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# Seafloor massive sulfide deposits support unique megafaunal assemblages: Implications for seabed mining and conservation

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ABSTRACT

Mining of seafloor massive sulfides (SMS) is imminent, but the ecology of assemblages at SMS deposits is poorly known. Proposed conservation strategies include protected areas to preserve biodiversity at risk from mining impacts. Determining site suitability requires biological characterisation of the mine site and protected area(s). Video survey of a proposed mine site and protected area off New Zealand revealed unique megafaunal assemblages at the mine site. Significant relationships were identified between assemblage structure and environmental conditions, including hydrothermal features. Unique assemblages occurred at both active and inactive chimneys and are particularly at risk from mining-related impacts. The occurrence of unique assemblages at the mine site suggests that the proposed protected area is insufficient alone and should instead form part of a network. These results provide support for including hydrothermally active and inactive features within networks of protected areas and emphasise the need for quantitative survey data of proposed sites.



## 1. Introduction

Increasing anthropogenic pressure on terrestrial, fresh-water and marine ecosystems has resulted in the need for improved conservation measures, including the provision of suitable protected areas (Linke et al., 2011; Geldmann et al., 2013). This need is reflected in the Convention on Biological Diversity (CBD) which calls for signatory countries to conserve 17% of terrestrial and inland water, and 10% of coastal and marine areas by 2020 through “ecologically representative and well connected systems of protected areas and other effective area-based conservation measures” (United Nations Environment Programme, 2011). However, established protected areas globally only cover approximately 13% of terrestrial and 3% of marine habitats (Watson et al., 2014). The majority of marine protected areas have been established in coastal areas and provide benefits such as preserving species and habitats, acting as controls to study fishing effects and as source sites for genetic diversity and recruitment to neighbouring fisheries (Costello, 2014; Green et al., 2014). However, there is also a need to establish protected areas in the deep sea, which is exposed to anthropogenic pressures including disposal of rubbish, dumping of chemical and radioactive waste, extraction of oil and gas, and other extractive activities such as fishing and deep-sea mining (Ramirez-Llodra et al., 2011).

One of the deep-sea resources to be mined is seafloor massive sulfides (SMS), with exploitation expected to occur in the southwest Pacific before 2020 (Baker and Beaudoin, 2013). SMS deposits form through hydrothermal activity. Hot acidic water filters up through the seabed and, as it cools, releases dissolved minerals that can accumulate to form chimney and mound structures on the seafloor. There are 165 recorded SMS deposits worldwide (Hannington et al., 2011), existing across a range of tectonic environments (Boschen et al., 2013). These deposits are rich in base metals, such as iron, copper, zinc and lead (Krasnov et al., 1995),

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which often occur at a mineral grade comparable to deposits on land (Hannington et al., 2011).

Five contracts for SMS exploration have been issued by the International Seabed Authority in international waters on the South West Indian Ridge, Central Indian Ridge and the Mid Atlantic Ridge (https://www.isa.org.jm/deep-seabed-minerals-contractors?qt-contractors_tabs_alt=1). In the Western Pacific, Neptune Minerals Inc. holds tenements in the Exclusive Economic Zones of seven countries – Japan, Papua New Guinea, Solomon Islands, Vanuatu, Fiji, Tonga and New Zealand. These tenements cover approximately 175 000 km$^2$ of prospecting licence applications and granted prospecting licences (http://www.neptuneminerals.com/our-business/tenements/).

Alongside their mineral wealth, SMS deposits also provide a variety of benthic habitats that support different biological communities. These habitats include hydrothermally active areas, often with chimneys and vents; hydrothermally inactive areas with relict chimney structures; and non-hydrothermal hard substrata such as lava flows and bedrock. Active areas support a hydrothermal vent community that is reliant on hydrothermal activity to survive and cannot exist away from active vents (Van Dover, 2000). Vent communities typically have a small number of species that occur in large numbers (Grassle, 1985), with rapid growth rates of individuals enabling them to mature quickly and colonise new vent habitat (Lutz et al., 1994). Both inactive SMS areas and non-hydrothermal hard substrata are colonised by a peripheral community, typically consisting of background species that occur on hard substrata elsewhere within the deep sea (Galkin, 1997; Collins et al., 2012). This fauna can develop large populations in close proximity to active vents by utilising the additional food sources, such as bacterial mat dislodged from the vents (Erickson et al., 2009). It has also been suggested that a third community, one consisting of specialised fauna adapted to the weathered sulfide environment, may exist at inactive SMS deposits (Van Dover, 2011). However, there are a limited number of studies of inactive SMS deposits and only one has identified faunal assemblages that appear to be unique to inactive SMS areas (Boschen et al., 2015).

All communities inhabiting SMS deposits and the surrounding seabed are potentially at risk from mining activities. Although vent communities undergo natural habitat loss through changes in hydrothermal or volcanic activity (Lutz et al., 1994; Tunnicliffe et al., 1997), perturbation from mining could be an additional stressor, introducing the problem of cumulative negative impacts (Van Dover, 2011). SMS mining is expected to remove the majority of fauna from the immediate area (Van Dover, 2011, 2014), with additional impacts, such as habitat removal, altered hydrothermal flow and smothering with suspended sediment (Coffey Natural Systems, 2008; Van Dover, 2011; Boschen et al., 2013; Van Dover, 2014). Many vent species are endemic to a particular region, and so habitat loss poses a serious risk to the persistence of certain vent fauna. The fauna found in the peripheral and inactive communities is typically composed of sessile, slow-growing suspension feeders (Galkin, 1997; Collins et al., 2012; Boschen et al., 2015) and may take decades to recover from disturbance, if they are able to recover at all (Van Dover, 2011; Boschen et al., 2013).

Within the New Zealand region, SMS deposits occur in the northern section of the New Zealand Exclusive Economic Zone (EEZ). These deposits are rich in silver and gold (de Ronde et al., 2011) and prospecting licences were issued for multiple areas along the Kermadec Volcanic Arc to Neptune Minerals Inc. in 2002 (https://permits.nzpam.govt.nz/aca/). Hydrothermal communities along the Kermadec Volcanic Arc include species endemic to the region, such as the vent mussels *Gigantidas gladius* and *Vulcanidas insolatus* (Von Cosel and Marshall, 2003, 2010) and the vent shrimps *Alvinocaris alexander* and *Lebbeus wera* (Ahyong, 2009). There is also preliminary evidence for unique assemblages of fauna that occur in regions of inactive SMS deposits (Boschen et al., 2015). However, the large video samples (200 m length) used by Boschen et al. (2015) may not have adequately accommodated the patchiness of SMS deposits, complicating the attempt to establish clear linkages between unique assemblages and inactive SMS habitat.

One of the proposed mitigation strategies for SMS mining is to preserve at-risk habitats and communities through the provision of protected areas, which is a well-established concept in both terrestrial and marine conservation (Pressey and Botrill, 2009, Partnership for Interdisciplinary Studies of Coastal Oceans (2007)). In waters beyond national jurisdiction, protected areas include “preservation reference zones”, defined as “areas in which no mining shall occur to ensure representative and stable biota of the seabed in order to assess any changes in the biodiversity of the marine environment” (International Seabed Authority, 2010). Such areas, also known as “set-aside sites” and “Reference Sites”, should have similar physical and biological characteristics to the mine site and should be located so as not to be impacted by mining activities (Coffey Natural Systems, 2008; Collins et al., 2013). These sorts of recommendations are sound in principle but have had limited field testing to date, with only one previous study on the practical applications of Reference Sites for SMS mining (Collins et al., 2012).

As part of an initial survey of the Kermadec Volcanic Arc SMS deposits, Neptune Minerals Inc. identified a potential mine site, termed “Proteus 1”, and a Reference Site on Rumble II West Seamount (Fig. 1). The survey report suggested there could be differences between the seabed communities at these sites, however this was based on limited shipboard real-time observations (Beaumont and Rowden, 2011). The key objective of the present study was to determine the structure of megafaunal assemblages at both sites, their linkages with environmental variables and ultimately to assess whether the Reference Site would be a suitable protected area for the proposed mine site of Proteus 1. An additional aim was to investigate the possible existence of assemblages unique to inactive SMS areas and if they exist, to evaluate the

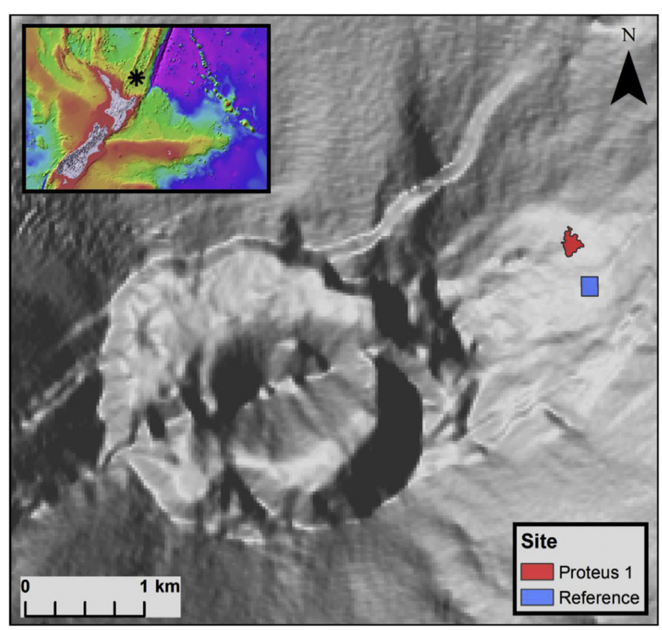


**Fig. 1.** Location of study sites, Proteus 1 and the Reference Site, on a digital terrain model of Rumble II West Seamount. Inset: Location of Rumble II West on the Kermadec Volcanic Arc, indicated by the star. The Arc is represented by the parallel raised areas of bathymetry (in orange) that stretch northeast from New Zealand towards Tonga.