Executive Summary

Abyssal Pacific sediments in the Clarion-Clipperton Zone (CCZ) harbour abundant mineral resources, in the form of nickel- and copper-rich manganese nodules, that are of increasing commercial and strategic interest. Abyssal sediments may also be major reservoirs of biodiversity. It has been extremely difficult to predict the threat of nodule mining to biodiversity (in particular, the likelihood of species extinctions) because of very limited knowledge of (a) the number of species residing within areas potentially perturbed by single mining operations, and (b) the typical geographic ranges of species within the nodule province. In this project, we have used state-of-the-art molecular and morphological methods to evaluate biodiversity and geographic ranges of three key faunal groups in the abyssal Pacific nodule province: polychaete worms, nematode worms, and protozoan foraminifera. Together, these groups constitute >50% of faunal abundance and species richness in abyssal sediments, and represent a broad range of ecological and life history types.

The primary goals of this project, involving scientists and collaborators from five countries, have been as follows:

1) To estimate, using modern molecular and morphological methods, the number of polychaete, nematode and foraminiferal species at two to three stations spaced at ~1,500 km intervals across the Pacific nodule province.

2) To evaluate, using state-of-the-art molecular and morphological techniques, levels of species overlap and, if possible, rates of gene flow, over scales of 1,000 - 3,000 km for key components of the polychaete, nematode and foraminiferan fauna.

3) To broadly communicate our findings to the scientific and mining-management communities, and make specific recommendations to the International Seabed Authority on minimising risks to biodiversity resulting from mining.

To address these project goals, we collected macrofaunal and meiofaunal samples, using special 'DNA-friendly techniques', at three sites spaced at intervals of ~1,000–2,000 km across the Pacific region targeted for nodule mining. The sampling programme involved three research cruises in which project personnel (8-20 people per cruise) spent 83 days at sea and collected a total of 40 box core and 32 multiple cores samples. Collected samples of foraminifera, nematodes and polychaetes were then transported to laboratories in the USA, the United Kingdom, Japan and

France for sorting and detailed morphological and molecular analyses. Our analyses, results and syntheses have been reported as 16 presentations at international scientific meetings and workshops, and as 20 publications in the peer-reviewed scientific literature. Many more presentations and publications are planned for the near future.

Our results indicate high, unanticipated, and still poorly sampled levels of species diversity for all three sediment-dwelling faunal components (foraminifera, nematodes and polychaetes) at our individual study sites. Cryptic speciation (i.e., the presence of multiple species previously identified as single species) appears to be very common in the polychaetes and nematodes. Habitat heterogeneity also appears to be higher than previously appreciated. We speculate that the total species richness of sediment-dwelling foraminifera, nematodes and polychaetes (a subset of the total fauna) at a single site in the CCZ could easily exceed 1,000 species. Our results from all faunal components suggest that there is a characteristic fauna of the abyss, i.e., that abyssal habitats have sustained species radiations and are not merely sinks of non-reproducing individuals transported from ocean margins. In addition, there is significant evidence that the community structure of the foraminifera and polychaetes differs substantially over scales of 1,000–3,000 across the CCZ.

Our findings suggest that marine protected areas (MPAs) should be erected to safeguard biodiversity in the CCZ in the face of nodule mining. We recommend that MPAs should be set up as follows.

1) MPAs should be placed at multiple locations across the CCZ, at the very least in the eastern, central and western portions of the region of mining claims.

2) Because of the steep latitudinal gradients in productivity and community structure within the equatorial Pacific, the MPAs should be designed to protect biodiversity across the entire width of the CCZ, i.e., from 7o–17o N latitude.

3) The MPAs should be large enough to encompass major areas of the known benthic habitat types in the CCZ, including abyssal hills with and without nodules, rocky ridges, and multiple seamounts of various elevations above the seafloor.

4) Each MPA must be large enough for most of its area to be buffered from the direct and indirect impacts of nodule mining activities, including influences from sediment plumes in the water column and at the seafloor.

5) Because benthic processes and community structure in the CCZ are strongly influenced by processes in the water column above, it is highly desirable for management of the MPAs to include control of substantial human activities (mining, energy exploitation, waste disposal, and commercial fishing) from the abyssal seafloor to the ocean surface. This recommendation is consistent with the concept of ecosystem based management (Pikitch et al., 2004).

It is critically important to recognise that our recommendations are based on a limited, albeit rapidly growing, database on biodiversity and species ranges in the CCZ, and should be applied using the precautionary principle. Specifically, where data are inadequate to exclude

potential harm to the environment from a particular human activity (in this case nodule mining), the activity should be conservatively managed to ensure environmental protection.

Our ongoing studies, collaborative projects (e.g., the Census of Diversity of Abyssal Marine Life), and workshops (specifically the Pew-funded workshop to *Design Marine Protected Areas for Seamounts and the Abyssal Nodule Province in Pacific High Seas,* which took place Oct 23-26, 2007) are helping to better resolve biodiversity levels and species ranges in the abyssal Pacific and provide explicit guidance in the near future to the International Seabed Authority in the conservation of abyssal Pacific ecosystems.

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