

Environmental Impact Assessment and Examination of Environmental Conservation Measures for Deep-Sea Mining in Seamounts

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Conservation Measures for Deep-Sea Mining in Seamounts
(海山における海洋鉱物資源開発に関する環境影響評価と環境保全策の
検討)

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論 文 内 容 の 要 旨

Cobalt-rich crusts (“crusts”), potential mineral resources, are found mainly on seamounts at depths of 800-2,500 m in the Northwest Pacific, and mining for cobalt-rich crusts is considered by many countries. However, a lack of knowledge about the environmental impact of crust mining is hindering the development of a regional environmental management plan (REMP) for the Northwest Pacific. One of the environmental impacts of particular concern is the generation of large amounts of suspended particles, i.e., sediment plumes. There is also a lack of basic knowledge about ecological connectivity among seamount habitats in the Northwest Pacific, which is another major issue in the development of REMPs. The movement of organisms between deep seamounts is mainly caused by the dispersal of planktonic larvae, but there are only a few such studies in the world, and almost none have been conducted in the Northwest Pacific.

With these backgrounds, I conducted research that could contribute to environmental impact assessments and environmental management plans for crust mining in seamounts.

Chapter 1 summarized the research background and review related previous studies.

In Chapter 2, a method to assess temporal changes in the amount of suspended particles concentration in the deep sea from image data was devised using deep learning. This method was intended to be applied to future monitoring of sediment plumes from mining. The model succeeded in detecting particles in the images with high accuracy (AP50 > 85%, F1 score > 82%). During the observation period, the world's first crust excavation test was conducted, providing an ideal situation to see whether this model could measure rapidly changes in the concentration of suspended particles in the deep sea. The time series data showed relatively little variation in particle number under natural conditions, but two turbidity events occurred during and after mining. These results showed that the method could be used to investigate both the time variation of naturally occurring low levels of suspended particles and large rapid fluctuations such as the sediment plumes from mining.

In Chapter 3, field observations and hydrodynamic modeling of the flows were conducted around the Scripps Guyot, a flat-topped seamount with contract areas for crust exploration issued by the International Seabed Authority (ISA). The objective was to understand the basic hydrodynamic characteristics of the seamount summit. The field

observations showed that the semi-diurnal and diurnal tidal currents are about 4.1 times stronger at the summit of the seamount than at the same depth on the slope and base. The hydrodynamic model suggests that internal tides enhance the tidal current at the summit, and that the strength of the tidal current varies by a factor of about 9.6 within the summit. This study highlighted the significance of considering site-specific tidal current differences in predicting the dynamics of sediment plumes from mining.

In Chapter 4, sediment plume dispersion and deposition were simulated across the summit of the Scripps Seamount based on the hydrodynamic model described in Chapter 3. The physical properties of the sediment plume and mining operations were set based on measurements from the crust excavation test in 2020. The simulation results showed that the distance of sediment plume deposition varied by a factor of 6.5 (120-800 m) depending on the location of the sediment plume release site at the summit of the seamount. Sediment plumes tended to be deposited as thin layers over long distances in areas with strong internal tides, and as thick layers over short distances in areas with weak internal tides. The results of this study suggested that avoiding areas with strong internal tides as mining sites may contribute to reducing the seamount habitat impacted by sediment plume deposition while avoiding areas of weaker tides may help limit the thickness of deposited sediment.

In Chapter 5, biophysical modeling was conducted to quantify connectivity through larval dispersal among 18 seamounts within the scope of the REMP program being developed by the ISA. It was shown that the seamounts formed a single dispersal network, but that the network could be fragmented if seamounts with potential for mining were excluded. Two seamounts with potential mining were identified as important stepping stones. Predominant eastward or westward currents, likely related to the North Equatorial Intermediate Current, made the upstream, distant seamounts vital larval sources. Trajectories of Argo floats and gene flows of amphipods provided physical and biological support for the modeled dispersal. This study highlighted the potential for effective conservation area placement based on a seamount network connected by upstream-based larval dispersal.

Finally, Chapter 6 summarized the overall results of the study and discusses future prospects and issues.