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The effects of hydrocarbons on meiofauna in marine sediments in Antarctica

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ABSTRACT

The effects of hydrocarbons in marine sediments on Antarctic meiofaunal communities (nematodes and copepods) were investigated in a five year field experiment at Casey Station, East Antarctica. The effects of four different types of hydrocarbons were examined: clean mineral lube oil, used mineral lube oil, synthetic lube oil marketed as being rapidly biodegradable, and diesel fuel (Special Antarctic Blend). Sediments were sieved to remove macrofauna and then treated with one of the oils, then deployed in trays on the seabed (12–18 m) under sea ice, along with control, uncontaminated sediment. Samples of the meiofaunal communities were collected at one, two and five years and nematodes identified to genus and copepods to family. There were significant differences between meiofaunal communities in hydrocarbon-treated sediment compared to controls, but each hydrocarbon type had quite different effects. Effects persisted to five years and communities showed no signs of recovery or becoming more similar to controls. Nematodes were more sensitive to hydrocarbons than copepods, showing very distinct community differences between different treatments which persisted over the five years. In contrast, copepod communities showed less distinct, more variable changes, which decreased in severity over five years. Nematode abundance initially decreased in hydrocarbon treatments in comparison to controls, except for the biodegradable oil treatment, and this persisted also over five years. In contrast, copepod abundance initially increased in hydrocarbon treatments compared to controls, and then declined, and by five years abundances were lower in hydrocarbon treatments than in controls. Whilst structural community, abundance and diversity differences for nematodes and copepods remained after 5 years, the nematode functional parameters based on feeding types and maturity characteristics showed a substantial degree of recovery after 5 years, suggesting some functional recovery of the nematode community. This experiment demonstrates that different hydrocarbons can have very different effects on sediment meiofauna and that despite strong patterns of community effects it was very difficult to characterize effects on different taxa. The effects of oils in sediments are also likely to persist for periods greater than five years and could take decades to recover.

1. Introduction

Hydrocarbon pollution represents one of the greatest environmental risks to Antarctic marine ecosystems. A small pollution event in Antarctica can have greater significance than occurrences of similar magnitude elsewhere in the world (Clarke and Harris, 2003) as the extreme environment, sea ice and isolation makes responding very difficult (Raymond et al., 2017). The principal forms of human activity in Antarctica are limited to scientific research, fishing and tourism. The increase in human activities in certain areas of the continent has raised concerns about pollution and impacts, particularly to coastal ice-free rocky areas, where research stations and tourism are concentrated. Hydrocarbon pollution originates from a variety of sources including shipping and local input from stations (Cripps and Priddle, 1991). The biggest oil spill to occur in Antarctica was in 1989 when an Argentine resupply vessel, *Bahia Paraiso*, ran aground in the Bismarck Strait 2 miles from a scientific research station operated by the United States, near the tip of the Antarctic Peninsula, spilling about 600,000 l of fuel (Kennicutt et al., 1991). In 2001 a Chilean ship contracted by Ecuador, the *Patriarche,* ran aground and spilled 1500 l of diesel fuel off the north-west Antarctic coast (CEP-IV-IP62, 2001). The most recent spill was from the *MS Explorer*, an adventure travel ship which sank in Antarctic waters after hitting an iceberg on November 2007 carrying about 190,000 l of marine gas oil, 24,000 l of lubricant oil and 1200 l of

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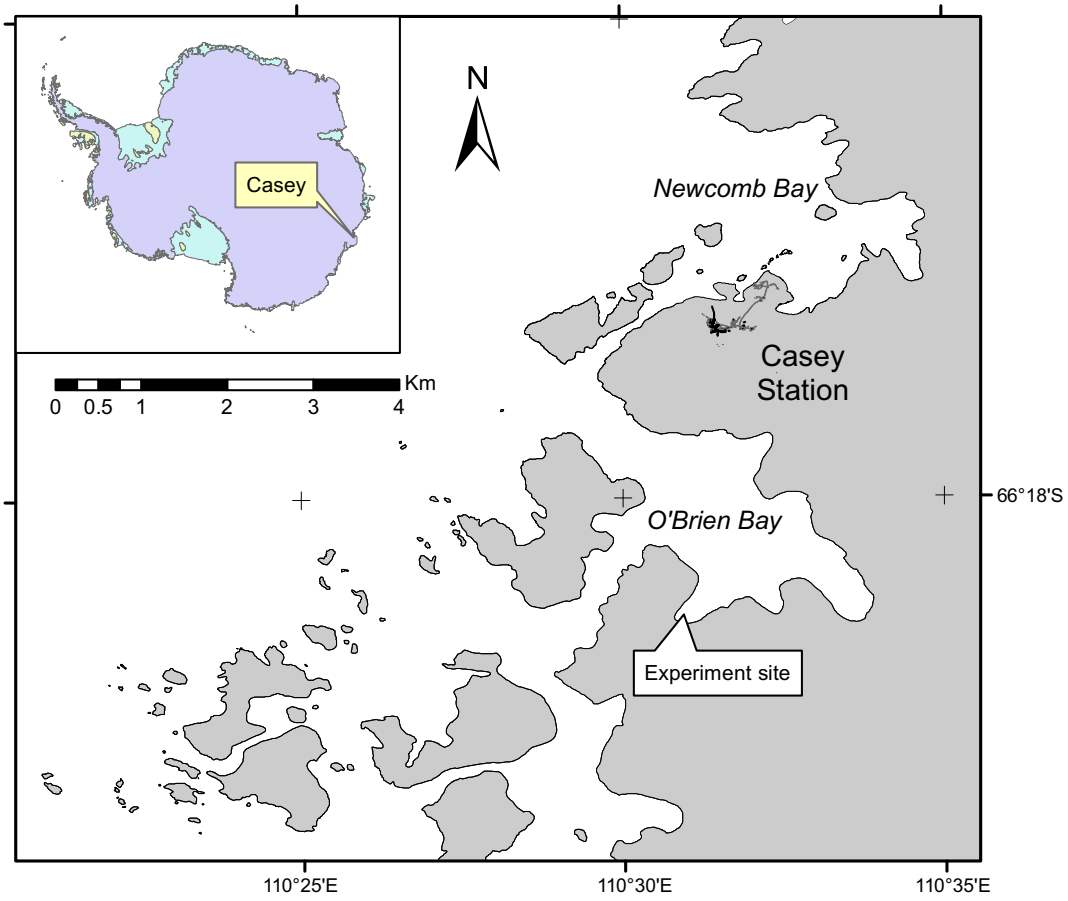

Fig. 1. The location of Casey station in Antarctica and the experimental site in O' Brien Bay.

petrol (Stewart and Draper, 2008). There is also a risk of hydrocarbon spills from station fuel storage and resupply operations (Raymond et al., 2017). In 1990, a spill of 91,000 l of SAB diesel fuel occurred from a fuel storage facility at Casey Station (Deprez et al., 1999). Past research has shown that the coastal environment around Casey Station has been contaminated with heavy metals and petroleum hydrocarbons (Stark et al., 2014; Stark et al., 2005). Sediment macrofaunal assemblages at contaminated sites are significantly different and less diverse than at control sites (Stark et al., 2003a). Pollution sources at Casey Station include an old waste disposal site, a wastewater outfall and fuel spills. The effects of hydrocarbon pollution on benthic ecosystems range from smothering of benthic organisms, toxicity of different compounds and additives in hydrocarbons, to effects on food availability and nutrient concentrations (Cripps and Priddle, 1991; Danovaro et al., 1995; Stark et al., 2003b; Voudrias and Smith, 1986). It has been estimated that between 1 and 13% of spilled oil makes its way into subtidal sediments, and is highest where concentrations of particulate organic matter are high (Lee and Page, 1997). Despite remediation of waste disposal sites such as was done at Casey Station (Stark et al., 2006a), by removing the source of hydrocarbons, little is known about how long it will take benthic communities to recover from existing hydrocarbon contamination (Stark et al., 2006b).

Benthic meiofauna have been widely used as an indicator of disturbance and environmental impacts (Balsamo et al., 2012; Beier and Traunspurger, 2001; Kennedy and Jacoby, 1999; Schratzberger et al., 2000; Vincx and Heip, 1991; Zeppilli et al., 2015). There are very few studies, however, of Antarctic meiobenthos, and none from East Antarctica. Meiofauna are an essential component of marine benthic sediment communities providing ecosystem services including sediment bioturbation and recycling of organic matter (Schratzberger and Ingels, 2017). Meiofauna have been shown to be a good indicator of environmental changes including pollution (Balsamo et al., 2012; Moreno et al., 2009; Moreno et al., 2011). These small and abundant organisms are bound to the sediment throughout their life history and are sensitive to environmental changes. The abundance and diversity of meiofauna communities are correlated with environmental parameters such as sediment particle size (Vanhove et al., 2004; Veit-Kohler et al., 2008), organic enrichment (Schratzberger and Warwick, 1999), food availability and physical parameters such as salinity, currents and oxygen availability (Doulgeraki et al., 2006; Vanhove et al., 1995). The impact of oil on meiobenthos depends on the type and concentration of oil, and sensitivity of the organisms (Coull and Chandler, 1992; Heip et al., 1985; Zeppilli et al., 2015). The effects of an oil spill can be more serious for animals living on the sediment surface than those burrowing in the sediments (Cabioch, 1980). Contamination history may also play an important role, with communities from sites with a history of contamination displaying greater tolerance to hydrocarbons (Carman et al., 2000). Copepods tend to show more sensitivity towards metal pollution and organic enrichment compared to nematodes (Lee et al., 2001; Moore and Bett, 1989; Shiells and Anderson, 1985; Sutherland et al., 2007).

This study investigates the effects of hydrocarbons on meiofaunal assemblages (nematodes and copepods) recruiting to marine sediments over 5 years. A manipulative field experiment was done in which four different types of hydrocarbons (Clean lubricant oil, Used lubricant oil, Biodegradable lubricant oil and Special Antarctic Blend diesel fuel) were added to marine sediments and deployed in trays in a shallow marine bay covered by sea ice for most of the year. We tested the hypotheses that different hydrocarbons would have different effects on meiobenthos; that they would affect abundance, diversity and functional community parameters; and that responses would change over time. This study is part of a large interdisciplinary project examining