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Reply to Boehm and Carragher: Multiple lines of evidence link deep-water coral damage to Deepwater Horizon oil spill

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Reply to Boehm and Carragher: Multiple lines of evidence link deep-water coral damage to *Deepwater Horizon* oil spill

Our original study (1) used visual inspection as well as biological and geochemical analyses of corals and the surrounding sediment to provide complementary and compelling evidence linking the *Deepwater Horizon* (DWH) oil spill to the presence of damaged deep-water corals and brittle stars 11 km from the site of the leaking oil.

The probability that the impact to this coral community occurred independently of the DWH spill can be estimated on the basis of three facts. (*i*) This is the only site among 20 deep-water coral communities associated with authigenic seep carbonates in the northern Gulf of Mexico where visual inspection over the past decade has revealed evidence of notable damage to corals. (*ii*) The presence of dead and dying tissue and the attachment of living ophiuroids to the corals indicate that the impact was recent (Fig. 1). (*iii*) The average age of four coral colonies sampled from the site is 460 ± 35 y [according to radiocarbon dating as in Prouty et al. (2)]. Assuming that an independent event had an equal chance of occurring at any of the other seep-related coral sites (1 in 20) and during any of the past 460 y at this site (1 in 460) yields a probability of the damage to corals happening coincidently at this place and time of approximately 0.0001.

In addition, there is no evidence from Bureau of Ocean and Energy Management seismic data, National Oceanic and Atmospheric Administration multibeam data, or high-resolution autonomous underwater vehicle multibeam data to indicate slope failure and the underwater landslide suggested by Boehm and Carragher (3) as an alternate explanation for the damage to this site. It is also noteworthy that the coral community examined in our study (1) is on top of a discrete ridge. There is no known mechanism by which material from an underwater landslide would gather at the top of a ridge and not also be apparent in the surrounding area.

The coral community examined in our original article is 11 km to the southwest of the Macondo well at a depth of 1,370 m (1), placing it in the path of a documented deep-water plume enriched with petroleum hydrocarbons. A maximum of oil constituents centered at ~1,400 m was observed within 2 km of these corals between June 23 and 27, 2010 (4), and levels of polycyclic aromatic hydrocarbons considered to be toxic to marine organisms were measured up to a distance of 13 km to the southwest of the Macondo well, at depths between 1,000 and 1,400 m between May 9 and 16, 2010 (5). Both of these studies support our findings (1) and describe discrete measurements that represent a minimum amount of petroleum hydrocarbons that could have impacted coral communities over the 86 d of the DWH spill.

The consistent biomarker ratios between coral samples and the oil from the DWH spill were determined using comprehensive 2D gas chromatography coupled to a time-of-flight mass spectrometer (GC×GC-TOF-MS). Although oil samples in the area are indeed difficult to distinguish, GC×GC-TOF-MS is capable of separating, identifying, and quantifying compounds that may not be resolved by the 1D chromatographic techniques (6) referred to by Boehm and Carragher (3).

Fig. 1. Recently impacted coral with attached brittle star from the site described by White et al. (1).

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