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Differences in recovery between deep-sea hydrothermal vent and vent-proximate communities after a volcanic eruption

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ABSTRACT

Deep-sea hydrothermal vents and the surrounding basalt seafloor are subject to major natural disturbance events such as volcanic eruptions. In the near future, anthropogenic disturbance in the form of deep-sea mining could also significantly affect the faunal communities of hydrothermal vents. In this study, we monitor and compare the recovery of insular, highly productive vent communities and vent-proximate basalt communities following a volcanic eruption that destroyed almost all existing communities at the East Pacific Rise, 9°50′N in 2006. To study the recovery patterns of the benthic communities, we placed settlement substrates at vent sites and their proximate basalt areas and measured the prokaryotic abundance and compared the meio- and macrofaunal species richness and composition at one, two and four years after the eruption. In addition, we collected samples from the overlying water column with a pelagic pump, at one and two years after the volcanic eruption, to determine the abundance of potential meiofauna colonisers. One year after eruption, mean meio- and macrofaunal abundances were not significantly different from pre-eruption values in vent habitats (meio: 8–1838 ind. 64 cm^{-2} in 2006; 3–6246 ind. 64 cm^{-2} in 2001/02; macro: 95–1600 ind. 64 cm^{-2} in 2006; 205–4577 ind. 64 cm^{-2} in 2001/02) and on non-vent basalt habitats (meio: 10–1922 ind. 64 cm^{-2} in 2006; 8–328 ind. 64 cm^{-2} in 2003/04; macro: 14–3351 ind. 64 cm^{-2} in 2006; 2–63 ind. 64 cm^{-2} in 2003/04), but species recovery patterns differed between the two habitat types. In the vent habitat, the initial community recovery was relatively quick but incomplete four years after eruption, which may be due to the good dispersal capabilities of vent endemic macrofauna and vent endemic dirivultid copepods. At vents, 42% of the pre-eruption meio- and 39% of macrofaunal species had returned. In addition, some new species not evident prior to the eruption were found. At the tubeworm site Tica, a total of 26 meio- and 19 macrofaunal species were found in 2009, which contrasts with the 24 meio- and 29 macrofauna species detected at the site in 2001/02. In the basalt habitat, community recovery of meiofauna was slower with only 28% of the original 64 species present four years after eruption. The more limited dispersal capabilities of meiofauna basalt specialists such as nematodes or harpacticoid copepods probably caused this pattern. In contrast, 67% of the original 27 macrofaunal species had recolonized the basalt by 2009. Our results suggest that not only vent communities, but also species-rich communities of vent-proximate habitats require attention in conservation efforts.

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1. Introduction

All organisms living at deep-sea hydrothermal vents and on vent-proximate basalt are subject to natural disturbances, i.e. volcanic eruptions. On fast spreading ridges like the 9°50′N East Pacific Rise (EPR), eruptions occur frequently, with time intervals of only 15 years, and vent sites are typically separated by a few kilometers (Haymon et al., 1991; Shank et al., 1998; Tolstoy et al., 2006). In contrast, vent sites on slow spreading centers are more distant from each other and major disturbance events occur less frequently (German et al., 1996; Humphris et al., 2002; Murton et al., 1994). Organisms occur in a wide range of environmental conditions, and it is crucial to consider dispersal and connectivity patterns of meio- and macrofauna in order to address recovery mechanisms in response to disturbance and productivity regimes. Vent animals live in highly dynamic environments, with intermittent exposure to temperature peaks, substantial concentrations of hydrogen sulfide, variable heavy metal exposure, and reduced oxygen availability, but high in situ primary production. Megafauna, such as tubeworms or mussels, act as foundation species and provide a habitat for the associated macro- and meiofauna (Fisher et al., 2007; Van Dover, 2000). The endemism, abundance, and biomass of vent macrofaunal communities is much higher, but diversity is much lower than sedimented deep-sea habitats at similar depths (Moalic et al., 2012; Tunnicliffe, 1992). Macrofaunal dispersal between isolated vent sites occurs primarily in the larval stage, but demersal, dispersal and migration can also occur (Mullineaux et al., 2010, 2005). In general, meiofauna are similarly diverse to macrofauna, but are not exceptionally abundant, and many vent meiofaunal species are not restricted to vents, but also occur on proximate basalt (Gollner et al., 2010b, 2007). The dispersal mechanisms of vent meiofauna have not been studied yet.

On basaltic rock proximate to vents under ambient deep-sea conditions, low temperatures are stable and in situ primary production is negligible. The source of nutrition is suspended photosynthetic-derived material from surface waters and particulate organic matter originating from the nearby active vents (Erickson et al., 2009; Levin et al., 2009). Dominant macrofauna include sparsely distributed sponges, hydroids, anemones, squat lobsters, ophiuroids, and holothurians (Galkin, 1997). In addition, vent-associated macrofaunal taxa were found on proximate basalt, although in low abundance and low biomass (Gollner et al., 2015; Marcus and Tunnicliffe, 2002). At 9°50′N East Pacific Rise, a species-rich but low abundance meiofaunal community was documented on vent-proximate basalt (Gollner et al., 2010b). Dispersal and biogeography of basalt species are almost unknown, but a macrofaunal study showed unexpectedly high levels of genetic differentiation for squat lobsters (Thaler et al., 2014).

The East Pacific Rise, like other mid ocean ridges, has rich deposits of metals in the form of massive sulfide deposits (SMS). Currently, various regions along the Mid Atlantic Ridge and the Indian Ocean Triple Junction are being explored for mining (SPC, 2013). Exploitation of sulfide minerals is expected to disturb communities living at hydrothermal vents and in surrounding areas (Van Dover, 2011). The first deep-sea massive sulfide mine could open in Papua New Guinea as soon as 2016 (Gramling, 2014). However, the scale of environmental impacts remains to be determined, and there are many unknowns in the ecology and connectivity of populations at active and inactive SMS deposits (Boschen et al., 2013; Van Dover, 2011). Recommendations to evaluate the possible impact of mining (disturbance) include identification of conservation areas, as well as determination of natural conservation units for key species with different size and life histories and dispersal strategies (Van Dover, 2011). Different life-histories of meio- and macrofauna include for example mode of development (direct benthic versus planktonik), dispersal (as adults versus as larvae), generation time (less than one year versus more than one year), or potential number of off-spring (small versus large) (Warwick, 1984). Within the meiofauna, nematodes show less dispersal potential than copepods (Giere, 2009). The effect of disturbance on the vent-proximate basalt areas has received relatively less attention than vent habitats, although future mining operations will probably mostly impact the vent-surroundings with their mining-machines. Volcanic eruptions naturally disturb hydrothermal vents and the vent-proximate areas; understanding these recovery mechanisms will help to formulate plans for future conservation.

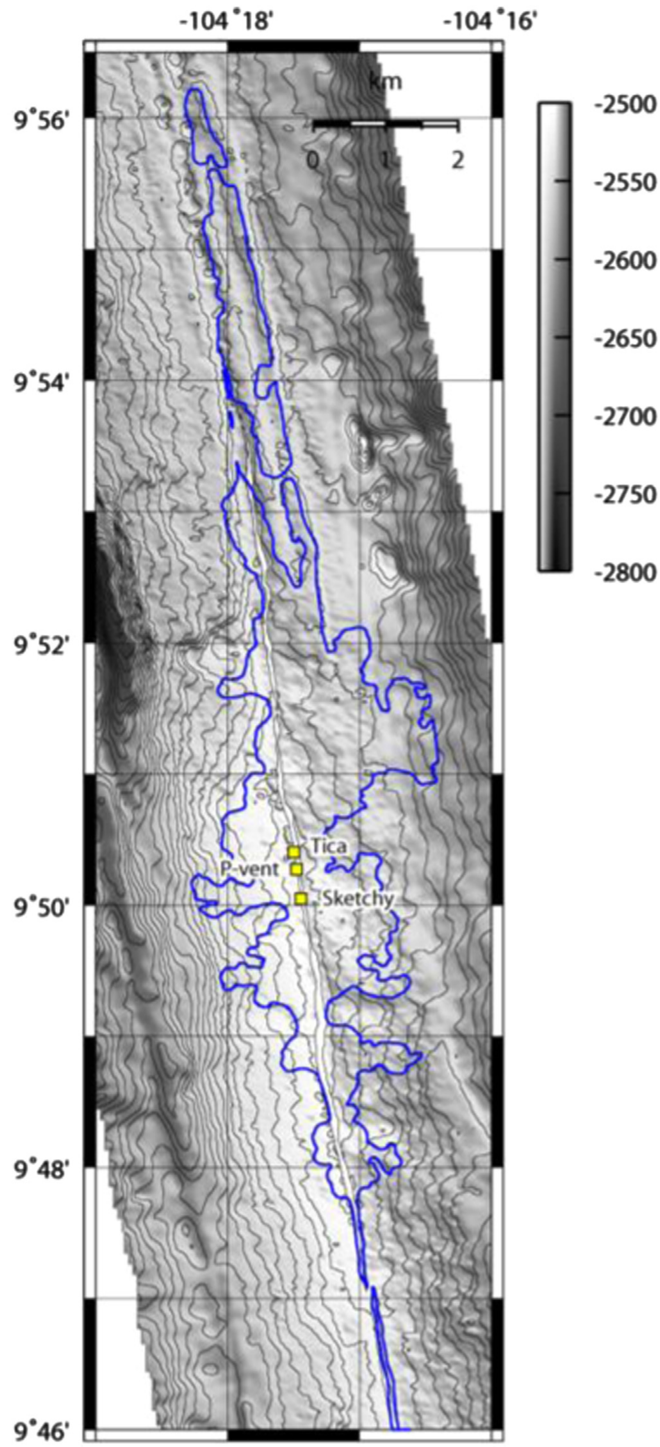

Fig. 1. Vent sites Tica, P-Vent, and Sketchy on the East Pacific Rise. Several km^2 (blue (black) outline) of the area were flooded with lava during an eruption in 2005/2006. Depth (grey scale) is given in meters. Map courtesy of Soule et al. (2007).

The recent volcanic eruption at the 9°50′N EPR in 2005/2006 covered an area of several km^2 with lava (Tolstoy et al., 2006) (see Fig. 1) and provided the opportunity to examine colonization and recovery patterns of meio- and macrofauna in hydrothermal vent