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A sediment mesocosm experiment to determine if the remediation of a shoreline waste disposal site in Antarctica caused further environmental impacts

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ABSTRACT

A shoreline waste disposal site at Casey Station, Antarctica was removed because it was causing impacts in the adjacent marine environment (Brown Bay). We conducted a field experiment to determine whether the excavation created further impacts. Trays of clean, defaunated sediment were deployed at two locations within Brown Bay and two control locations, two years prior to remediation. Trays were sampled one year before, 1 month before, 1 month after and two years after the excavation. An increase in metals was found at Brown Bay two years after the remediation. However there was little evidence of impacts on sediment assemblages. Communities at each location were different, but differences from before to after the remediation were comparable, indicating there were unlikely to have been further impacts. We demonstrate that abandoned waste disposal sites in hydrologically active places in Antarctica can be removed without creating greater adverse impacts to ecosystems downstream.

1. Introduction

The guiding principles for environmental management in Antarctica come from the Protocol for Environmental Protection to the Antarctic Treaty. On the subjects of waste disposal, waste management and site clean-up, the protocol states that abandoned waste disposal sites should be cleaned up providing removal does not create greater adverse environmental impact than leaving the material in its existing location. Although several waste disposal sites have been removed from Antarctica (e.g. Crumrine, 1992) there have been no published reports of studies to test whether removal was achieved without creating further impacts.

The abandoned Thala Valley waste disposal at Casey Station, East Antarctica was identified as a priority for clean-up by the Australian Antarctic Division because the site was hydrologically active and known to be causing adverse environmental impacts in the adjacent marine bay (Cunningham et al., 2005; Stark et al., 2005). Every year the summer melt saw large volumes of water flowing through the waste disposal site, eroding waste material and entraining dissolved and particulate contaminants (Snape et al., 2001). A range of environmental impacts have been reported in the downstream receiving environment, Brown Bay, including elevated levels of contaminants in sediments, changes in soft-sediment assemblages and impacts on recruitment (Stark et al., 2003a; 2004; 2003b, c). A large scale clean-up and remediation of the site was done in the summer of 2003/04 (Stark et al., 2006b). Such operations are difficult to undertake, are expensive and require new techniques for every component from waste removal to monitoring. We used the opportunity to test and develop techniques to help inform future clean-up operations in Antarctica.

A comprehensive monitoring program was designed to look at processes on a range of time scales (Stark et al., 2006b). Over the longest time scales, monitoring will be used to determine whether impacted communities in Brown Bay have recovered and consequently, whether the investment in remediation has delivered the hoped-for environmental improvements. The final sampling for the long-term monitoring has yet to be completed. One of the main concerns in planning the operation was that it could disturb the site to such a degree that a large pulse of contaminants, in particular metals bound in the site matrix, would be released into the adjacent marine environment. To address this, short term monitoring was put into place during the operation to assess if contaminants were released (Stark et al., 2006a). This monitoring was designed to inform operational practices in real-time so that they could be modified and improved if required, however, it would not indicate whether any such release of contaminants caused additional adverse environmental impacts beyond adding to the

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contaminants already in the marine environment, for example adverse impacts on the seabed communities.

Here we report a sediment field mesocosm experiment designed to determine whether the excavation operation, and any associated release of contaminants, created any further impacts on the biota in the bay, and hence whether the general obligations under the environmental protocol, of no 'greater adverse environmental impact than leaving waste material in its existing location' were satisfied.

In designing the study, the main challenge we faced lay in detecting further impacts in already impacted communities, particularly in a situation where we do not have comparable impacted sites that could be used either as controls or replicates. In our previous studies, which identified that Brown Bay was impacted, we addressed this lack of replication of impacted sites by comparing with multiple reference locations (Stark et al., 2003a, b). We predicted that any additional adverse impacts in the already impacted Brown Bay would be subtle and would require an experimental design with a beyond-BACI type approach (Underwood, 1991, 1994). Without an appropriate experimental design and suitable test we would not be able say with confidence whether the clean-up had been completed without causing greater adverse environmental impacts.

We designed a manipulative field mesocosm experiment using recruitment to a standard, clean, defaunated sediment. Manipulative experiments offer several advantages over observational or mensurative experimental sampling. They enable the influence of the variable of interest to be examined (e.g. a disturbance such as pollution) while reducing other sources of variation such as habitat (e.g. grain size in sediments) and patch size. Such experiments are increasingly being used as monitoring tools in ecological and environmental monitoring programs e.g. (Connell, 2001; Cunningham et al., 2003; Glasby, 1998; Powell et al., 2005; Stark, 2008; Stark et al., 2004). In environmental monitoring contexts the hypothesis being tested is often of differences among locations (one or more being impacted). However, natural spatial variation and environmental heterogeneity can make it very difficult to distinguish the effects of anthropogenic disturbance, particularly in soft sediments where assemblages are patchy and the abundance of organisms varies at a range of spatial scales (Barry and Dayton, 1991; Morrisey et al., 1992a,b).

Mesocosm recruitment experiments utilising new habitat reduce heterogeneity associated with natural substrata, provide a degree of uniformity, and facilitate replication. They are only affected by ongoing or new disturbances, as opposed to being a result of past disturbances. They offer the means to demonstrate a link between cause and effects where impacts are hypothesised to occur and where there may be evidence of a correlation between patterns of differences and presence of a disturbance such as pollution (Underwood and Peterson, 1988). One situation in which they offer an advantage over mensurative experiments is where an impact (e.g. sediment contamination) is known to exist, but some activity is to take place (such as remediation efforts) that may lead to change in the impact status, e.g. further impacts or recovery. If biological communities at the impacted location are known to be different from controls, and where there is no

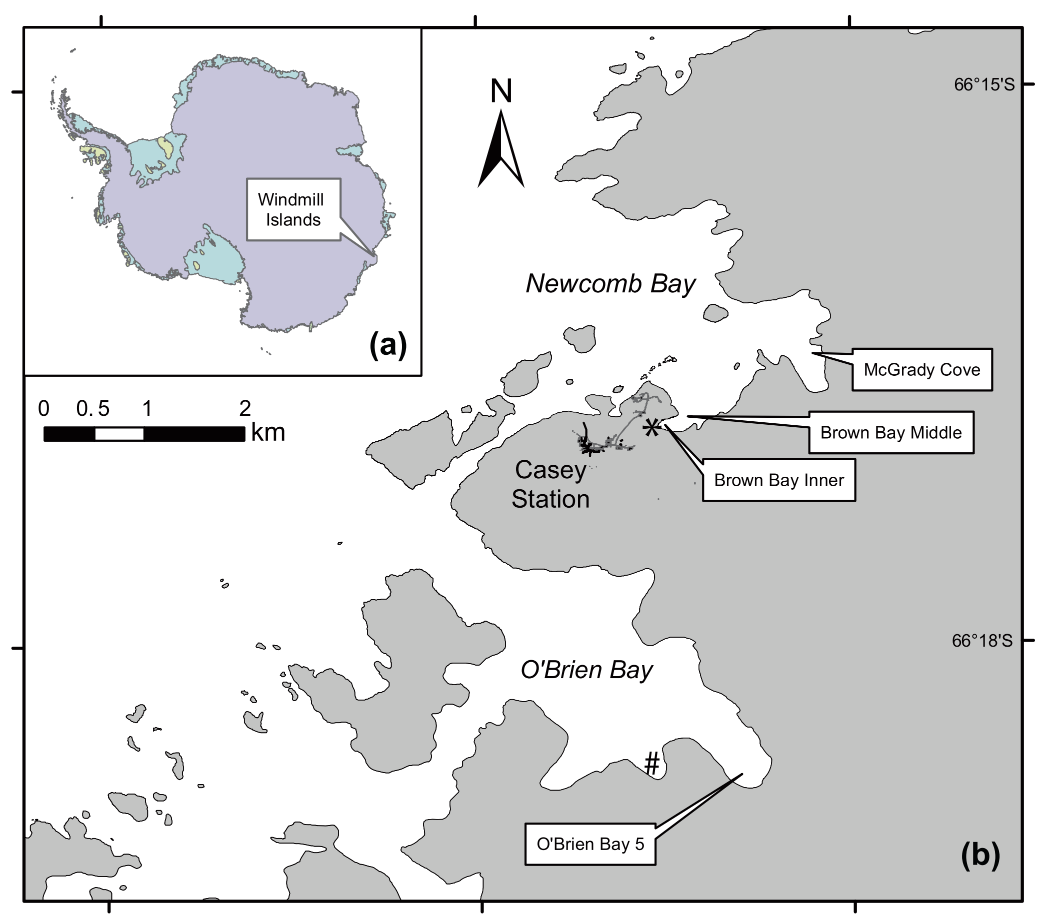

Fig. 1. (a) Location of Casey Station and (b) deployment locations for the experiment. * = location of Thala Valley remediation operation and former waste disposal site; # = site where sediment was collected for the experiment.