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Impact of Deepwater Horizon spill on food supply to deep-sea benthos communities

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ABSTRACT

Deep-sea ecosystems encompass unique and often fragile communities that are sensitive to a variety of anthropogenic and natural impacts. After the 2010 Deepwater Horizon (DWH) oil spill, sampling efforts documented the acute impact of the spill on some deep-sea coral colonies. To investigate the impact of the DWH spill on quality and quantity of biomass delivered to the deep-sea, a suite of geochemical tracers (e.g., stable and radio-isotopes, lipid biomarkers, and compound-specific isotopes) was measured from monthly sediment trap samples deployed near a high-density deep-coral site in the Viosca Knoll area of the north–central Gulf of Mexico prior to (Oct-2008 to Sept-2009) and after the spill (Oct-10 to Sept-11). Marine (e.g., autochthonous) sources of organic matter (OM) dominated the sediment traps in both years, however after the spill, there was a pronounced reduction in marine-sourced OM, including a reduction in marine-sourced sterols and *n*-alkanes and a concomitant decrease in sediment trap organic carbon and pigment flux. Results from this study indicate a reduction in primary production and carbon export to the deep-sea in 2010–2011, at least 6–18 months after the spill started. Whereas satellite observations indicate an initial increase in phytoplankton biomass, results from this sediment trap study define a reduction in primary production and carbon export to the deep-sea community. In addition, a dilution from a low-^{14}C carbon source (e.g., petro-carbon) was detected in the sediment trap samples after the spill, in conjunction with a change in the petrogenic composition. The data presented here fills a critical gap in our knowledge of biogeochemical processes and sub-acute impacts to the deep-sea that ensued after the 2010 DWH spill.

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1. Introduction

Between 20 April and 15 July 2010 the Deepwater Horizon (DWH) blowout event in the northern Gulf of Mexico (GOM) released an estimated 4.1–4.6 million barrels (~650,000 m^3) of oil to the GOM (Kessler et al., 2011; Griffiths, 2012; McNutt et al., 2012) and up to 500,000 t of hydrocarbon gas (Joye et al., 2011). A 100-m thick deep-water plume of neutrally buoyant water enriched with petroleum hydrocarbons from the DWH was also documented at 1000 m depth in June 2010 (Camilli et al., 2010; Reddy et al., 2012). Whereas a majority of the oil and gas remained below the sea surface (Camilli et al., 2010; Reddy et al., 2012), oil was detected at the surface, with the spatial extent of the spill controlled by circulation and wind-induced drift (Fig. 1; Le Hénaff et al., 2012). Large marine snow formation may have potentially accelerated the rapid downward transport of oil-contaminated surface water to the pelagic ecosystems (e.g., Passow et al., 2012). DWH impact assessments of deep-sea benthic ecosystems observed localized responses (White et al., 2012; Hsing et al., 2013; Fisher et al., 2014a), including signs of coral stress (e.g., varying degrees of tissue loss, sclerite enlargement, excess mucous production), and reductions in benthic faunal abundance and diversity (Montagna et al., 2013; Fisher et al., 2014b). For example, at 11 km to the SW of the DWH spill, 86% of the coral colonies imaged in the area exhibited signs of

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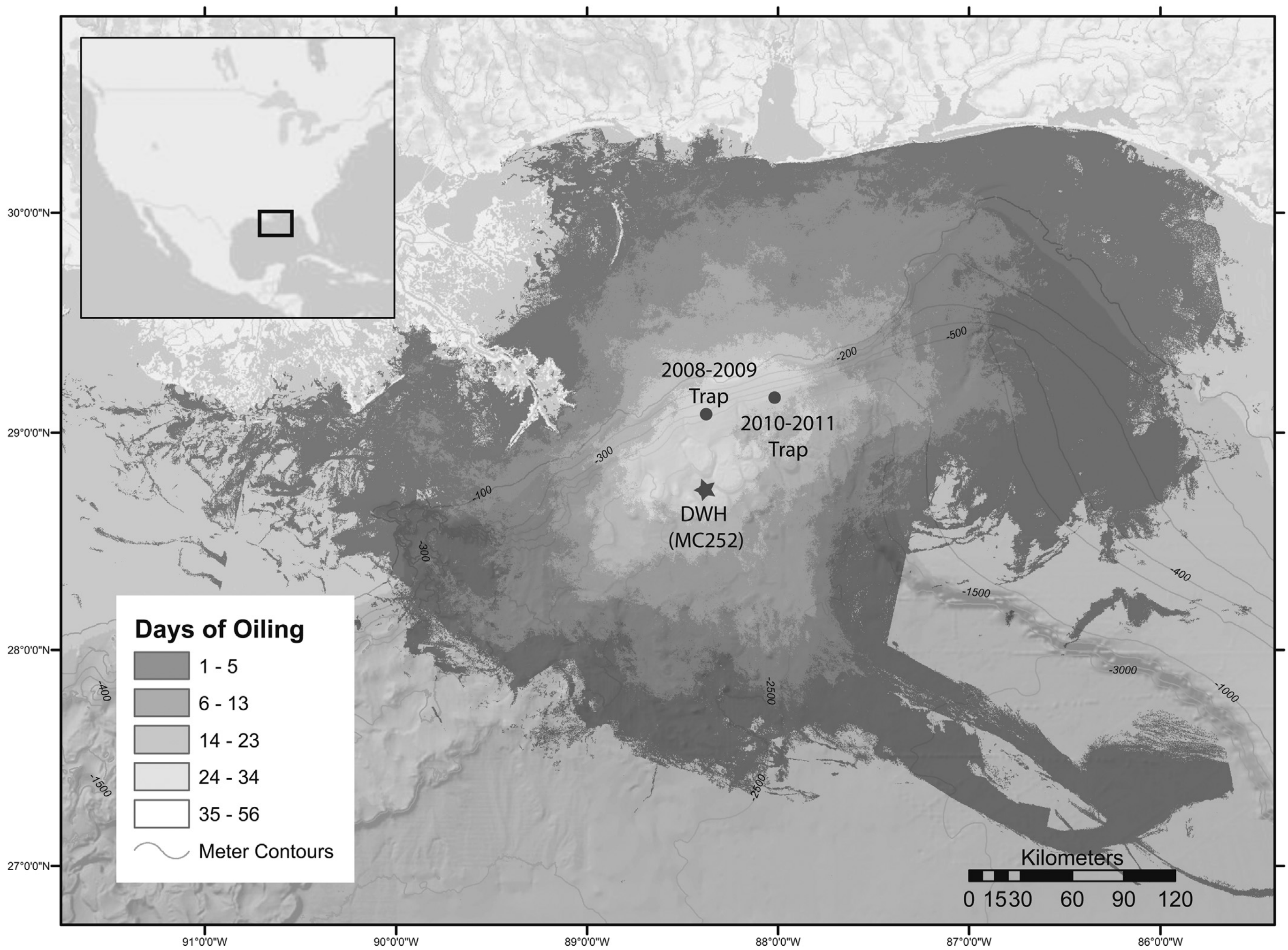

Fig. 1. Map of Gulf of Mexico showing the location of sediment trap deployments in 2008–2009 and 2010–2011 at 476 m and 416 m, respectively, and the Deepwater Horizon location at MC252. The 100 m contour intervals are shown. Locations are superimposed on the number of days of oiling accessed from NOAA's Environmental Response Management Application (ERMA) for the Deepwater Horizon Oil Spill (http://gomex.erma.noaa.gov/erma.html#/x=-88.25810&y=27.03211&z=6&layers=23036).

impact (White et al., 2012). Other studies have documented the footprint of the DWH spill on deep-sea benthic communities (Montagna et al., 2013; Fisher et al., 2014b), trophic transfer of petro-carbon into the planktonic food web (Graham et al., 2010; Chanton et al., 2012; Cherrier et al., 2014; Prouty et al., 2014a) and intermediate trophic levels (Quintana-Rizzo et al., 2015), as well as potential recovery of deep-sea corals (Hsing et al., 2013). However, questions remain as to how the 2010 DWH event impacted biomass production, specifically phytoplankton abundance and community structure (Abbriano et al., 2011). Based on positive chlorophyll anomalies detected in the northern GOM in August 2010, Hu et al. (2011) suggested that the northern GOM might have experienced a phytoplankton bloom after the DWH spill, although planktonic cycles are variable. This is consistent with observations of phytoplankton blooms after the IXTOC-1 oil spill in the southern GOM in 1979 (Jernelov and Linden, 1981), when phytoplankton thrived possibly due to a reduction in predation (e.g., Vargo et al., 1982; Sheng et al., 2011). Yet, other studies have shown oil slicks to hinder air-sea exchange and light penetration resulting in a decrease in photosynthesis (Nuzzi, 1973; Dunstan et al., 1975; Miller et al., 1978).

The delivery of organic matter (OM) to the deep-sea is an important component of the oceanic carbon cycle and is crucial to sustaining the ecosystems that inhabit depths below the photic zone. For example, most deep-sea corals are suspension feeders, feeding primarily on surface derived organic carbon that is transported to depth (Druffel et al., 1995; Roark et al., 2009; Prouty et al., 2011). Deep-sea corals therefore may be sensitive to changes in nutrient transport from surface waters to the seafloor and have the potential to record OM source through incorporation into skeletal structures (Williams et al., 2007; Williams and Grottoli, 2010; Sherwood et al., 2011; Prouty et al., 2014a,b). Differentiating the various sources of OM to the GOM benthos is particularly complex given that relative inputs of terrestrial and marine OM can vary both spatially and temporally (e.g., Hedges and Parker, 1976; Trefry et al., 1994; Bianchi et al., 1997, 2002; Goñi et al., 1998; Mead and Goñi, 2006; Wysocki et al., 2006; Waterson and Canuel, 2008; Sampere et al., 2011). This complexity is largely related to freshwater and sediment input from the Mississippi-Atchafalaya River (MAR) Basin combined with seasonally high rates of primary productivity (>100 g C m^{-2} $year^{-1}$). Since river discharge is tightly coupled to nutrient delivery into surface waters of the GOM (Fig. 2b), periods of high riverine input deliver terrestrially-derived OM into the GOM, stimulating primary productivity. Previous