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Deep-sea mining: developing an environmental management framework

20th July 2022
Issue 582

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Source:
Hyman, J., Stewart, R. A., Sahin, O., Clarke, M. and Clark, M. R. (2022) Visioning a framework for effective environmental management of deep-sea polymetallic nodule mining: Drivers, barriers, and enablers. *Journal of Cleaner Production* 337: 130487.

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Mining lumps of ore found on deep seabeds could be a means of supplying metals required for transitioning to a green economy, such as those needed to produce electric-vehicle batteries. However, limited knowledge of the deep-sea environment and the likely impacts of mining present challenges for the environmental management of such operations. In this study, researchers present an analysis of key drivers, barriers and enablers to construct a practical environmental management framework for deep-sea mining.

Abyssal plains are relatively flat areas of seabed, covering more than half the Earth and found at 3.5–6.5 kilometres below the ocean surface. Lumps of ore approximately 2–8 cm in diameter accumulate on these plains – at a density of up to 15 kilogrammes per square metre.

The ore is rich in several metals – the lumps are called 'polymetallic nodules' – with global deposits holding more nickel, manganese and cobalt than all land-based reserves, as well as significant amounts of copper.

Considerable amounts of these metals are needed for the successful transition to clean-energy technologies, such as lithium-ion batteries to power electric vehicles. Demand for nickel is expected to be over 25 times the current level by 2050, and the demand for cobalt, copper and manganese more than 15 times higher.

Most polymetallic nodule deposits are found in the high seas (outside any national jurisdiction) and are regulated through the International Seabed Authority under the UN Convention on the Law of the Sea. As yet, mining of these nodules has not taken place; however, it is expected to begin within the next ten years. Given the limited ecological knowledge about deep-sea habitats, developing reliable environmental management processes for mining presents a challenge.

The researchers, based in Australia, Canada and New Zealand, conducted a review of literature published between 2010 and 2021 from scientific journals, book chapters and reports by regulatory bodies and other organisations. They identified three types of issues that were mentioned

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repeatedly relating to the environmental management of polymetallic nodule mining (but not in the mining of other deep-sea minerals). They categorised these issues as **drivers** (motivating factors behind mining), **barriers** (obstacles to effective environmental management), and **enablers** (best practices for environmental management) and gathered specific issues into overall themes within each of the three groups.

The researchers found that the **key drivers** supporting the mining of polymetallic nodules were: clean energy transitions, diversification of mineral supply and life-cycle improvements. Adoption of green technologies, such as lithium-ion batteries to power electric vehicles, is expected to lead to demand for nickel, cobalt and copper exceeding quantities available from land-based mining before 2050. In many cases land-based mining also faces concerns over environmental and social impacts, presenting a need to find alternative sources. As deep-sea mining largely takes place in international waters, there is potential for the proceeds to be internationally and equitably distributed rather than retained by individual countries.

The **key barriers** to robust environmental management in deep-sea mining, according to the researchers, are a lack of knowledge about the environment and associated impacts, and doubts about social acceptability – considering the environmental costs versus the benefits of mining. Current knowledge about abyssal plains does not allow for detailed, quantitative environmental impact assessments, and even clear underlying data are hard to obtain. Limited understanding of the environmental services provided by abyssal plains also presents a challenge when setting thresholds for harmful environmental effects. Attempts to gather more information before beginning mining operations could delay progress, while calls for a moratorium could discourage existing private-sector investment in important research, say the researchers.

The researchers propose that the **key enablers** for good environmental management in deep-sea mining are the precautionary approach, the ecosystem approach and the use of adaptive management – flexible decision-making that can be modified in the face of uncertainty. They argue that mining operators should use precautionary principles in their planning and mitigation activities to promote a proactive approach to environmental-risk management. They also suggest that adopting an ecosystem perspective, rather than considering indicators in isolation, could provide a useful framework for understanding ecosystem services and assessing degrees of harm. The use of adaptive management is vital, they claim, to ensure that information acquired while conducting mining activities is incorporated into ongoing evaluations of impacts and mitigation actions.

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The researchers integrate their findings into a framework for effective environmental management which involves acknowledging the drivers, addressing the barriers and initiating best practice. They note that the subjective nature of the study's methodology is a limiting factor and they identify priorities for future research with an emphasis on issues affecting the implementation of best practice.