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Limitations and improvements in the application of international maritime law to deep-sea mineral resource development

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Abstract. Due to the growing demand for marine resources, deep-sea mining has become one of the most important areas of global maritime policy. However, ambiguous provisions in international maritime law continue to pose a regulatory challenge. This study focuses on the application of international maritime law to the exploitation of mineral resources in the deep sea and is based on document analysis and case studies. This study examines two key questions: the specific limitations of existing international maritime law (represented by the United Nations Convention on the Law of the Sea) with regard to the regulation of deep-sea mining, and how to improve legal framework to ensure more effective governance. The results reveal several shortcomings in current international maritime law, including unclear delineation of responsibilities and inadequate regulatory mechanisms for deep-sea mining. The study ultimately proposes targeted improvement measures, such as revising treaty provisions and establishing a comprehensive regulatory platform, to meet practical requirements in the field of deep-sea mining management.

Keywords: international law of the sea, deep-sea mining, united nations convention on the law of the sea, marine resource development

1. Introduction

With the increasing pace of global industrialization, land-based mineral resources are becoming increasingly limited. This has led to deep-sea areas rich in polymetallic nodules, sulphide deposits and cobalt-rich crusts coming to the forefront of international resource development. However, deep-sea mining poses an irreversible threat to marine ecosystems, while the existing international maritime legal framework still lacks comprehensive and targeted regulatory provisions. Existing research on marine policy focuses primarily on general principles of international maritime law and macro-level marine management issues, leaving significant gaps: Few studies have examined in detail how these legal standards apply specifically to deep-sea mining and do not address the regulatory challenges unique to this emerging industry. This research focuses on the applicability of international maritime law to the exploitation of deep-sea mineral resources and aims to examine two key questions: Firstly, what are the limitations of current international maritime law in regulating mineral extraction activities on the high seas? Second, how can the international maritime legal framework be improved to meet the governance requirements for the orderly development of deep-sea mining? To answer these questions, this study uses two methods: examining relevant provisions of international maritime law through literature analysis and examining the application of these laws in actual deep-sea mining projects through case studies. This research has high academic and practical value: it fills a gap in research on deep-sea mining regulation, provides a basis for optimizing the global marine governance system, and promotes the sustainable development of marine resources. Furthermore, the study will provide insights into predicting the future development of legal governance in the field of deep-sea mining and present targeted recommendations for mitigating potential regulatory uncertainties and environmental risks.

2. Overview of deep-sea mining and international maritime law

2.1. Current status of global deep-sea mining development

Deep-sea mining refers to the extraction of mineral resources, such as polymetallic nodules, polymetallic sulfides, and cobalt-rich crusts from the deep seabed. These minerals are rich in critical metals like copper, nickel, and cobalt, which hold strategic

importance for global energy transition and high-tech industries. With growing resource demand and technological progress, deep-sea mining has become a significant approach to developing marine mineral resources [1].

Currently, commercial mining activities in the International Seabed Area have not yet officially begun, but exploration efforts are actively underway. As of July 2025, the International Seabed Authority (ISA) has issued 30 exploration contracts to various entities, including states, intergovernmental organizations, and private companies [2]. Based on current progress, experts predict that deep-sea mining may achieve commercialization within national exclusive economic zones by 2026–2030, while commercial development in the International Seabed Area depends on whether the ISA can finalize the "Mining Code" by 2025. The Clarion-Clipperton Zone, located in the eastern Pacific Ocean, is currently the most promising region for mining. This zone spans approximately 4.5 million square kilometers, comparable in width to the continental United States. Conservative estimates suggest that the reserves of many mineral elements in this zone may even exceed the total reserves found on land.

2.2. Core provisions of international maritime law on deep-sea mining

The International Seabed Area holds significant potential for exploration, development, and scientific research [3]. The "Area" refers to the seabed, ocean floor and subsoil beyond national jurisdictional limits, covering 49% of the Earth's surface. Regarding to previous investigation activities in the seabed area and surveys related to potential economic exploration, such as the commercial exploitation of deep-sea resources, the United Nations Convention on the Law of the Sea (UNCLOS) has established detailed models and systems for managing the seabed and any human activities affecting this zone. The Area is unique in many respects, particularly in that it is not subject to any state authority. Therefore, Part XI of the United Nations Convention on the Law of the Sea defines the legal regime applicable to the international seabed and establishes the core principles of its legal framework:

The first is the “common heritage of mankind”: Article 137 of the United Nations Convention on the Law of the Sea explicitly stipulates that all natural resources within this area belong to all humankind, and that the International Seabed Authority (ISA) organizes and supervises activities within this area on behalf of all humankind.

The second is marine environmental protection: Article 145 requires the International Seabed Authority to protect the marine environment from the effects of activities carried out in the seabed areas, and may take “necessary measures.”

3. Limitations on the application of international law of the sea with regard to the extraction of raw materials from the deep sea

3.1. Ambiguity of the legal framework

The limitations of the "Common Heritage of Mankind" principle are clearly evident. Although this principle is widely recognized, its practical implementation still faces multiple challenges:

First, the definition of the beneficiary remains ambiguous, as the principle does not specify whether humanity as a whole or individual states should benefit, nor does it clarify how to balance the interests of current and future generations [4].

Second, the benefit-sharing mechanism remains underdeveloped. The ISA tends to focus primarily on economic gains when defining benefits, while overlooking non-economic values such as deep-water ecological services. This oversight hinders the effective implementation of a fair benefit-sharing system.

Besides, under Article 82 of UNCLOS, coastal states that exploit non-living resources on 200 nautical miles away on the continental shelf must make contributions in kind to the ISA.

However, rules governing how such payments should be coordinated with the benefit-sharing mechanism for activities in the Area remain unclear, creating potential for jurisdictional overlap and disputes.

3.2. Supervision and enforcement mechanisms are inadequate

A comparison between the United Nations Convention on the UNCLOS and Multilateral Environmental Agreements (MEAs) reveals the absence of a unified international regulatory body and standardized norms. Most MEAs establish specific institutions to determine how the regime should operate, develop new rules when necessary, and enhance implementation. These typically include a Conference of the Parties, a Secretariat, scientific and technical committees, and often a compliance committee [5]. This institutional approach makes the relevant regimes more adaptive, as there is a structured process for updating and revising existing measures. In ocean governance, there are indeed sectoral bodies that perform some of these functions, such as the International Seabed Authority (ISA), the International Maritime Organization (IMO), and regional fisheries management organizations. However, these bodies are sectoral rather than comprehensive in scope, each focusing on a specific set of issues. For instance, regional fisheries management organizations may have limited capacity to address all fish species or broader environmental concerns. Regional Seas Programmes (RSPs) represent a potential vehicle for more integrated governance of

specific marine regions, but the number of RSPs that effectively fulfill this role remains relatively small. While there are regular Meetings of States Parties to UNCLOS, their role is quite limited, dealing primarily with administrative and budgetary matters. The UN General Assembly adopts annual resolutions on oceans and fisheries and facilitates informal consultations on ocean issues. Nevertheless, the ocean-governance landscape remains a patchwork of institutions with scattered mandates and uneven effectiveness, raising fears that some environmental problems will slip through the cracks unaddressed.

The ISA has made slow progress in developing unified international regulatory standards, with significant disagreements among parties on three key issues: (1) Environmental Protection Standards: These include ecological baseline data collection, methodologies for assessing environmental impact and setting environmental limits. (2) Financial Payment and Benefit-Sharing Mechanisms: Some states support a simple ad valorem copyright system based on fixed rates. (3) Inspection, Compliance, and Enforcement Mechanisms: Some member states advocate for establishing an independently operated body, while others believe these functions should be fulfilled by the Legal and Technical Committee of the International Maritime Organization based on its existing mandate.

Furthermore, the ocean is a fluid and interconnected system, meaning environmental impacts from mining activities, such as sediment plumes and water pollution, can spread across borders. However, significant legal gaps remain in current international law regarding the definition of "serious harm," the identification of liable parties for transboundary damage, and ensuring adequate compensation.

4. Case study: the limitations of international maritime law in the “Nauru-1” deep-sea mining project

The "two-year rule" originates from the Annex of the 1994 Implementation Agreement. It stipulates that if a member of the ISA Council submits a request and confirms that every endeavor to arrive consensus have been exhausted, the Secretary-General of the ISA must present a work plan within two years. If the Council does not agree on the plan within this period, the version of the plan most favorable to development shall be adopted [6]. In 2021, Nauru Ocean Resources Inc.'s application to exploit deep sea mineral extraction in the Pacific-based CCZ invoked the "two-year rule" [7]. According to this rule, the ISA was obligated to adopt provisions on use by 2023. However, the ISA held two sessions but still failed to reach a consensus, resulting in a regulatory vacuum. As contractors plan to submit applications for mining licenses, ISA faces the challenge of making decisions within an incomplete legal framework. Applying the "two-year rule" has further intensified a normative conflict between the mandatory approval obligation and the existing institutional deficiencies.

5. Approaches to refining international maritime law for deep-sea mining governance

5.1. Revision and supplementation of the core international legal system

Reflecting on the shortcomings of the legal framework, the primary step is to accelerate the finalization and elaboration of the "Regulations on Exploitation of Mineral Resources in the Area." The top priority is to expedite the negotiation and adoption of the ISA's "Mining Code". These regulations must incorporate clear and operational environmental standards, specific post-closure monitoring plans, and mandatory environmental liability insurance or financial guarantee mechanisms. Moreover, details on the implementation of the "common heritage of humanity" principle should be clarified and refined. Subsequent regulations or legal instruments should explicitly define the order of priority among beneficiaries, ensuring that developing countries, are given preferential status in the distribution of benefits. Concurrently, specific modalities for benefit-sharing should be explored. Beyond monetary distribution, alternative approaches such as funding public projects, and investing in education and infrastructure—providing benefits "in-kind"—should be considered to ensure that benefits more directly reach the people.

5.2. Establish a unified international coordination platform for deep-sea mining oversight

To create a single international platform—and a single set of rules—for deep-sea mining, the International Seabed Authority’s supervisory and enforcement powers must be strengthened; an independent technical oversight and verification body should therefore be established within the ISA itself. This mechanism should be empowered to review the domestic regulatory records of sponsoring states and conduct random on-site inspections of activities in the "Area" to ensure compliance with the rules. Also, there is a need to harmonize and coordinate national legislations. Countries should be encouraged to adopt the highest international standards established by the ISA when formulating their own deep-sea mining laws, so as to prevent "regulatory arbitrage." In this regard, China's "Deep Seabed Area Resource Exploration and Development Law" and the legislative practices of other states can serve as important references [8].

5.3. Improve the compensation system for ecological damage liability in deep-sea mining

A clear legal framework for environmental liability and compensation must be established. The "Mining Code" should enshrine the principle of strict liability, ensuring contractors bear responsibility for environmental damage regardless of fault. Concurrently, clear criteria for identifying environmental harm and guidelines for calculating compensation amounts need to be developed. And a layered financial security mechanism should also be instituted. This would mandate contractors to provide adequate financial guarantees, such as insurance policies or bank bonds, sufficient to cover the environmental cleanup and restoration costs potentially arising from a maximum credible accident.

6. Discussion

6.1. Balancing deep-sea development with marine ecological conservation through legal refinement

The UNCLOS grants coastal states relevant rights and sufficient authority to manage living resources sustainably, while taking measures to safeguard biodiversity of marine [9]. The 1995 UN Fish Stocks Agreement was an important step in further developing the concept of international cooperation, particularly with regard to shared fish stocks and stocks of highly migratory fish. It placed greater emphasis on concepts such as biodiversity conservation, stating that ecosystem administration and the precautionary principle should be execution by Regional Fisheries Management Organizations (RFMOs). The work of the UN Food and Agriculture Organization (FAO) concerning illegal, unreported and unregulated (IUU) measures relating to fishing and ports are particularly important. Furthermore, the UN General Assembly has influenced state behavior through its annual resolutions. Two notable examples include resolutions calling for a moratorium on fishing using large-scale pelagic nets and those urging RFMOs to adopt measures protecting vulnerable marine ecosystems from destructive fishing practices [10]. The objective of legal refinement does not involve a total ban on deep-sea mining, but to minimize its environmental risks through sound regulations grounded in the precautionary principle. Given the fluid and interconnected nature of the ocean and the fragility of deep-sea ecosystems—scientific studies indicate that areas subjected to test mining still show significant disturbance 44 years later—commercial development should be deferred while scientific understanding remains incomplete. Priority must now shift to rigorous study of deep-sea ecosystems and mining's potential impacts. Governance should embrace innovation—graded decisions, benefit-sharing, dynamic laws, tiered approvals and ecological-debt instruments—to resolve the development-versus-conservation dilemma.

6.2. The adaptability of improved international maritime law to technological advances in deep-sea mining

A stable, predictable, and equitable international legal framework inherently serves as an incentive for technological development. When enterprises across nations have a clear understanding of environmental standards, liability boundaries, and licensing procedures, they are more inclined to make long-term and large-scale technological investments.

At the same time, legal rules must also retain a degree of flexibility, enabling them to incorporate new scientific insights and adapt to technological iterations. For instance, a periodic regulatory review and amendment mechanism could be established. Concurrently, the development of innovative technologies such as Germany's "Deep-Sea Sampling II" project should be encouraged. This project aims to create a closed-loop system that prevents pollutants from entering the marine environment, thereby achieving deep-sea sampling with minimal ecological impact.

7. Conclusion

This study focuses on the application of international maritime law to deep-sea mineral extraction and has reached clear conclusions. With regard to the research question concerning the limitations on the applicability of international maritime law, three major shortcomings in the current legal framework were identified: differences in the rights and obligations of the parties involved, inadequate oversight and enforcement mechanisms, and provisions that lag behind new mining technologies. On the question of how the legal system can be improved, the study proposes specific ways forward, such as revising the provisions of the United Nations Convention on the Law of the Sea, establishing a unified oversight platform and improving environmental compensation systems. Nevertheless, this study has certain limitations. It focuses primarily on the analysis of international legal norms and lacks an in-depth examination of the implementation status of national domestic laws that are consistent with international maritime law. Future research could broaden the scope of the investigation of the interactions between domestic and international law and further validate the feasibility of proposals to improve the legal situation through additional case studies. Given the continuous development of deep-sea mining technology, subsequent research could also address legal responses to new issues such as intelligent mining machines and cross-border joint mining activities. In summary, this study fills a gap in a thorough analysis of the application of international maritime law to deep-sea mining. Its conclusions and recommendations

provide practical guidance for optimizing global maritime policy, promoting the sustainable use of mineral resources in the deep sea, and reconciling the twin objectives of resource exploitation and marine ecology protection. With the commercialization of deep-sea mining on the horizon, the findings of this study will help to establish a clear, equitable and environmentally sound legal framework, thereby laying the foundation for the long-term, orderly governance of this emerging industry.

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