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The effects of oil pollution on Antarctic benthic diatom communities over 5 years

R. Polmear [a], J.S. Stark [b], D. Roberts [c], A. McMinn [a,*]

[a] Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart 7001, Tasmania, Australia
[b] Australian Antarctic Division, Channel Hwy, Kingston 7050, Tasmania, Australia
[c] Antarctic Climate and Ecosystems CRC, University of Tasmania, Hobart, Tasmania, Australia

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ABSTRACT

Although considered pristine, Antarctica has not been impervious to hydrocarbon pollution. Antarctica's history is peppered with oil spills and numerous abandoned waste disposal sites. Both spill events and constant leakages contribute to previous and current sources of pollution into marine sediments. Here we compare the response of the benthic diatom communities over 5 years to exposure to a commonly used standard synthetic lubricant oil, an alternative lubricant marketed as more biodegradable, in comparison to a control treatment. Community composition varied significantly over time and between treatments with some high variability within contaminated treatments suggesting community stress. Both lubricants showed evidence of significant effects on community composition after 5 years even though total petroleum hydrocarbon reduction reached approximately 80% over this time period. It appears that even after 5 years toxicity remains high for both the standard and biodegradable lubricants revealing the temporal scale at which pollutants persist in Antarctica.

1. Introduction

Hydrocarbon pollution in coastal ecosystems is a well known and growing global problem (National Research Council, 2003; Oil Tanker Spill Statistics, 2009; Australian Maritime Safety Authority, 2012). Antarctica is not immune to this issue with several well-documented large spills in recent decades (e.g. Cripps and Priddle, 1991; Aislabie et al., 2004). Antarctic operations are dependent on the import of all fuels and oils for machinery, transport, and power (Aislabie et al., 2004). In Antarctica, spills and leakages have generally occurred close to fuel transfer, storage and refuelling facilities (Cripps and Priddle, 1991) or from abandoned waste disposal sites (Deprez et al., 1999). Hydrocarbon compositions from spills and leakages have mostly been from commonly used fuel and oil mixes, including Special Antarctic Blend diesel fuel, Mobil 0W40 lubricant, petrol, aviation kerosene and other less common fuels and oils (Powell et al., 2010). Hydrocarbon pollution events or their gradual accumulation in Antarctic marine sediments, as elsewhere, are a major source of stress for benthic communities (Cunningham et al., 2003; Stark et al., 2003, 2005; Thompson et al., 2007; Powell et al., 2010). However, compared with other areas the effects of hydrocarbon pollution on Antarctic benthic communities are relatively poorly understood.

Early hydrocarbon degradation studies in Antarctica focussed on biodegradation and remediation by bacteria around areas of opportunistic spills or leaks near stations (Cavanagh et al., 1998; Powell et al., 2003). To date, microbial studies have examined the effects of different hydrocarbons over short temporal scales (Powell et al., 2005), long temporal scales (Powell et al., 2010), previous exposure to hydrocarbons (Powell et al., 2007) and environmental effects on degradation (Delille et al., 2009). Infaunal communities have been similarly studied on short term scales (Stark et al., 2003; Thompson et al., 2007), long term scales (Smith and Simpson, 1998) and with multiple hydrocarbons (Thompson et al., 2007). A long term ecological experiment investigating the effects of multiple hydrocarbons on the near shore benthic ecosystem of Casey Station, Antarctica, was initiated by the Australian Antarctic Division in the 2001/2002 austral summer (Thompson et al., 2006, 2007; Powell et al., 2010). This experiment was established to investigate benthic bacteria, diatom, meiofaunal and macrofaunal community responses to hydrocarbon pollutants.

Outcomes of the study include the identification of significant effects of oils on infaunal recruitment after one year but no difference between biodegradable lubricant and standard lubricant (Thompson et al., 2007). Powell et al. (2010) noted differences in microbial communities between biodegradable lubricant and

* Corresponding author. Tel.: +61 3 62262980.
E-mail address: Andrew.mcminn@utas.edu.au (A. McMinn).

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standard lubricant over 5 years. Here, we analyse changes in the benthic diatom community in response to exposure to hydrocarbons over 5 years from the same experiment.

Antarctic benthic microalgae consists mostly of diatom species (Cunningham and McMinn, 2004; Al-Handal and Wulff, 2008). While diatom communities occupy most aquatic habitats and are resilient to environmental change, individual taxa often have relatively narrow environmental tolerances (Cremer et al., 2003). By quantifying the diatom community change in response to hydrocarbon pollution, a greater understanding of how Antarctic benthic microalgae, and more broadly how Antarctic marine benthic ecosystems are impacted by hydrocarbons, will be gained (Cremer et al., 2003).

Diatoms preserved in sediment cores have been used to investigate a wide range of environment responses, including oil contamination (Parsons et al., 2014). Here we use similar techniques to investigate the response of diatoms preserved in surface sediments to hydrocarbon pollution from biodegradable and standard-lubricant, on recruitment and development of Antarctic benthic diatoms over 5 years. This study also aims to provide an assessment of the community impact of pollution from both types of lubricant, in order to determine whether biodegradable lubricant is suitable for use in Antarctica in place of standard lubricants.

2. Methods

2.1. Study site

Sediment for the translocation experiment was collected, treated and deployed at O'Brien Bay (66°18′S, 110°32′E) in the Windmill Islands near Casey Station, Antarctica (Fig. 1) in November, 2001. The final samples were removed 5 years later, in December 2006. The location was free of contaminants, displaying only background levels of hydrocarbons. Further site specific details are documented in Powell et al. (2010).

2.2. Experimental design and sampling

The experimental design for this study is described in detail in Thompson et al., 2006, 2007 and Powell et al., 2010. To summarise: sediment was collected from O'Brien Bay and kept at −1.6 ± 0.2 °C and at 34.2 ± 0.1 psu salinity. Sediment was sieved through a 500 μm mesh to remove infauna and left to settle overnight in plastic bins. The overlying water was decanted and the sediment was homogenised by stirring into a slurry before the lubricants were slowly added, in a ratio of approximately 150 ml of lubricant to 35 L (47 kg wet wt) of wet sediment. A final concentration of approximately 4000 mg/kg TPH was the target, which is similar to heavily polluted sediments (4500 mg/kg) near other Antarctic stations (e.g., McMurdo Sound) (Lenihan et al., 1990). Contaminated and control sediments were stirred for equal amounts of time and left to settle for approximately 25 h. Floating lubricants in the overlying water were siphoned off prior to deployment. In this study we examined the effects of Mobil 0 W-40 (standard lubricant) and Fuchs Titan GT1 (biodegradable lubricant) in comparison to the control, which received the same processing but without the addition of a contaminant. Treated sediments were placed in open plastic trays (600 × 350 × 100 cm), lined with mesh (300 μm) and arranged in a randomised block design (Thompson et al., 2006). Samples were retrieved by divers using 2 cm diameter sediment cores in the trays, and here we examine samples collected after 5 weeks, 2 years and 5 years. Samples were stored in glutaraldehyde until analysed.

2.3. Slide preparation and identification

Preparation methods and identification were adapted from Cunningham et al. (2003). Glutaraldehyde was removed through a series of washes with distilled water (three in total). The washed pellet was then placed in a 10% hydrogen peroxide solution for 72 h to remove any organic content. Three further washes removed the hydrogen peroxide and organics and the resuspended diatoms were then pipetted onto coverslips and mounted onto slides using Norland optical adhesive 61 (Norland Products Inc., Cranberry, HJ, USA). Diatom counts were made using a Zeiss Standard 20 light microscope (Carl, Zeiss, Germany) with 1000× magnification and phase contrast illumination. A minimum of 400 benthic diatom frustules were counted per slide and only specimens with more than half the frustule preserved were included in the count. Taxa known to be associated with sea ice or planktonic habitats were

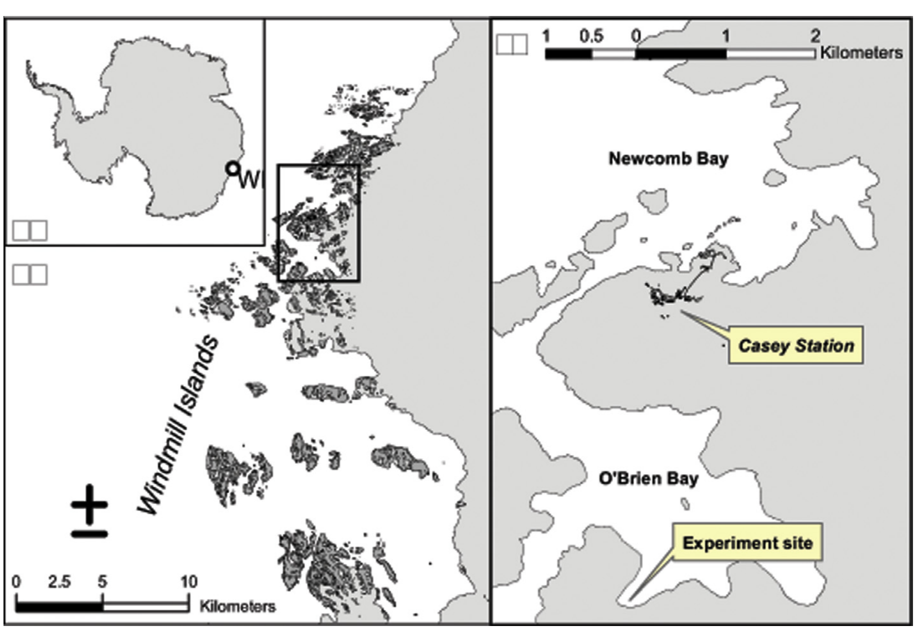

Fig. 1. Adapted from Powell et al. (2007) showing the Windmill Islands, East Antarctica, and the experiment site at O'Brien Bay.

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