010. This is time 5-yr aggregate map; the time series is available at the SKYTRUTH® website: (http://bit.ly/1aLX5UF).

On April 20th 2010, a chain of events that ultimately resulted in the most significant offshore oil release in U.S. history began. The *Deepwater Horizon*, a dynamically positioned offshore mobile drilling unit, was drilling a production well in the Macondo Prospect, located in Mississippi Canyon lease block 252, about 40 miles offshore if the southeast coast of Louisiana. The night of April 20th 2010, rig operators experienced a loss of well control, resulting in an uncontrolled blowout. The explosion and subsequent fire on the platform killed eleven men and injured sixteen others. The blowout preventer, which should have cut the riser pipe at the seafloor and sealed the blown out well, failed and the fire on the platform raged for two days. On April 22nd, the *Deepwater Horizon* sank, initiating an uncontrolled release of oil and gas from the seafloor that lasted for 87 days and introduced some 5 million barrels of oil (210 million gallons) and 500,000 metric tons of methane into the Gulf of Mexico ecosystem.

I am qualified to provide testimony on the impacts of the Macondo blowout based on my detailed knowledge of the Gulf ecosystem and through my role as Director of a large research consortium that is tracking long-term impacts and recovery from the Macondo blowout. I was among the first academic responders to the DWH oil spill, serving as chief scientist on the second academic response cruise on board the *R/V Walton Smith* in May/June 2010. Being out on the water in May/June 2010, August/September 2010, and November/December 2010, I witnessed, first hand, the devastating environmental consequences of this deep-water oil well blowout. I was part of the scientific team that discovered the "underwater oil plumes" and led the effort that discovered freshly deposited sedimentary layers containing weathered oil that extended over a large parts Gulf seabed in late August 2010.

Since 2010, we have continued and expanded our work in the Gulf with the aim of conducting long term monitoring studies and directed laboratory experiments to elucidate the impacts of oil, chemical dispersant, and dispersed oil on Gulf microbial communities, in both the water column and in deep sea sediments. I am the Director of the "Ecosystem Impacts of Oil and Gas Inputs to the Gulf" (ECOGIG) research consortium (www.ecogig.org), a group of 29 scientists conducting DWH-related research. Our consortium is funded on a competitive basis by the Gulf of Mexico Research Initiative (GoMRI), which was created to administer the $500M research fund BP provided to support DWH-related research over a 10-year period. The ECOGIG mission is to understand the environmental signatures and impacts of natural hydrocarbon seepage versus that of abrupt, large hydrocarbon discharges on coupled benthic and pelagic processes in deepwater ecosystems in the Gulf of Mexico, and to chart the long-term effects and mechanisms of ecosystem recovery from the 2010 Macondo blowout.

My testimony today is limited to issues relevant to offshore, deepwater environments and I will describe the major lessons learned and long impacts of the Macondo Blowout. I also hope to impress upon you the need for developing an academic response network, complete with necessary infrastructure – tools and technology – to be on the water within days of disaster. This network of academic responders would work closely and collaboratively with National Incident Command. Such a collaboration would reduce response time to an offshore spill, potentially limiting long term damage to offshore and nearshore ecosystems. A shortened response time saves resources and could save lives, and will also reduce hydrocarbon exposure, acute ecological impacts, and economic impacts (fisheries, tourism). The cost-benefit of investing in effective oil spill response and mitigation technologies and infrastructure is almost assuredly positive, given the high density of oil production platforms in the Gulf and the increasing number of drilling endeavors undertaken in ultra-deep water and in extremely gas-rich (e.g. Tertiary) reservoirs.

Preface

The Gulf of Mexico ecosystem is representative of a highly stressed oceanic environment – multiple stressors affect the system from almost every direction and this was the case before the Deepwater Horizon/Macondo oil well blowout. Nutrient over-enrichment, seasonal hypoxia, fishery stress, pollution, intense industry activity, warming waters, and ocean acidification have collectively pushed the Gulf ecosystem to the point of collapse. The Macondo Blowout was yet another anthropogenic impact and it has had a tremendous affect on this ecosystem.

Lessons Learned from the Deepwater Horizon Disaster

Assessing impacts of an offshore, open ocean oil discharge represents a formidable challenge.

At the peak of the DWH incident, oil covered 29,000 square miles of the Gulf's surface, an area comparable in size to the state of South Carolina (32,020 square miles). An oceanographic research vessel travels at about 10 miles an hour. Imagine attempting to characterize the vegetation and soil all across South Carolina by driving in a car at 10 miles an hour across the state. Given the large area, you could only take a sample every few hours, perhaps 8 samples a day if you and your partner shared the driving. And if taking a single sample required 3 hours (~this is the amount of time required to collect a depth profile of water samples at a depth of 1500m), it would take a very long time to characterize the entire state.

This example provides insight to the situation faced by scientists attempting to characterize Gulf offshore environments in the wake of the DWH discharge. The sheer size of the open ocean area impacted by the DWH discharge and the fact that the ocean is extremely dynamic –the water moves and chemical signatures can change on time scales of minutes to hours – underscores the daunting challenge this incident posed to oceanographers. The spatial and temporal complexity of the arena and the presence of oil complicated collection of basic geochemical and biological data. Characterize the distribution of oil and gas, aiming to discover novel features, and quantify impacts, made this task Herculean. The regular sea-going gear we use to collect samples is not made for oily water; extraordinary effort was required to clean bottles, sensors, etc. between sample collections. And, choices had to made: one could characterize smaller areas at greater resolution or characterize larger areas at more coarse resolution – one could not do both on a short cruise.

The infusion of oil and gas to the system meant that the biological system was rapidly evolving. This meant that time series data were critical, so that we could track the response of various parts of the system to perturbation. Though insufficient data of this type were collected for offshore water column and sediment habitats, the one published suite of time-series measurements made over a 10-month period (March – December 2010) underscores the clear importance of time-series data, as opposed to 'snap-shot' sampling (i.e. a single week or two sampling campaign) (Crespo-Medina et al. 2014). An enormous amount of time and multiple ships conducting comparable operations would have been required to properly sample and characterize the entire area impacted by the discharge.

Possessing prior system knowledge, i.e. experience working in the area and familiarity with the bathymetry of the seabed, was integral for our group's discovery of the deepwater plumes. We discovered the plumes because we had a good idea of the direction the deep currents was moving and we knew the bathymetry of the area because many of us had been involved in the only long-term Gulf benthic observatory (at Mississippi Canyon lease block 118) which lies to the N/NW of the Macondo wellhead, so had seabed maps of the area. In depth system knowledge provided us with instincts – and the willingness to trust our instincts – and this led to our discovery of the plumes (Diercks et al. 2010, Joye et al. 2011). We shared the locations of the plumes with federal responders and with other scientists, which led to additional discoveries (Camilli et al. 2010, Valentine et al. 2010, Kessler et al. 2011).

To facilitate and improve the efficacy of future open-ocean oil spill response, a foundation of strong coordination, communication and trust is needed between academic responders and federal incident command officials. Ideally, this foundation should be in place and vetted before the next incident occurs. As described in the testimony below, academic scientists have a great deal of expertise to offer the federal responders and this expertise should be brought to bear immediately in future response scenarios. Furthermore, in hindsight, significant investments in infrastructure and technology and basic research are required to be prepared for the next deepwater discharge. Such bold moves will increase the ability of responders to identify the multitude of system-scale impacts and assure collection of the proper samples to quantify those impacts.

Environmental baselines are necessary and must be obtained.

How do you quantify whether and to what extent something has changed (i.e., an impact) when you do not know the original condition (i.e., the baseline)? The answer is that it is difficult and it requires that you essentially make an educated guess as to what the original condition was. Environmental baselines are sorely lacking across the Gulf of Mexico ecosystem. Despite numerous Minerals Management Service (now the Bureau of Ocean and Energy Management) funded studies to describe Gulf physical oceanography (e.g., MMS 204-022, "Cross-shelf exchange processes and the deepwater circulation…) and deepsea chemosynthetic and hard bottom communities (e.g. MMS 2009-046, "Investigations of chemosynthetic communities on the lower continental slope…"; MMS 2009-039, "Northern Gulf of Mexico Continental Slope Habitats and Benthic Ecology Study"; and MMS 2007-004, "Characterization of Northern Gulf of Mexico Deepwater hard-bottom communities with emphasis on *Lophelia* coral"), the basic microbiology of the Gulf system and the ability of microorganisms to oxidize oil and gas were essentially unconstrained at the baseline level in 2010. There was no data available on water column oil degradation rates and very little available on water column methane oxidation rates (Wankel et al. 2010). Prior to the DWH, someone once described my work on oil and gas microbiology in the Gulf as esoteric. In the post-DWH world, that word would never be used because we now know that microbiological research is absolutely critical.

Few long-term baseline data sets that include basic microbiology are available for the Gulf (Joye et al. 2014). The NOAA/National Institute for Undersea Science and Technology Mississippi Canyon block 118 (MC118) Gas Hydrate Microbial Observatory and a NSF funded 5-year, though only 2 research cruises, Hypersaline Ecosystems Microbial Observatory programs are notable exceptions. The MC118 site is less than 20km from the site of the Macondo blowout and data from this program provided critical baseline data that was used to assess microbial community changes in the water column and sediments following the DWH incident (Crespo-Medina et al. 2014, Yang et al. 2014). Without such critical baseline data, it would have been impossible to quantify changes in pelagic microbial oil and gas degrading communities in response to the blowout. Still, other parts of the pelagic “microbial” community such as phytoplankton and small zooplankton, are unknown because we do not know much about them in the first place. Thankfully, baseline data were available for some cold water coral communities and that has facilitated research aimed at quantifying Macondo-related impacts to those communities (White et al. 2012, Fisher et al. 2014a, 2014b).

Environmental baselines are also lacking on the natural distributions of hydrocarbons and their geochemical “fingerprint” for the Gulf. Fingerprinting oil to a specific reservoir requires ultra-clean sampling protocols in the field and sophisticated instrumentation in the laboratory. We need to know how the natural distribution of oil (dissolved hydrocarbons) and gas (methane) vary across the Gulf system and we need to be able to identify and isolate specific sources (reservoirs). We need to understand variability in concentration and fingerprint at the scale of an individual seep field, in a lease block, and between regions (e.g. Mississippi Canyon, Green Canyon, Alaminos Canyon, etc.). Furthermore, we must obtain basic information on oil and gas degradation rates in the environment, how they vary over space and time, and we have to know what constrains these activities. One cannot conclude that “microbes ate all the oil” based on the observation that oil is no longer measurable in a water sample; the fact is that the oil may have instead moved to another location (e.g. the seafloor) where you were not looking.

Finally, to be prepared for the next incident, the research community needs well-validated models of deep circulation and the ability to deploy 10s-100s of robotic floats with the appropriate instruments (fluorometers) to detect oil. We have much better models of the Macondo area now (Goni et al. 2015) and of some of the unique physics that led to development of the deepwater plumes, for example (Zachary et al. 2015), but we need comparable models for the entire Gulf ecosystem. This is a goal that can be achieved, with proper research funding. In fact, one could argue that such floats with CDOM fluorometers should be deployed now, to start obtaining the desperately needed environmental baselines. The research community must push the envelope to develop other instruments specific to hydrocarbons that can be deployed on autonomous vehicles.

This will permit characterization of large areas with minimal demands for ship time.

Obtaining proper environmental baselines for the Gulf system is something that every environmental scientists conducting post Macondo research realizes. This necessary goal can be achieved as part of DOI/BOEM's mission, since they are mandated to provide funding to support documentation of environmental baselines through the Environmental Studies Program. BOEM's budget for the ESP is a $35M a year and those funds must cover all areas impacted by oil and gas development. Obtaining proper baselines for the Gulf and elsewhere (e.g. The Arctic) will cost substantially more than $35M per year and I believe these cost could and should be shared by industry. Sufficient environmental baselines are in the best interest of the industry and the Trustees. Thus, I encourage Congress and the Administration to increase BOEM's funding and to give them increased authority to require industry to obtain baseline and ongoing (annual) environmental monitoring data at all locations impacted by oil and gas development. The requisite data collected, proper protocols, and sampling intervals should be determined by a Panel of Experts selected and convened by BOEM officials, potentially in collaboration with NOAA's Emergency Response Division. Industry should shoulder the costs of this monitoring program and the funds should be administered competitively by BOEM.

Knowing the flow rate is a critical to closing the "oil budget".

Knowing the discharge rate is essential for selecting and employing the most appropriate method of intervention to seal a discharging well. Quantification of the discharge rate over time – and knowing and whether, and if so how much, it varies over time, is also essential for determining the total hydrocarbon discharge, a value of obvious importance in the NRDA process. I have heard many people say there was no technology available to quantify the flow rate when the Macondo blowout began. This statement simply is not true. Scientists had determined the flow rate of discharging vents in deepsea hydrothermal systems using particle imaging velocimetry (PIV, Westerweel 1993), optical plume velocimetry (OPV; Crone et al. 2008) or acoustic scintillation (Di Iorio et al. 2005, 2012) before the Macondo Blowout. The first evidence that the discharge rate was well above the stated rate of 1000 or 5000 barrels of oil per day (BOPD) came from satellite imagery: the satellite-derived estimate of 26,500 barrels a day was called the "MacDonald Minimum" by the New York Times (the number was generated by Prof. Ian MacDonald at Florida State University). The first estimate of the Macondo well discharge rate based on (very poor quality) digital video footage of the discharging wellhead was obtained by PIV and the value was 57,000 ± 10,000 BOPD (Crone and Tolstoy 2010). It is noteworthy that release of this video footage required three congressional subpoenas. Later in the discharge, Camilli et al. (2011) reported a flow rate of 52,700 BOPD. There is no reasonable explanation for why the flow rate was not quantified early on and continuously. However, because it was not, we will never truly know how much oil was discharged from the Macondo wellhead. And not knowing the absolute discharge rate makes generating and closing the oil budget impossible.

In the future, immediate and continuous assessment of the discharge rate should be an absolute requirement of the responsible party.

Patching other holes in the oil budget.

- Deepwater plumes and sedimented, weathered oil

The discovery of deepwater plumes enriched in oil and gas was not an accident. The literature was rich with papers describing the formation of underwater oil-rich plumes in the event of a deepwater blowout and field experiments verified model results. On the first academic response cruise on board the R/V Pelican in early May 2010, Vernon Asper and Arne Diercks discovered the deepwater plumes (Diercks et al. 2010) and on the second academic response cruise, we characterized the chemistry and microbiology of those plumes in great detail (Joye et al. 2011, Crespo-Medina et al. 2014). **How much of the discharged oil was in the deepwater plume?** That value is not well constrained but the number that is most commonly stated is 30%. All of the discharged gas, namely methane, some 500,000 metric tonnes of it, was trapped within the deepwater plumes (Joye et al. 2011). Notably, discharged gas is not included in the "oil budget".

A significant fraction, some 5 to 15% of the discharged oil, was deposited to the seafloor as "marine 'oil' snow" (Chanton et al. 2014, Valentine et al. 2014), covering an area of over 8,000 square kilometers. Our research team collected cores from many sites at various distances from the wellhead in May 2010. We re-sampled some of those areas in August 2010 and discovered layers of recently deposited oil-containing material that were absent in May 2010. These layers were observed many 10's of miles from the wellhead, showing that "oil snow" deposition was a widespread phenomenon. The freshly deposited layer exhibited a dark coloration; these cores smelled strongly of hydrocarbons and the water overlying the cores contained a visible rainbow sheen of oil. These cores were not from known hydrocarbon seep; this oil had not seeped into the sediments from below, it had rained down onto the sediments from above. The depth of the layer was up to several cm thick in some places; layers that thick would take hundreds of years to accumulate under natural sedimentation regimes. The animals, worms and such, living in the sediment had been suffocated. These cores were like nothing any of us had ever seen.

We now know that this oil-containing material reached the seafloor through the mechanism of marine oil snow sedimentation, a process that was unrecognized and unappreciated prior to the DWH disaster. Marine oil snow forms by several different mechanisms, abiotically through oil-mineral aggregation, and biologically through the activity of bacteria and phytoplankton (Passow 2014, Joye et al. 2014). Environmental conditions determine which type of marine snow is most important for the transfer of oil to depth and the primary mode of oil snow formation can vary by location and time. Mobilization and redistribution of this sedimented, weathered presents a long-term, persistent impact of the oil on benthic ecosystems that are exposed, possibly multiple times, to oil components that sank to the seabed.

Marine oil snow could also serve as an important food source for many planktonic species as well, making oil contaminated snow a mechanism to move oil into the food web. Macondo-derived hydrocarbons were found in floating particulate matter in the Gulf as far as 190 km southwest of the wellhead in 2010, and the ancient hydrocarbon isotopic signal persisted into 2011 and 2012. This particulate phase appears to have been ingested by zooplankton and it entered the food web. There is also evidence consistent with the hypothesis that Macondo hydrocarbons entered the food web of coastal organisms to the north of the spill site.

Sedimentation of oil was not included in the original federal oil budget. We now know that the formation of marine oil snow particles is an important fate of oil. This fate must be considered in future response plans and its importance quantified, through direct measurements of sedimentation and trophic transfer, relative to other potential fates and impacts of oil.

- The failure to constrain rates of microbial oil degradation

Despite the fact that oil was present in the deepwater plume and on the sea surface, no actual rates of oil degradation were carried out. By “actual rates” I mean that oil degradation rates were not determined using highly sensitive radiotracer techniques. The one degradation rate that was published was from a lab bottle experiment and it represented a potential rate of one group of compounds, alkanes (Hazen et al. 2010). The “turnover constant” for this one, very labile, group of compounds, the alkanes, was then applied to all the various components of oil, from benzene to polycyclic aromatic hydrocarbons, by some other scientists and the media, leading to the highly inappropriate conclusion that microorganisms magically degraded the Macondo “oil” on a ~10 day time scale. Another journal in Science (Camilli et al. 2010) published much slower oil degradation rate, but that value was largely overlooked.

There is no evidence that ‘magic microbes’ consumed all the Macondo oil. The reasons why we do not how much of the Macondo oil the microbes did, in fact, consume are as follows: The reasons microbial degradation rates were not determined include: 1) making these rate measurements is extremely difficult and time-consuming, 2) the radiotracers are very expensive, and 3) the measurements requires specialized shipboard accommodations (e.g., radioisotope-usage isolation vans). The scientific community is better prepared now to make these measurements – robust methods are now available – but the bottleneck may be expertise as few people make these laborious measurements.

In contrast to oil, methane consumption rates were well constrained and it is clear that microbial processes were unable to completely consume the methane discharged from the Macondo wellhead (Crespo-Medina et al. 2014). Though there remains some debate about the fate of methane (e.g. Kessler et al. 2011 and Crespo-Medina et al. 2014), the differing conclusions are largely a function of the timing of sampling and the time-scale sampled (the former lacked samples from early in the discharge when activity was maximal while the latter presented a comprehensive data set representing a 10-month time series).

Because no direct measurements of oil (component) degradation rate exist, we are left to make assumptions about the potential for the microbial community to degrade oil and that results in very large error bars and an unconstrained oil budget. The federal oil budget released in August 2010 stipulated that approximately 50% of the discharged oil was not accounted for in a quantitative sense. Some fraction of this now lies along the seabed. Another portion was certainly consumed by microbial processes. However, we cannot know, in an absolute sense, how much of this oil remains in the system in some (weathered) form or where this oil ended up.

In the future, we must constrain the quantity and fate of oil and gas in deepwater plumes; we must constrain the formation and fate (sedimentation vs. trophic transfer) of marine oil snow; and, we must quantify rates of oxidation of model oil compounds, e.g. hexadecane as a model alkane, naphthalene as a model PAH, etc.

Dispersants

Chemical dispersants break down surface oil slicks, creating a spectrum of sizes of dissolved oil particles. The general principle behind application of dispersants is that they reduce the amount of oil that reaches the shoreline and that they increase rates of microbial oil degradation by increasing the available surface area of oil that is subject to microbial attack. Importantly, these chemicals are also assumed to be inert, doing no harm to the environment.

The decision to apply dispersants during the DWH response was not taken lightly and ultimately, I believe it came down to minimizing coastal impacts with a true belief that offshore impacts of dispersants would be minimal. As it turns out, the evidence that dispersants increase oil biodegradation rates is contradictory (Kleindienst et al. 2015). There is no scientific consensus that chemical dispersants increase rates of microbial oil degradation. In fact, since the DWH incident many papers have been published documenting that dispersed oil, and in some cases dispersant alone, are more toxic and harmful than oil alone. Negative impacts of dispersants have been documented in marine phytoplankton (Ozhan and Bargu 2014), ciliates (Ortmann et al. 2012, Almeda et al. 2014), rotifers (Rico-Martinez et al. 2013), fish (Ramachandran et al. 2014, Brette et al. 2014), corals (DeLeo et al. 2015) and coral larvae (Goodbody-Gringley et al. 2012).

Clearly, the assumption that dispersants are inert and impart no negative ecosystem consequences was wrong. Much more research is required to quantify the impacts of dispersants and dispersed oil on the biological components of the Gulf system before they are again used as a primary mode of oil spill response. Notably, today, blowout preventors are being instrumented with automated dispersant applicators. Available science suggests this is a bad idea and argues that this practice should be halted until either a truly biologically inert dispersant is developed or concrete evidence is produced to contradict and invalidate the available work that underscores the inherent negative impacts of dispersant/dispersed oil exposure.

Long term Impacts of the Deepwater Horizon Disaster

Damage to deepwater ecosystems

Deepwater benthic ecosystems, including cold-water corals (White et al. 2012, Fisher et al. 2014a, 2014b) and benthic invertebrates (Montagna et al. 2013) were significantly impacted by weathered oil sedimentation. Cold water coral ecosystems are critical benthic habitats in the Gulf of Mexico and elsewhere. Few people realize that only half of the world's coral reefs lie within the photic zone; the other half lies in deeper, dark water. These deep, cold-water coral environments provide fishery habitat as well as other ecosystem services. Corals, and octocorals in particular, are excellent sentinels for anthropogenic impact in the deep sea: They sample the surrounding water, normally live for 100's to 1000's of years, and when impacted, their dead branches or skeletons remain attached to the sea floor providing a record of impact that can last for up to a decade. Exposure to dispersants and dispersed oil made a bad thing worse, at least for the corals (DeLeo et al. 2015).

Cold water corals are slow growing animals; since they grow at a rate of around 1 cm per year, a meter tall coral is 100 years old. Several coral ecosystems in the vicinity of Macondo were severally impacted from the Macondo blowout. The most serious impacts with within about 11 km of the spill site, but corals over twice that distance away and at much deeper depth (to 1900m) were also visibly impacted resulting in dying branches on these normally very long lived corals. Full recovery will not happen in our lifetimes.

The injuries to corals were not confined to the nearby deep sea communities. The mesophotic corals were also injured in large numbers on the shelf. Prof. Ian MacDonald's group at Florida State documented 400 injured coral colonies at two sites, but this represents a small fraction of the total coral habitat known to exist on the shelf under the area covered by surface oil and under the airborne dispersant flight lines.

Resuspension and remobilization of sedimented oil could generate multiple and new exposures to both corals and invertebrate communities, prolonging Macondo's impact on vital deepwater habitats.

Benthic invertebrates may be considered "worms in the mud" but these animals provide important services to their environment: their movement, whether it be burrowing or simply trudging along the surface, serves to mix and oxygenate sediment, increasing oxygen penetration into sediments and allowing the microorganisms in the sediments to mineralize more organic carbon. Thus, benthic invertebrates can affect the rate of sediment organic matter turnover, which also serves to remineralize nutrients. These sedimentary processes are inherently linked to processes in the surface ocean: Remineralized nutrients from the deep are ultimately returned to the surface ocean where they support primary production. Primary production in surface waters fuels the food web but also supports a natural particle flux to the benthos. This delicate balance between nutrient supply to the surface ocean from the deep seafloor and return flux of some fraction to the deep through natural sedimentation was turned on its head by the massive sedimentation event following the Macondo blowout. This benthic-to-surface connection is poorly constrained at baseline levels and we need more data to constrain the magnitude of this perturbation.

Benthic invertebrate communities, especially within a 5-10 mile radius of the wellhead, were wiped out. How long it will take them to recover is unknown. Likewise, damaged coral communities have been documented 10’s of miles from the wellhead. These communities are still showing impact and though we know it will require 100’s of years for the most damaged coral communities to recover, we are still documenting impacts that were not documented in 2012 and it is likely that the true magnitude of the deepsea impact may never be fully appreciated.

Notably, there is no set-back distance that would have prevented these catastrophic impacts. The regulations in place still allow drilling and production to occur far too close (500m) to sensitive communities. I encourage Congress and the Administrative to review these set-back distances and to increase them to minimize damage to sensitive chemosynthetic communities. The deep sea is very poorly surveyed and its fauna are very poorly known. As noted previously, baseline studies of the distribution and status of deepwater communities near oil and gas development sites, even if this is video surveys run by the industry, need to be reviewed by BOEM/BSEE and trained scientists. We need to better understand the baseline conditions in the deep sea to better understand where the more unique communities are found in the sea of mud that is most of the deep sea floor. More in depth knowledge of the biodiversity and population connectivity of the deepsea fauna is needed to understand the effects of the next disaster or cumulative impacts of anthropogenic impacts on the oceans.

Microbial community shifts

The massive infusion of hydrocarbons to the Gulf system in the Macondo area resulted in a rapid shift in hydrocarbon-degrading microbial community composition that, in some places, remains detectable today (Yang et al. 2014). Whether the present microbial hydrocarbon degrading community is providing the same ecosystem services or maintaining their previous levels of activity is unknown. Assessment of time-series changes in phytoplankton, zooplankton and meso-pelagic organisms is lacking, so it is unclear whether their populations were impacted similarly. However, given the variable ability of some organisms to tolerate oil exposure, shifts in community composition are likely. The long-term impacts of such shifts and the time required for the base of the food web to achieve a new steady state is unknown.

Moving Forward

During the DWH response, it became clear that the research community lacked sufficient resources in the form of manned submersibles, ROVs, and AUVs to adequately and rapidly respond. Germany, France, Russia, Japan and China have invested much more vested in deep-sea technology than the US has in the past twenty years and it shows. Deep-sea assets and technology development and instrument acquisition are necessary to support basic scientific exploration and discovery. These tools are also absolutely essential to track, quantify, map, and verify open ocean water column and benthic impacts of incidents like the Macondo blowout. Training and instrumenting an academic task force to aid in response to offshore blowouts and other natural disasters is a worthy investment. I encourage Congress and the Administration to increase BOEM’s funding and scope of work to facilitate and improve future response efforts.

Thank you for the opportunity to testify today. I would be happy to answer any questions that you have.

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