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Legal perspectives on deep-sea mining: International Seabed Authority governance and closure gaps, with lessons from Australia

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1 Abstract

Deep sea mining (DSM) operates under 2 distinct legal contexts: domestic law within national jurisdiction and United Nations Convention on the Law of the Sea (UNCLOS) Part XI with the International Seabed Authority (ISA) in areas beyond national jurisdiction (ABNJ). This review integrates international law, ISA Mining Code Phase 2 negotiations and emerging national approaches to identify areas of consensus, points of conflict and persistent governance gaps.

Three developments in 2024–2026 intensify the governance challenge: more than 40 nations have called for a precautionary pause or moratorium; the International Court of Justice's 2025 advisory opinion is expected to strengthen environmental obligations under international law, and US executive action under the Deep Seabed Hard Mineral Resources Act (DSHMRA) is accelerating domestic seabed licensing outside the ISA framework. In Australia, the Environment Protection Reform Act 2025 (Cth), the new National Environmental Protection Agency from 1 July 2026, and the seabed mining ban in New South Wales (NSW) demonstrate that domestic governance is evolving rapidly in ways directly relevant to future DSM sponsorship decisions.

The synthesis finds that the current international regime cannot yet support exploitation with confidence. Key gaps include incomplete exploitation rules (environmental thresholds, liability, closure), contested ISA accountability and transparency, structurally fragmented enforcement at sea, and underdeveloped financial assurance and post-closure obligations. Australia's comparatively mature terrestrial approaches to environmental assessment, compliance and mine closure offer transferable design lessons, but require significant adaptation to ABNJ conditions. Australia is therefore well placed to advocate for coherent, enforceable exploitation rules and practical compliance and closure mechanisms before DSM exploitation is authorised.

Keywords: *deep sea mining, UNCLOS, International Seabed Authority, mine closure, exploitation regulations, environmental governance, Australia*

Introduction

Deep sea mining (DSM) governance operates along 2 primary paths. Within exclusive economic zones (EEZs) and continental shelves, DSM activities are regulated by domestic legal frameworks. The global distribution of mineral resources and International Seabed Authority (ISA) exploration areas is shown in Figures 1 and 2. In areas beyond national jurisdiction (ABNJ), particularly the 'Area', Part XI of the United Nations Convention on the Law of the Sea (UNCLOS) designates seabed mineral resources as the common heritage of humankind and vests regulatory authority in the ISA. The ISA administers access, benefit sharing and environmental protection through its developing Mining Code, which establishes the environmental, operational and financial conditions for DSM (Levin et al. 2025; Pecoraro & Shah 2026). This governance framework traces its conceptual origins to Arvid Pardo's 1967 address to the United Nations General Assembly, which articulated the common heritage principle and informed the adoption of UNCLOS Part XI.

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The genesis of this paper lies in the rapid and uneven evolution of DSM governance. Between 2025 and 2026, the United States advanced domestic DSM initiatives under the *Deep Seabed Hard Mineral Resources Act* (DSHMRA) of 1980, administered by the National Oceanic and Atmospheric Administration (NOAA). These unilateral efforts risk outpacing ISA rulemaking and contribute to increasing governance fragmentation (ISA 2024; Pecoraro & Shah 2026). Following President Trump's April 2025 Executive Order, 'Unleashing America's Offshore Critical Minerals and Resources', federal agencies including NOAA and the Bureau of Ocean Energy Management (BOEM) initiated measures to facilitate commercial DSM both within the U.S. EEZ and in ABNJ (Executive Office of the President 2025; BOEM 2026a). Collectively, these developments underscore an increasingly complex and evolving regulatory landscape with significant implications for governance coherence and environmental oversight.

The Metals Company (TMC) exemplifies these tensions, pursuing polymetallic nodule extraction under ISA exploration contracts while simultaneously advancing a commercial pathway under DSHMRA. Greenpeace argues that such activities are inconsistent with UNCLOS obligations, which require DSM in the Area to be conducted exclusively under ISA authority (Greenpeace 2026), highlighting the normative challenges arising from parallel governance pathways (Table 1).

Table 1 Chronology of key U.S. deep sea mining actions under the Trump Administration II (2025–2026)

Phase	Date	Agency	Action	Notes	Sources
1	24 April 2025	White House	Executive Order 14285 signed	Directs BOEM, NOAA and Department of the Interior to expedite offshore critical minerals development in U.S. EEZ and international waters.	Executive Order 14285 (2025); Federal Register, 90 Fed. Reg. 17,559 (2025); Harvard EELP Tracker (2026)
2	10 November 2025	BOEM	Area Identification – American Samoa	~18 million acres designated for environmental review and potential leasing for polymetallic nodules (cobalt, lithium, nickel, manganese).	BOEM (2025a); Perkins Coie (Nov 2025); CRS Report R48302 (2026)
3	12 November 2025	BOEM	Request for Information – Commonwealth of the Northern Mariana Islands (CNMI)	RFI Docket BOEM-2025-0351; ~35.5 million acres; comment period extended to 12 Jan 2026; 65,585 submissions received.	Federal Register, 90 Fed. Reg. (12 Nov 2025); BOEM (2025b); Mongabay (18 Dec 2025); Harvard EELP Tracker (2026)
4	21 January 2026	NOAA	Final rule – streamlined permitting (DSHMRA)	Consolidated exploration and commercial recovery applications; single environmental review. Effective immediately.	Federal Register, 91 Fed. Reg. 2642 (21 Jan 2026); NOAA (2026a); Gibson Dunn (Feb 2026); Mondaq (Jan 2026)
5	22 January 2026	NOAA	Hydrographic survey – American Samoa	Seabed mapping of federal waters off American Samoa to identify critical mineral deposits and generate baseline environmental data.	NOAA (2026b); Harvard EELP Tracker (2026); Inside Climate News (11 Mar 2026)
6	29 January 2026	BOEM	Request for Information – Alaska OCS	RFI Docket BOEM-2025-0318; ~113–114 million acres; ferromanganese crusts and heavy mineral sands; >90,000 submissions; extended to 1 Apr 2026.	Federal Register, 91 Fed. Reg. 3924 (29 Jan 2026); BOEM (2026a); CRS Report R48302 (2026); Alaska Beacon (27 Jan 2026)
7	18 March 2026	BOEM	Area Identification – CNMI (expanded)	Area expanded to ~69 million acres spanning both flanks of Mariana chain; nearest tracts ~57 miles from Saipan. *US National Environmental Policy Act* (US NEPA) Environmental Assessment to follow.	BOEM (2026b); BOEM CNMI Area ID Memo (2026); Isla Public/KPRG News (19 Mar 2026); Harvard EELP Tracker (2026)

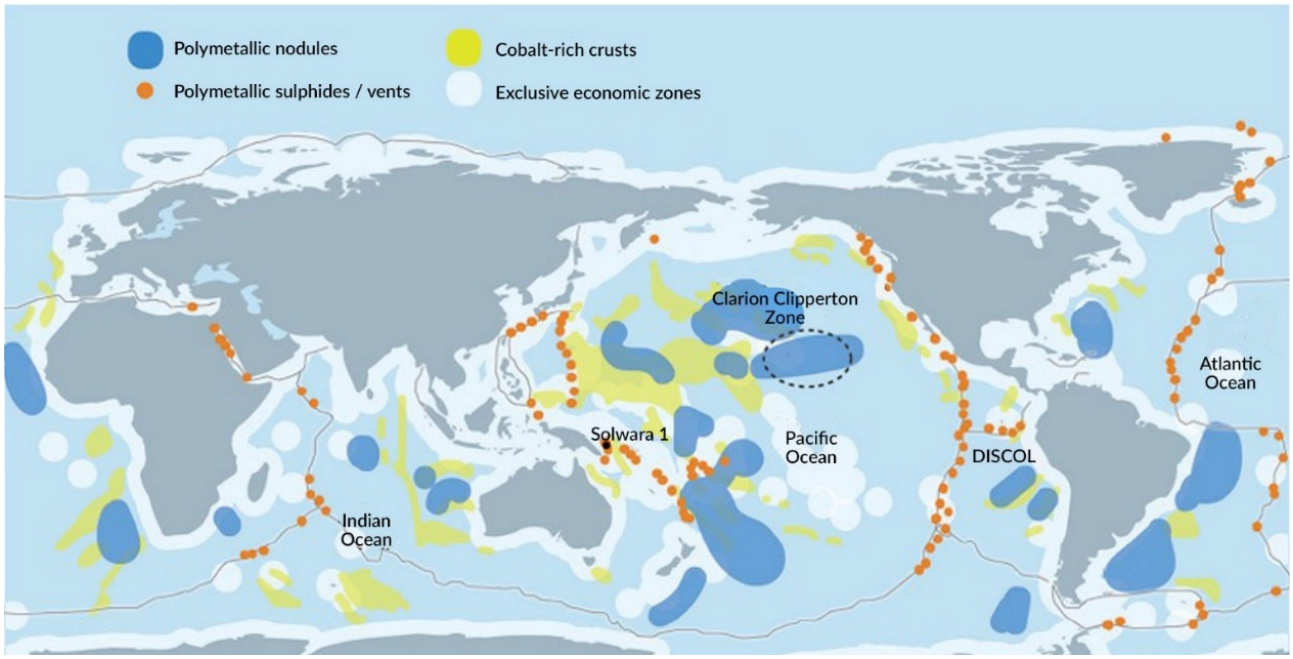

Figure 1 **Global distribution of deep sea mineral resources – polymetallic nodules, sulphides, cobalt-rich ferromanganese crusts – and national EEZs, showing major geological features and jurisdictional boundaries (modified from Deep Sea Mining Campaign 2026)**

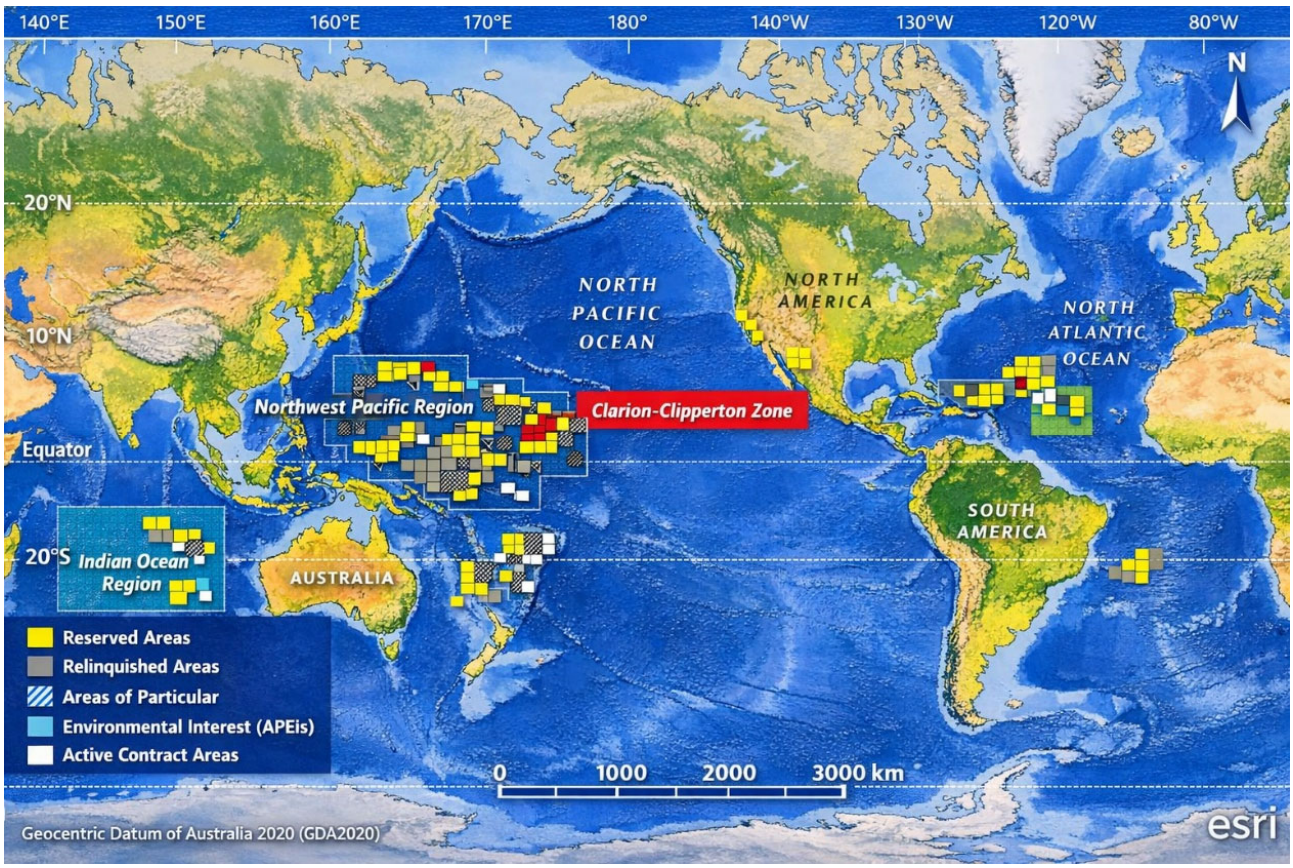

Figure 2 **Status of deep sea mineral exploration areas showing reserved areas (yellow), relinquished areas (grey) and areas of particular environmental interest (hatched). Map presented in GDA 2020 with latitude–longitude graticule; Basemap: ESRI (redrawn). Source: modified after International Seabed Authority (2026)**

This review builds on prior work – including Blanchard et al. 2023, Singh & Jaeckel 2024, Graydon 2023 and Pecoraro & Shah 2026 – and extends it by integrating international law, environmental governance and Australian domestic regulation. Its distinctive contribution is to treat DSM simultaneously as a question of regulatory frameworks and a problem of governance in practice, positioning mine closure and rehabilitation as a central phase of analysis.

The Mining Code defines environmental, operational and financial conditions for DSM; however, regulations for exploitation remain incomplete. Critical gaps persist in environmental protection standards, liability mechanisms and enforceable closure and post-closure obligations (ISA 2024). These gaps heighten governance uncertainty, create potential legal and financial risks, and underscore the need for precautionary and adaptive management strategies. Lessons from terrestrial mining – particularly Australia's experience with environmental assessment, compliance and mine closure – offer transferable insights that could inform the development of robust, enforceable and globally coherent DSM exploitation standards (Arpi & Rothwell 2025; Van Dover 2020).

Australia's domestic DSM framework reflects its constitutional structure as a federation operating within a Westminster system and common law tradition. The *Offshore Minerals Act 1994* (Cth) provides the principal mechanism for regulating offshore mineral exploration and extraction. The *Environment Protection and Biodiversity Conservation Act 1999* (Cth) – substantially reformed by the *Environment Protection Reform Act 2025* (Cth) – imposes stringent environmental impact assessment (EIA) requirements and embeds the precautionary principle as a statutory obligation. NSW's Environmental Planning and Assessment Amendment *(Seabed Mining and Exploration*) *Act* 2024, banning seabed mineral exploration, signals growing domestic political sensitivity, while the AU–US A$8.5 billion critical minerals agreement underscores the geopolitical stakes of securing access to these resources (Arpi & Rothwell 2025).

2 Methods

This review synthesises legal and governance material on DSM using an integrative design that combines doctrinal legal analysis, empirical studies and policy documentation to develop new conceptual frameworks (Snyder 2019). This approach is well-suited to interdisciplinary and rapidly evolving governance domains, where evidence spans legal instruments, environmental science and institutional analysis, and where the objective is interpretive integration rather than statistical aggregation.

Searches were conducted between February and March 2026 across multidisciplinary databases (Google Scholar, ProQuest Central and HeinOnline) and authoritative institutional websites. Search strings combined DSM-related terms with governance and legal concepts, including UNCLOS, the ISA, Mining Code, EIA, enforcement, liability, closure and financial assurance. Searches were restricted to English-language sources, generally from 2016 onwards unless considered seminal.

Records were screened in 2 stages – title/abstract screening followed by full-text assessment – against predefined eligibility criteria. Included sources comprised peer-reviewed studies addressing DSM environmental impacts, regulatory frameworks, or governance mechanisms and authoritative grey literature from recognised institutions such as the ISA, the Pew Charitable Trusts Code Project and the United Nations. Excluded materials included non-analytical opinion pieces, industry promotional content and conference abstracts lacking full papers.

The search process initially identified approximately 312 records. After removal of duplicates (n = 47), 265 records underwent title and abstract screening, with 67 progressing to full-text review. Of these, 34 were excluded, primarily due to limited methodological transparency or lack of relevance. An additional 24 authoritative grey literature sources were incorporated through targeted searching and citation chaining, resulting in 57 included sources. A supplementary search covering 2023–2025 yielded 47 additional records, of which 11 met inclusion criteria.

Four research questions guided the review:

- RQ1: What regulatory and governance frameworks have been proposed or implemented for DSM?
- RQ2: What environmental risks and uncertainties are consistently identified in the DSM literature?
- RQ3: What lessons from surface mining, rehabilitation and mine closure are relevant to DSM regulation?
- RQ4: What regulatory gaps and best practice principles are identified across jurisdictions and governance scales?

Legal contextualisation is integrated throughout the analysis, situating UNCLOS Part XI, the ISA Mining Code and the BBNJ Agreement within their broader geopolitical and scientific context. Comparative insights are drawn from terrestrial mining governance, including Australian Commonwealth and state-based frameworks, to understand how mine closure obligations and rehabilitation standards have evolved in response to historical failures and community expectations.

Consistent with the integrative design and heterogeneity of sources, no single formal risk-of-bias tool was applied. Instead, sources were evaluated based on relevance, transparency of reasoning or methodology, and institutional authority. Two overarching evidence considerations are noted: first, DSM governance literature is predominantly framed by precautionary and risk-based perspectives; second, the relative absence of international relations and political economy analyses (Oztig 2025) represents a structural limitation in the existing body of scholarship. Figure 3 illustrates publication trends in DSM research indexed in Scopus from 1970 to 2025, showing a prolonged period of low output prior to approximately 2005, followed by sustained growth from 2008 onwards. This increase corresponds with the expansion of governance, environmental and legal scholarship alongside intensified ISA regulatory activity.

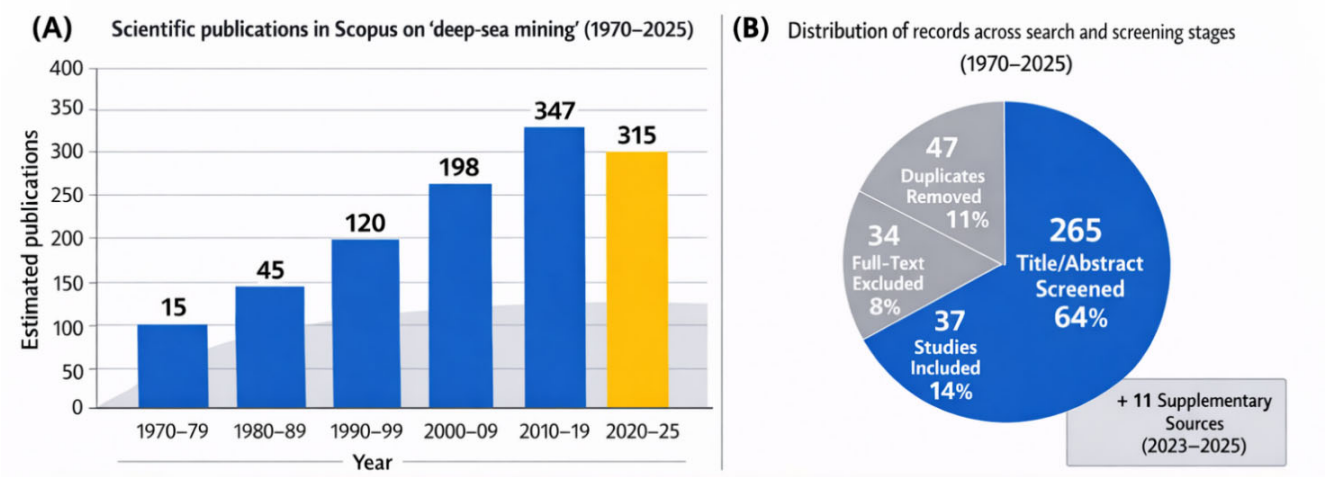

Figure 3 Publication trends and screening workflow in deep sea mining literature (1970–2025); (a) Scopus publication counts by period (1970–2025); (b) Proportional distribution of records across screening stages (percentages only)

Three distinct phases of academic and regulatory activity can be identified. The first phase (pre-2005) is dominated by foundational legal scholarship responding to UNCLOS 1982 and the 1994 Implementing Agreement. The second phase (2005–2016) reflects accelerating academic and policy interest, coinciding with the issuance of ISA exploration contracts and the expansion of ecological research.

The third phase (2016–2026) aligns with intensified negotiations on exploitation regulations, the entry into force of the BBNJ Agreement (January 2026) and the increasing pace of unilateral national licensing initiatives.

3 International legal frameworks

3.1 Overview and synthesis

The literature consistently identifies the ISA, operating under the UNCLOS, as the central rule maker for environmental and closure standards in the Area. However, persistent gaps – particularly in relation to closure – are increasingly recognised as a critical barrier to the credible authorisation of DSM (Singh et al. 2025). Singh et al. 2025 argue that a precautionary regulatory pause is both legally available and practically justified, given that exploitation regulations must establish workable closure, post-closure and liability requirements under conditions of limited baseline knowledge. Within this framing, 'closure risk' emerges as a core governance concern: where credible end-states, monitoring durations, triggers and remedial mechanisms cannot be demonstrated, authorisation may fail to meet UNCLOS obligations for effective environmental protection.

Across the 2016–2026 literature, there is broad convergence that DSM exploitation cannot be credibly authorised without 3 foundational elements: binding and enforceable closure and post-closure obligations; robust financial assurance mechanisms aligned with long-term monitoring horizons and highly uncertain ecological recovery trajectories; and clearly defined liability and remedy pathways (Van Dover 2020; Levin et al. 2020; Smith 2022). Within this framework, precautionary instruments – such as moratoria, regulatory pauses and staged or adaptive approvals – are increasingly conceptualised as integral components of closure governance, particularly in addressing irreversible environmental risks for which satisfactory post-closure outcomes cannot yet be guaranteed (Levin et al. 2020; ISA 2024). Despite these developments, DSM-specific closure criteria – especially scientifically defensible end-state definitions – and fit-for-purpose financial assurance models remain underdeveloped, sustaining a significant governance gap for both the ISA and States seeking alignment with terrestrial mine closure practice (Smith 2022; ISA 2024).

Complementing these challenges, the ISA's Mining Code Exploration Regulations provide a structured but incomplete foundation for environmental governance in the Area, establishing baseline obligations for environmental data collection, monitoring, reporting and contractor performance. While comparatively mature at the exploration stage, these instruments do not resolve the legal, financial and ecological dimensions of exploitation, closure and post-closure stewardship (ISA 2024). Key thematic findings from this synthesis are presented in Table 2.

Table 2 Key thematic synthesis findings and implications for Australia

Theme	Synthesis	Implication	Key sources
Regulatory location (national jurisdiction vs ABNJ)	DSM is governed by domestic law in EEZ/continental shelf, but by UNCLOS Part XI via the ISA in ABNJ; legal credibility depends on the (unfinished) Mining Code for exploitation.	Comparisons must be jurisdiction-specific; domestic 'best practice' cannot substitute for ISA enforceability in ABNJ.	United Nations 1982; Krögeret al. 2025
Core international architecture (UNCLOS + ISA)	UNCLOS frames the Area as a common heritage and imposes environmental duties; ISA must operationalise 'effective protection' through concrete standards.	ISA legitimacy depends on transparency, science-responsiveness and distributive fairness.	United Nations 1982, Art. 136, 140, 145, 192, 194
Mining Code status (exploration mature; exploitation incomplete)	Exploration rules exist, but exploitation regulations remain unresolved on thresholds, liability and closure.	Treat exploitation as premature absent conditions precedent (thresholds, stop-rules, liability, closure).	Krögeret al. 2025; Pickens et al. 2024; Rosenbaum & Singh 2024
Accountability deficit (ISA institutional design)	LTC functions with limited transparency, weak accountability and restricted public participation; the ISA's institutional design systematically undervalues broader interests.	Australia should advocate for transparency, independent science and review mechanisms within the ISA.	Lily et al. 2023
Enforcement gaps (at-sea fragmentation)	ISA relies on sponsoring/flag/port States; no binding coordination; verification gaps undermine compliance.	DSM needs binding inspection protocols and interoperable monitoring systems.	Lily et al. 2024
Sponsoring State obligations and investment law tension	States face a regulatory paradox: tightening environmental due diligence under UNCLOS may simultaneously expose them to investor-state arbitration claims.	Design sponsorship laws to meet UNCLOS duties and manage arbitration exposure.	Pecoraro 2019; International Tribunal for the Law of the Sea 2011

Theme	Synthesis	Implication	Key sources
Precaution and 'pause' debate	Post-2016 scholarship treats moratoria, pauses and staged approvals as functional governance tools because closure risk cannot yet be managed.	A pause/moratorium is the prudent default until conditions precedent are demonstrably in place.	Singh et al. 2025; Martinelli 2025
Closure risk and terrestrial analogy limits	DSM end-states are uncertain, recovery may be multi-decadal or unattainable, and liability/remedy pathways remain unclear; terrestrial closure concepts need significant adaptation.	Transfer design lessons from Australia's strengths; avoid assuming terrestrial rehabilitation analogies 'solve' DSM impacts.	Rosenbaum & Singh 2024; Graydon 2023
BBNJ Agreement and regime interaction	BBNJ (effective 17 Jan 2026) adds ABNJ EIA expectations and biodiversity governance tools; coordination with ISA procedures is unsettled, creating legal uncertainty for DSM approvals.	Australia can support clearer coordination rules (EIA alignment; ABMTs/MPAs coherence) to reduce fragmentation.	Timelex 2026; Singh et al. 2025
Geopolitics and fragmentation risk	Strategic competition and unilateral licensing initiatives (US DSHMRA) risk outpacing multilateral rulemaking and weakening compliance incentives.	Priority is coherent international rules with enforceable compliance/closure before exploitation proceeds.	Pecoraro & Shah 2026; Woods & Guillet 2025

4 United Nations Convention on the Law of the Sea framework

The UNCLOS (1982), often described as the 'constitution for the oceans', establishes the primary legal framework for ocean governance. It defines maritime zones, allocates jurisdictional rights and responsibilities, and designates the Area and its mineral resources as the common heritage of humankind. The 1994 Agreement Relating to the Implementation of Part XI of UNCLOS modified and clarified the DSM regime, facilitating near-universal acceptance of the Convention.

UNCLOS imposes several key environmental obligations relevant to DSM. These include Article 192, which requires States to protect and preserve the marine environment; Article 194, which obliges States to prevent, reduce and control marine pollution; and Article 145, which requires effective protection of the marine environment from harmful effects arising from activities in the Area. These obligations are implemented through the international law concept of due diligence, as interpreted by the International Tribunal for the Law of the Sea (ITLOS) in its 2011 advisory opinion, and are reinforced by the precautionary principle (Levin et al. 2025).

UNCLOS also established the principal institutions governing ocean affairs, including the ISA, the ITLOS and the Commission on the Limits of the Continental Shelf. Consequently, DSM operates within a dual governance framework: coastal States exercise jurisdiction over activities occurring on their continental shelves, while the ISA regulates mineral activities in the Area (Tassin Campanella 2023). Despite this framework, significant governance gaps remain, particularly regarding post-closure obligations, liability, compensation and long-term environmental stewardship in ABNJ.

4.1 International Seabed Authority governance

The ISA, comprising 169 member States and the European Union, is responsible for regulating DSM activities through the development and implementation of the Mining Code, the administration of exploration and exploitation contracts and compliance oversight. Governance responsibilities are divided among 4 principal organs: the Assembly, Council, Legal and Technical Commission (LTC) and Secretariat. Although the LTC functions as a subsidiary body, it has emerged as the most influential institution within the regulatory process, attracting criticism regarding transparency, accountability and decision-making oversight (Lily et al. 2023).

The ISA's Mining Code consists of a combination of binding regulations and non-binding standards and guidelines. Exploration contracts, generally granted for 15 years, require contractors to undertake environmental baseline studies, submit periodic reports and progressively relinquish portions of their contract areas. However, following Nauru's invocation of the so-called '2-year rule' in 2021, negotiations on exploitation regulations intensified, yet several fundamental issues remain unresolved. These include environmental thresholds, liability arrangements, compliance mechanisms and equitable benefit sharing.

A particularly significant deficiency is the absence of binding environmental performance standards capable of objectively determining acceptable levels of environmental harm (Levin et al. 2025). While proposals such as environmental compensation funds, enhanced sponsoring State obligations and stronger compliance mechanisms have been advanced, these reforms have not been formally adopted. Consequently, calls for a precautionary pause or moratorium on commercial DSM continue to grow amid concerns regarding regulatory preparedness.

4.2 Legal tensions and accountability

DSM governance is further complicated by the interaction between UNCLOS obligations and international investment law. Foreign investors involved in ISA-sponsored mining projects may be protected under bilateral investment treaties and other investment agreements, potentially exposing States to investor-state arbitration if environmental regulations are strengthened or mining approvals are restricted (Pecoraro 2019).

This tension has prompted scholars to question whether the current regulatory framework satisfies the UNCLOS requirement of 'effective protection' of the marine environment. Articles 145, 192 and 194 collectively require credible scientific evidence demonstrating that serious environmental harm is unlikely and that robust,

enforceable safeguards are in place (Singh & Jaeckel 2024). At present, this threshold appears unmet due to deficiencies in environmental thresholds, cumulative-impact assessments, independent scientific verification, operational stop-rules and comprehensive closure and liability frameworks.

The anticipated advisory opinion of the International Court of Justice on climate obligations is expected to further strengthen international expectations regarding due diligence and precautionary environmental governance. Simultaneously, concerns persist regarding an accountability deficit within the ISA, particularly arising from limited transparency within the LTC, inadequate publication of reasoning and restricted opportunities for independent review (Lily et al. 2023).

4.3 Enforcement gaps

The effectiveness of the DSM regulatory regime is ultimately constrained by significant enforcement limitations. The ISA possesses limited direct enforcement powers and lacks operational control over vessels engaged in mining activities. Instead, compliance depends heavily upon sponsoring States, flag States and port States, creating a fragmented and potentially inconsistent jurisdictional framework (Lily et al. 2024).

This fragmentation creates opportunities for regulatory gaps, particularly where vessels operate under the flags of non-member States or where enforcement responsibilities are inadequately coordinated. In the absence of binding inspection procedures, mandatory information-sharing mechanisms and comprehensive liability arrangements, effective compliance monitoring cannot be guaranteed.

Thus, 4 principal governance deficiencies can be identified:

1. Substantive gap – the absence of complete and enforceable environmental standards.
2. Institutional weakness – limited transparency, accountability, and oversight within ISA decision-making structures.
3. Legal conflict – tensions between UNCLOS environmental obligations and international investment protections.
4. Enforcement deficit – fragmented jurisdiction and inconsistent compliance mechanisms.

Collectively, these deficiencies raise serious questions as to whether the current DSM regulatory framework can satisfy UNCLOS' requirement for the *effective protection of the marine environment*. Until these gaps are addressed, the legal and institutional foundations necessary to authorise commercial-scale DSM remain incomplete. Table 3 presents the governance frameworks for DSM across international and Australian settings.

Table 3 Governance frameworks for DSM across international and Australian settings

Governance level	Component	Description/principle	Primary legal source
International	United Nations 1982	The principal treaty governing ocean activities. Part XI and the 1994 Implementing Agreement establish the legal regime for seabed mining in ABNJ ('the Area').	United Nations Convention on the Law of the Sea (United Nations 1982)
International	Common heritage of mankind	Seabed resources beyond national jurisdiction are the collective heritage of humanity and must be managed for the benefit of all states.	United Nations 1982, Art. 136; United Nations General Assembly 1970
International	International Seabed Authority	Intergovernmental organisation responsible for regulating mineral-related activities in the Area and issuing exploration contracts.	International Seabed Authority 2024 (exploration contracts); International Seabed Authority 2024 (ISBA/29/C/CRP.1)
International	ISA Mining Code	A developing regulatory framework governing prospecting, exploration and proposed exploitation of seabed minerals.	International Seabed Authority 2024, Consolidated Text of the Draft Exploitation Regulations (ISBA/29/C/CRP.1)
International	Environmental protection	Mandates protection of the marine environment from the harmful effects of seabed mining. Precautionary approach applied to address uncertainty and ecological risks.	United Nations 1982, Art. 145; International Seabed Authority 2024 (ISBA/29/C/CRP.1)
International	Sponsorship requirement	Contractors undertaking mining activities must be sponsored by a State Party to UNCLOS, which exercises regulatory oversight and bears due diligence obligations.	United Nations 1982, Annex III; International Tribunal for the Law of the Sea 2011
International	Benefit sharing	Financial and economic benefits derived from seabed mineral resources must be shared equitably among states.	United Nations 1982, Art. 140
Australia (Federal)	Offshore Minerals Legislative Framework	Governs exploration and development of offshore minerals in Commonwealth waters adjacent to Australia.	*Offshore Minerals Act 1994* (Cth); Parliament of Australia 2023
Australia (Federal)	Environmental impact regulation	Environmental approvals required for offshore resource activities affecting matters of national environmental significance. Substantially reformed by the *Environment Protection Reform Act 2025* (Cth).	*Environment Protection and Biodiversity Conservation Act 1999* (Cth); *Environment Protection Reform Act 2025* (Cth); Department of Climate Change, Energy, the Environment and Water 2026; Parliament of Australia 2025
Australia (States)	State Mineral Development Legislation	State legislation regulating mineral exploration and development within state coastal waters.	*Mining Act 1978* (WA); *Mineral Resources Act 1989* (Qld)
Australia (Sub-national)	State environmental policies	Several Australian jurisdictions have implemented policy restrictions or prohibitions on seabed mining activities within coastal waters, including NSW's 2024 ban.	*Environmental Planning and Assessment Amendment (Seabed Mining and Exploration) Act 2024* (NSW); White & Case 2025

5 Environmental impacts and environmental impact assessment framework

5.1 Ecological risks and the limits of baseline knowledge

Fauna & Flora International 2020 concluded that the deep sea is vast, highly biodiverse, functionally interconnected and profoundly poorly understood. Three compounding risk factors stand out: current DSM technologies are not designed to achieve the 'no serious harm' standard required under UNCLOS; baseline ecological data are insufficient to enable reliable impact prediction; and biodiversity hotspots – polymetallic nodule fields, hydrothermal vents and seamount ecosystems – coincide spatially with the most commercially attractive mineral deposits. Calls for a moratorium have grown steadily since 2011, driven by accumulating scientific evidence that the spatial and temporal scales of DSM impacts substantially exceed the predictive and restorative capacity of current science and technology. This directly reinforces the precautionary principle arguments advanced by Singh & Jaeckel 2024 and the closure risk analysis of Singh et al. 2025.

5.2 Environmental impact assessment deficiencies, social dimensions and governance restraint

Two recent analyses of the ISA's EIA regime reach the same conclusion: the system is incomplete, inconsistent and not yet capable of ensuring environmental protection at the exploitation stage. Cassotta & Goodsite (2024) identify major structural gaps: unclear risk assessment standards, weak alternatives analysis, removal of cumulative-impact requirements from draft exploitation regulations and inadequate stakeholder participation. A complementary analysis in Frontiers in Marine Science Editorial Team 2025 similarly identifies vague risk standards, insufficient assessment of alternatives, absent cumulative-impact processes and limited stakeholder rights as systemic weaknesses, further recommending stronger judicial and administrative remedies.

These deficiencies are particularly significant in the Australian context. Australia's domestic EIA framework under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) sets a comparatively high standard, including requirements for cumulative-impact analysis and public participation.

This standard is being further elevated by the *Environment Protection Reform Act 2025* (Cth), which introduces National Environmental Standards, a new 'unacceptable impacts' test, restoration charges instead of offsets and significantly stronger compliance and enforcement powers (Parliament of Australia 2025; DCCEEW 2026a). Tranche 1 commenced on 20 February 2026, with the new National Environmental Protection Agency (NEPA) commencing on 1 July 2026. The gap between domestic and international EIA standards creates a credibility and consistency challenge for Australia as both an ISA member and a potential sponsoring State.

Across the environmental literature, recurring impact pathways (direct benthic disturbance, sediment plumes, noise/light, toxic releases and cumulative pressures) imply a relatively stable set of governance requirements:

1. High-quality baseline data and reference zones sufficient to detect change.
2. Explicit impact thresholds and decision triggers tied to UNCLOS' 'effective protection/no serious harm' expectations.
3. Cumulative-impact assessment at appropriate spatial and temporal scales.
4. Independent verification, reporting transparency and enforceable adaptive management.
5. Closure and post-closure monitoring obligations with financial assurance to ensure long-term compliance.

6 Discussion

6.1 Interpretation of principal findings

The discussion maps where international law (UNCLOS and related duties), ongoing ISA Mining Code negotiations and emerging national approaches align, conflict, or leave governance gaps. Evidence is assessed against 4 linked adequacy tests: legality (compatibility with binding obligations including due diligence and precaution); legitimacy (transparent, participatory decision-making); enforceability (practical implementation given the ISA's indirect enforcement model); and scientific adequacy (baseline knowledge, thresholds, cumulative impacts and adaptive triggers sufficient to meet 'no serious harm' expectations). Table 4 summarises main convergences and remaining deficiencies, including where Australian domestic practice provides useful – but limited – comparators.

The review finds that the current international regime cannot support exploitation with confidence: key safeguards in the Mining Code remain incomplete, ISA accountability is contested, enforcement at sea is structurally fragmented and sponsoring States face an investment law/due diligence tension. On RQ3, terrestrial mine closure experience offers a valuable but limited analogue. Australian mine closure practice – progressive rehabilitation, performance-based completion criteria and adaptive monitoring – cannot be transposed to DSM without significant adaptation, given the spatial scale, ecosystem complexity and scientific uncertainty of deep sea environments.

Table 4 Comparative strengths and weaknesses of DSM and Australian terrestrial mining governance

Theme	DSM (ABNJ / ISA)	Australia (terrestrial mining)	Transfer/limits	Key sources
Legal mandate	Common heritage; 'effective protection' duties; sponsorship model	Clear sovereign authority; statutory approvals + conditions; established remedies	Domestic tools can inform ISA standards, but ABNJ has weaker direct control	United Nations 1982; Kröger et al. 2025
Rule completeness	Exploration mature; exploitation regulations unfinished (thresholds, closure, liability)	Mature permitting; iterative reforms; clearer compliance architecture	Supports conditions precedent/pause until the exploitation package is complete	Pickens et al. 2024; Rosenbaum & Singh 2024
Accountability	LTC influence; limited transparency/reason giving; participation constraints	Administrative law norms; review pathways; public submissions (variable)	Reform priorities: transparency, independent science, review mechanisms	Lily et al. 2023
Enforcement	Indirect at-sea control; relies on sponsoring/flag/port States; verification gaps	Direct inspection powers, established sanctions and clearer regulator capacity	DSM needs binding inspection protocols + interoperable monitoring systems	Lily et al. 2024
EIA + evidence-based	Incomplete standards; contested thresholds; weak cumulative-impact methods	More prescriptive assessment practice, participation expectations and stronger domestic enforceability	Align ISA EIA with quantitative thresholds + stop-rules + independent verification	Frontiers in Marine Science Editorial Team 2025
Closure + liability	End-states uncertain; long time lags; post-closure obligations + remedies under-specified	Established closure planning, completion criteria, and financial assurance concepts (variable)	Transfer concepts, not assumptions: DSM may not be 'rehabilitable'	Levin et al. 2020; Singh et al. 2025
Regulatory risk	Sponsoring State due diligence + potential investment law exposure ('paradox')	Investment treaty risk exists but within a clearer territorial regulation context	Design sponsorship laws to meet UNCLOS duties and manage arbitration exposure	Pecoraro 2019; International Tribunal for the Law of the Sea 2011

6.2 Review strengths, limitations and comparison with existing literature

This review's key strength is its interdisciplinary scope. Synthesising environmental science, international law, investment law, institutional governance and social science perspectives yields a more comprehensive picture of DSM governance challenges than any single-discipline analysis can achieve. The supplementary update further improved currency by capturing key developments after the initial search period.

The principal limitations are methodological heterogeneity and scope constraints. The inclusion of doctrinal legal analysis alongside empirical studies introduces quality appraisal challenges. The predominance of precautionary perspectives in the literature may also limit the balance of the synthesis.

As noted by Oztig 2025, the absence of international relations and political economy scholarship represents a significant gap in the existing evidence base, one that constrains the comprehensiveness of governance assessments and is not fully addressed here.

6.3 Implications for Australia

Australia's approach to DSM reflects a precautionary, regulation-first posture grounded in UNCLOS and domestic environmental law. At the ISA, Australia will not support any exploitation application until a complete, enforceable regulatory framework – including standards and guidelines – is finalised (Australia 2023), consistent with its broader emphasis on science-based decision-making and ecosystem protection (Australia 2021). This caution is legally well-founded: the Seabed Disputes Chamber's Advisory Opinion imposes stringent due diligence obligations on sponsoring States, with liability arising where these are breached (Poisel 2012), while the intersection of DSM and international investment law creates further constraints on regulatory autonomy (Pecoraro 2019).

Domestically, Australia's sponsorship framework must reconcile obligations under the *Offshore Minerals Act 1994* (Cth) and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) as substantially reformed by the *Environment Protection Reform Act 2025* (Cth). The NSW seabed mining ban signals that sub-national political sensitivity is already entrenched in statute.

Scientific and regional assessments strengthen the case for restraint. Dunstan et al. (2025) identify critical gaps in baseline data and risk assessment that must be resolved before serious harm can be reliably avoided, while the Secretariat of the Pacific Regional Environment Programme 2022 has called for a precautionary pause pending resolution of those gaps. Geopolitical instability in the Indo-Pacific further complicates governance and sponsoring State legitimacy (McCook & Rothwell 2024).

Australia's legal obligations, scientific institutions and regional partnerships converge on a clear conclusion: DSM should not proceed until regulatory and environmental uncertainties are resolved. As an ISA member with recognised regulatory expertise, Australia is well placed to advocate for stronger LTC accountability, improved EIA standards and binding enforcement mechanisms, while ensuring its domestic framework keeps pace with those ambitions.

6.3.1 Deep sea versus land-based mining

In terrestrial mining, environmental baselines can typically be established through dense field sampling and long-standing datasets, impacts are spatially observable and regulators can use well-developed compliance tools (site inspections, rehabilitation trials, progressive closure milestones and enforceable completion criteria) to manage uncertainties. By contrast, DSM occurs in remote environments with limited baseline knowledge, low-frequency but potentially high-consequence ecological processes and monitoring and verification challenges that make it harder to demonstrate that predicted impacts are being avoided or contained at the scales required by UNCLOS' 'effective protection' expectations.

The closure comparison is stark. Australian terrestrial regimes rely on progressive rehabilitation, measurable completion criteria and financial assurance linked to foreseeable closure liabilities (Graydon 2023). In DSM, disturbed habitats may recover only over very long timescales (if at all) and conventional rehabilitation concepts may be inapplicable. The regulatory task shifts to preventing unacceptable harm through conservative thresholds, stop-rules and long-duration post-closure monitoring with funded remedies. For

Australia, ‘best practice cannot be imported solely as domestic standards; it must be translated into enforceable international conditions. Regional legitimacy dynamics – particularly in the Indo-Pacific – should be treated as a core input to Australian policy.

7 Conclusion

This paper has examined the evolving legal and regulatory framework governing DSM, focusing on the interaction between international and domestic regimes and their capacity to balance resource development with environmental protection. The analysis demonstrates that, despite significant regulatory progress, the international governance framework for commercial DSM remains incomplete and its institutional capacity is not yet commensurate with the scale, uncertainty and potential irreversibility of environmental harm associated with seabed mineral extraction.

At the international level, substantial gaps remain within the ISA emerging exploitation regime. Critical issues – including environmental thresholds, cumulative-impact assessment methodologies, liability and compensation mechanisms, financial assurance requirements and binding closure and post-closure obligations – have yet to be fully resolved. These deficiencies are compounded by persistent concerns regarding transparency, accountability and independent oversight within ISA decision-making processes, as well as the ISA’s structurally indirect enforcement model, which relies heavily on sponsoring, flag and port States.

Recent developments between 2024 and 2026 have heightened both the urgency and complexity of DSM governance. The International Court of Justice’s 2025 climate advisory opinion is expected to reinforce due diligence and precautionary obligations under international law. Concurrently, more than 40 States have formally supported a precautionary pause or moratorium on commercial DSM pending further scientific understanding, while United States licensing activities under DSHMRA have increased the risk of regulatory fragmentation outside the UNCLOS framework.

Collectively, these developments support a precautionary sequencing approach to DSM governance. Commercial exploitation should not proceed until key preconditions are demonstrably satisfied, including scientifically defensible environmental thresholds, robust cumulative-impact assessment methodologies, independent scientific verification processes, enforceable operational stop-rules and comprehensive frameworks for closure, liability, remediation and financial assurance. Without these safeguards, the ability of States and the ISA to fulfil their obligations under Articles 145, 192 and 194 of UNCLOS remains uncertain.

For Australia, the policy challenge extends beyond a binary choice of supporting or opposing DSM. Rather, it concerns how Australia can ensure that any future position aligns with its international legal obligations and principles of effective environmental governance. With recognised expertise in terrestrial resource regulation, Australia is well positioned to advocate within the ISA for stronger transparency and accountability, scientifically robust environmental standards and enforceable closure and liability frameworks.

Ultimately, the legitimacy of any future DSM industry will depend not on the existence of mineral resources or technological capability, but on whether governance institutions can credibly demonstrate that exploitation can occur without causing serious or irreversible harm to the marine environment. Until that threshold is met, the precautionary principle remains the most legally and environmentally defensible foundation for decision-making.

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