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Hercules 265 rapid response: Immediate ecosystem impacts of a natural gas blowout incident

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ABSTRACT

In late July 2013, the Hercules 265 drilling rig in the Northern Gulf of Mexico experienced a catastrophic loss of control. Large quantities of natural gas spewed into the environment for ~2 days before the well self-sealed through down-hole collapse below the seafloor. Ecosystem Impacts of Oil and Gas Inputs to the Gulf (ECOGIG) and collaborating Gulf of Mexico Research Initiative (GoMRI) consortia mounted a rapid response cruise to characterize the waters around the Hercules 265 rig, beginning just 4 days after the blowout. Our analysis showed an immediate microbial response to the elevated concentrations of methane in the water column, as evidenced by the drawdown of oxygen to hypoxic conditions, the incorporation of methane-derived carbon into particles, and measurable rates of methane-assimilation and nitrogen-fixation. Additionally, radium isotope measurements allowed us to constrain the timescale of bottom water exposure to the influence of the rig. A second sampling by the Center for Integrated Modeling and Analysis of Gulf Ecosystems (C-IMAGE) consortium indicated that the ecosystem had returned to near pre-blowout conditions within one month.

1. Introduction

Substantial quantities of oil and gas are released into the Gulf of Mexico by natural seeps and through anthropogenic mechanisms involving accidental discharge during the exploration, production, and transportation of hydrocarbons (Anderson et al., 2012) in addition to other commercial activities (Schleifstein, 2013). A variety of studies in the wake of the Deepwater Horizon (DWH) incident in 2010 revealed clear changes in the composition and activity of microbial communities exposed to increased concentrations of oil and gas over extended periods of time (Kessler et al., 2011; Redmond and Valentine, 2012; Crespo-Medina et al., 2014; Joye et al., 2014a). In particular, the microbial consumption of methane was linked to localized depletion of water column oxygen at depth (Joye et al., 2011; Kessler et al., 2011; Yang et al., 2014) and likely facilitated the movement of oil and gas carbon into particles and zooplankton near the shelf (Graham et al., 2010; Chanton et al., 2012; Cherrier et al., 2013). Larger organisms were also affected by the exposure, including a variety of corals (White et al., 2012; Fisher et al., 2014b; Fisher et al., 2014a) and fish (Murawski et al., 2014). Although the DWH spill has received an unprecedented level of attention from the oceanographic community, much of the scientific effort occurred after the spill was well under way and focused on the longer-term, cumulative effects of the introduction of massive quantities of oil and gas into a pelagic ocean ecosystem. Relatively little is known about the immediate responses of planktonic systems in the early stages of an anthropogenic release of oil and gas.

On the morning of 23 July 2013, the Hercules 265 drilling rig (operated by Walter Oil and Gas Corporation) located in South Timbalier Block 220 in the Northern Gulf of Mexico (55 miles offshore of Louisiana, Fig. 1A) lost control of one of its wells while performing completion work in preparation for natural gas production (BSEE, 2013). Two hours after the blowout began, the rig caught fire and continued to burn until the well self-sealed two days later (25 July) by natural bridging, or collapse of the well below the sea floor, blocking the flow of natural gas (BSEE, 2013).

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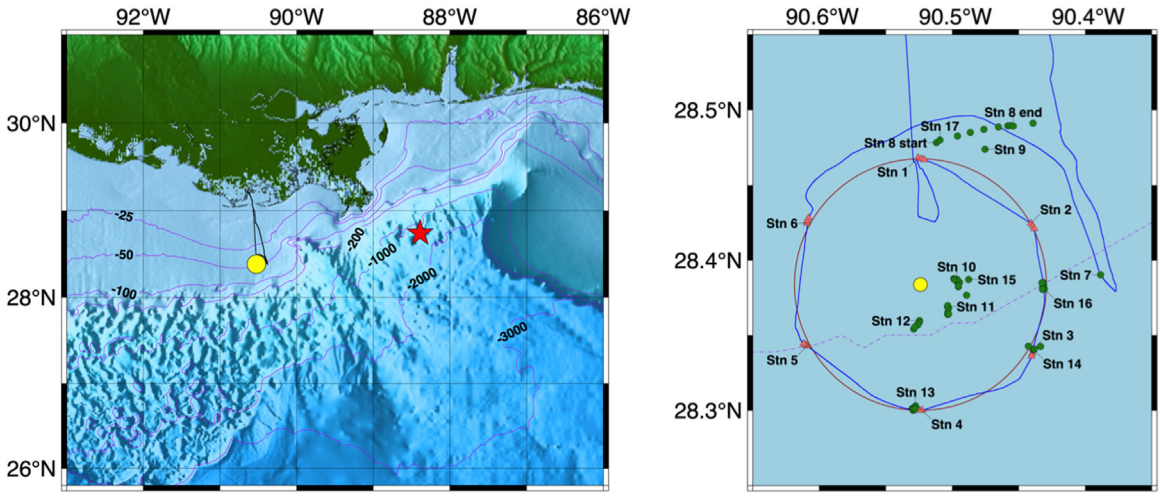

Fig. 1. (A) Chart showing the Mississippi Delta and the locations of the Hercules 265 drilling rig (yellow circle) and the Deepwater Horizon drilling rig (red star). Panel B shows the vicinity of the rig (yellow circle), the 50 m isobath (dashed red line), the day 1 cruise track (blue), drifter releases (red diamonds) along the 5 NM radius, and CTD casts (green circles).

Aerial surveys conducted by the Bureau of Safety and Environmental Enforcement (BSEE) and the non-profit organization On Wings Of Care (OWOC) indicated that the well had released primarily natural gas, as only a light sheen of oil was seen on the surface during the blowout (BSEE, 2013; Schumaker, 2013). It was assumed that the majority of the gas was expelled to atmosphere via the riser pipe.

Upon receiving word of the blowout, Ecosystem Impacts of Oil and Gas Inputs to the Gulf (ECOGIG) and collaborating consortia established through the Gulf of Mexico Research Initiative (GoMRI) organized a rapid response effort to assess the environmental impact of the Hercules 265 blowout (Joye et al., 2014b). The collaborating consortia included the Gulf of Mexico Integrated Spill Response (GISR), the Center for Integrated Modeling and Analysis of Gulf Ecosystems (C-IMAGE), the Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (CARTHE), and the Coastal Waters Consortium (CWC). Fortuitously, the blowout occurred near the end of a major ECOGIG field effort, so substantial resources were available on short notice. Within four days of the blowout (27 July), consortium scientists were aboard the R/V *Acadiana* deploying surface drifters, and began sample collection shortly thereafter (29–30 July).

This study is the first to explore the immediate impact of a large release of natural gas in a marine shelf environment and provides novel insight into the nature and timescale of the microbial community response to this sort of perturbation. Here we present the hydrographic context of the blowout, the water column distributions of methane and oxygen, and the rates of critical microbial processes in the seven days following the blowout. A subsequent visit to the blowout site roughly a month later provided additional insight into the timescale of recovery from the gas release.

2. Materials and methods

2.1. Rapid response cruise (27– 30 July 2013)

Samples were collected and experiments carried out near the Hercules 265 rig (28.384°N, 90.524°W, Fig. 1) aboard the R/V *Acadiana*. Four days after the blowout, six sets of Lagrangian surface drifters were deployed at 60° intervals at a distance of 5 nautical miles (NM) from the rig (Stn. 1–6, Fig. 1). Drifter trajectories gathered in real time informed the sampling efforts that began two days later. Based on these trajectories, we focused our survey to the SE of the rig, sampling in an arc 1.5 NM away from the rig (the closest the Coast Guard would allow sampling; Stns 10–12, 15) and on another arc 5–5.5 NM away (Stns 8, 13, 14, 16, 17). Dispersion of the drifters, which were affected by wind as well as water motion, provide an upper limit to mixing and dilution of surface water, which we estimated by comparing the initial area bounded by the drifters (dark orange shading in Fig. 2A) to the bounded area at later time points (Fig. 2B and C).

Water samples and hydrographic data were collected at these nine stations using an SBE 55 CTD and a rosette equipped with six 4 L sampling bottles. To meet water demands with these relatively small bottles, multiple casts (usually 4) were required to cover the entire water column (50–60 m depth), with all parameters at a given depth being sampled on the same cast. With the exception of Stn. 8, the R/V *Acadiana* held position for the duration of sampling at each station.

Nutrient samples (NO_3^-, NO_2^-, PO_4^{3-}, SiO_2) were frozen at sea and run within 1 month of collection using a Lachat QuikChem 8000 flow-injection analysis system. Samples were thawed, equilibrated at room temperature for at least 24 h and filtered (0.2 μm polycarbonate) prior to analysis. Due to possible bias from particle leaching using this methodology, these nutrient concentrations can be treated as upper limits. N^*, or deviation from Redfield Ratio, was calculated using the method outlined in Gruber and Sarmiento (1997).

Samples for dissolved methane quantification were collected as soon as the CTD rosette was secured on deck (Joye et al., 2011). Concentrations of C1 to C5 alkanes were determined using headspace extraction (Joye et al., 2011): 55 mL of sample was placed into a 75 mL helium-purged serum vial containing one pellet of NaOH to arrest biological activity in the sample by raising the pH. The sample was the mixed and stored refrigerated prior to analysis. To quantify methane concentration, a 1 mL gas phase sub-sample was injected into an SRI 8610c gas chromatograph equipped with a flame ionization detector. Concentrations were calculated by comparison to an aqueous methane concentration calibration curve prepared with a certified gas mix (1% methane in helium Scott Specialty Gases®) and sterile seawater.

These discrete methane measurements were used to calculate the average, depth-weighted concentration of methane in the water column at each station. The average concentrations were