

**Book Review – Rahul Sharma (ed), *Deep-Sea Mining Management, Policy and Regulations: Data Management, Environmental Monitoring, Techno-Economic Assessment, Law of the Sea and Regulatory Regimes* (Springer Nature Switzerland AG) 2025.**

**ISBN: 978-3-031-92736-2.**

### **Sanjeet Ruhal\***

The transition from exploration to exploitation of deep-sea minerals presents a complex governance challenge to the international law of the sea. As the International Seabed Authority (ISA) faces growing demand to oversee an industry vital for the green energy transition, Rahul Sharma's edited volume provides timely and robust interdisciplinary insights. The book offers a comprehensive examination of the challenges and opportunities available in deep-seabed mining (DSM), covering resource potentials, data management, and environmental monitoring, while providing an economic assessment and analysing the legal framework under the United Nations Convention on the Law of the Sea (UNCLOS). The volume brings together oceanographers, engineers, economists and legal experts with the aim to bridge the gap between technical, operational and regulatory frameworks. In so doing, the book synthesises and offers a layered analysis of the issues which make it relevant for both practitioners and scholars.

The volume opens with Sharma and Gales' foundational analysis of the resource potential of material drivers of deep-seabed minerals such as polymetallic nodules, ferromanganese crusts and sulphides. They highlight these as alternative sources for critical metals (e.g. Cu, Ni, Co) to meet growing global demands. The chapter advocates for balanced governance to ensure stability while addressing macroeconomic trends favouring green energy transitions.

A significant portion of the volume is focused on data governance and environmental monitoring. Part II of the book addresses critical aspects of data management practices for advancing sustainable deep-seabed mining, emphasising the integration of scientific, regulatory and technological frameworks. Contributors within this part highlight the relevance of the DeepData platform and the role of marine scientific research in addressing data

---

\* Lecturer of International Maritime Security Law, Officer-In-Charge, Research Degree Programme, IMO International Maritime Law Institute, Europe, [sanjeet.ruhali@imli.org](mailto:sanjeet.ruhali@imli.org).

deficiencies, providing practical recommendations on metadata standards, while acknowledging persistent gaps in baseline spatial, temporal and taxonomic information (Washburn, 2025; Mishiro et al., 2025).

Geospatial strategies further support resource assessment and modelling through an integrated framework (Bellenberg et al., 2025; Kaufmann et al., 2025). The examination of specific data management practices reveals both innovative methodologies and areas for improvement. For example, strategies tailored to polymetallic nodules and seafloor massive sulphides demonstrate effective use of geographic information systems (GIS) and standardised templates for ISA reporting, which facilitate data interoperability and long-term archiving (Bellenberg et al., 2025). Similarly, the discussion on geospatial data management and integration for marine mineral projects stresses the importance of databases for efficiency, risk mitigation and stakeholder communication. It addresses key challenges such as storage, security and choke points, providing actionable recommendations for multi-stakeholder collaboration (Kaufmann et al., 2025). Finally, the persistent challenges in deep-seabed data collection are critically analysed with calls for increased replication and reference site selection to enhance the reliability of environmental impact assessment (Washburn, 2025).

Part III examines methods for assessing and reducing the environmental impacts of DSM, with a particular focus on scientific integration, cumulative impacts, area-based management tools (ABMTs), rapid assessment techniques and sediment-plume modelling in conformity with UNCLOS and ISA frameworks.

Chapter 6 explores institutional frameworks and methodologies for strengthening scientific input into international environmental regulations. It advocates for structured scientific involvement to ensure sound, objective and informed decision-making under Article 243 of UNCLOS, using the London Convention and its Protocol as models to offer practical suggestions to bridge the gaps between science and policy (Verlaan, 2025). Chapter 7 presents DSM as a potential source for critical metals and focuses on the environmental risks and challenges of predicting and managing the combined effects of mining activities (Radziejewska et al.). Tracing the evolution of ABMTs within DSM governance, Fukushima and Arai distinguish between various tools and argue that a lack of clear definitions burdens contractors and regulators alike, emphasising the need for standard terminology and clearer guidelines. Chapter 9 proposes the use of rapid environmental assessment (REA) as a scalable tool to

effectively monitor DSM impacts. By integrating video imagery, machine learning, and citizen science, REA enables large-scale surveys and standardised regional comparisons (Tilot et al.).

Chapter 10 presents a comprehensive framework for monitoring and modelling sediment plumes, drawing insightful parallels from dredging practices to address environmental challenges effectively. It underscores the importance of data integration, adaptive management and threshold setting to provide practical guidance for sustainable operations through greater reliance on empirical evidence (Larsen et al.).

Part IV offers insights into the circular economy model and innovative strategies for sustainable metal supplies. It analyses the transition from land-based to marine extraction, focusing on integrating minerals into supply chains. Chapter 11 within this part proposes integrating polymetallic nodules processing with battery recycling to cut costs and strengthen supply chains (Sen and Mittal). Chapter 12 compares deep-sea and land-based mining, arguing that marine resources can diversify metal supplies and bypass terrestrial market monopolies and secure the supply chains necessary for the green transition.

Part V of the book dives deep into the regulatory and institutional challenges related to potential mining activities under UNCLOS, sustainable development goals (SDGs) and enforcement actions against the protesters and transitions to exploitation. Madureira links DSM with the UN Sustainable Development Goals 2030 and argues that it can support low-carbon transitions and benefit small island nations through equitable resource sharing. Willaert critically analyses jurisdictional complicity to explain the legal tensions between protest activities at sea and the freedoms of the high seas, using recent cases to review the conditions for peaceful demonstrations and availability of recourse for enforcement under UNCLOS. Chapter 15 outlines inspection, compliance and enforcement challenges for deep-seabed mining. It commends structural reforms to the ISA and innovative monitoring approaches. In its final chapter, the author reviews the legal and institutional transition to exploitation, explaining the impact of the “two-year rule” and the pending mining code (Salamanca-Aguado, 2025).

In short, this book is essential for anyone working on deep-sea mining policy. Its cross-disciplinary focus offers useful guidance for engaging with the ISA. Future editions would benefit from chapters on liability, damage valuation, environmental compensation and critical examination of potential mechanisms for benefit sharing of revenue generated from the common heritage of mankind. Overall, the volume is a scholarly and practical contribution

that maps the choices that determine whether DSM proceeds cautiously or moves into full exploitation.

## References

### References

1. Bellenberg, S., et al. (2025). Data management strategies for deep-sea exploration of polymetallic nodules and seafloor massive sulfides in the Area. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 63–86). Springer.
2. Fukushima, T., & Arai, Y. (2025). Evolution of area-based management tools for environmental impact assessment of deep-sea mining. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 227–256). Springer.
3. Igarashi, Y. (2025). Land-based mining versus deep-sea mining: How to achieve sustainable supply chain of critical raw minerals. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 395–408). Springer.
4. Kaufmann, M., et al. (2025). Geospatial data management and integration for resource and environmental modelling of marine systems. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 115–158). Springer.
5. Larsen, O., et al. (2025). Monitoring and modeling of deep-water sediment plumes from deep-sea mining. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 325–360). Springer.
6. Lily, H., & Chakraborty, A. (2025). Navigating challenges in inspection, compliance and enforcement ("ICE") for deep-seabed mining beyond national jurisdiction. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 447–484). Springer.
7. Madureira, P. (2025). Deep-seabed mining and the United Nations 2030 Agenda for Sustainable Development. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 409–422). Springer.
8. Mishiro, K., et al. (2025). Data management for marine scientific research. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 43–62). Springer.
9. Radziejewska, T., Madureira, P., & Mianowicz, K. (2025). Assessment of cumulative effects for environmental management of deep-sea areas targeted for resource

- extraction. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 185–226). Springer.
10. Salamanca-Aguado, M. E. (2025). Legal and institutional aspects of the transition to the exploitation phase of mineral resources in the "Area". In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 485–522). Springer.
  11. Sen, P. K., & Mittal, N. K. (2025). A policy perspective on integrating sea resource utilization with spent lithium-ion battery processing for energy metals recovery. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 361–394). Springer.
  12. Sharma, R., & Gales, P. (2025). Deep-sea mining: Resource potential and future prospects. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 3–42). Springer.
  13. Tilot, V., et al. (2025). The role of rapid environmental assessment in monitoring the environmental impacts of deep-sea mining. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 257–324). Springer.
  14. Verlaan, P. (2025). Facilitating scientific contributions to support development and implementation of global environmental protection regulations: Examples for seabed mining. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 159–184). Springer.
  15. Washburn, T. W. (2025). Data needs for holistic environmental impact assessments of deep-sea mining. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 87–114). Springer.
  16. Willaert, K. (2025). Deep-sea mining and protest activities: A difficult relationship. In R. Sharma (Ed.), *Deep-sea mining management, policy and regulation* (pp. 423–446). Springer.