

Why Cooperation on the Deep Seabed is Harder than on the Ozone Layer: A Comparative Analysis of Global Commons Governance

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Abstract. The deep seabed contains large reserves of metals central to the global energy transition, including manganese, nickel, cobalt and copper. How these resources are governed will shape both the marine environment and the legitimacy of international ocean governance. This paper asks why cooperation on the ozone layer succeeded under the Montreal Protocol, while cooperation on deep-seabed mining under the International Seabed Authority (ISA) appears far more contested. Drawing on the literature on common-pool resources and international environmental regimes, the paper identifies four conditions that distinguish the two cases—scientific consensus on harm, availability of viable substitutes, alignment of major economic interests, and the structural character of the resource. The ozone regime met all four; the emerging deep-seabed regime meets very few. The difficulty at the ISA is less a failure of diplomacy and more a structural feature of governing a rival common-pool resource under uncertainty and divergent interests. The comparison offers a framework for tracking which conditions may shift and how such shifts could affect prospects for cooperative seabed governance.

Keywords: deep-seabed mining, global commons, international seabed authority, Montreal Protocol

1. Introduction

There are some of the world's highest known concentrations of the metals needed for the energy transition in the deep ocean. Polymetallic nodules at the bottom of the sea contain manganese, nickel, copper and cobalt; cobalt-rich crusts on seamounts and sulfide deposits at hydrothermal vents are also rich in cobalt, zinc and rare earth elements [1]. With the increasing demand for these metals in electric vehicles, wind power and grid-storage systems, attention is now being given to whether to add seabed mining in the world's mineral supply chain.

Most of this seabed is beyond the territory of any one state. Under the United Nations Convention on the Law of the Sea (UNCLOS), it is to be regarded as the "common heritage of mankind" and is administered by the International Seabed Authority (ISA). Although the ISA signed exploratory agreements in the 1990s, there are no final rules for commercial development at present. By 2025, an increasing number of states have requested a temporary halt or cautious adjustment, and others

have proceeded with national licensing inside their exclusive economic zones or stated that they do not plan to license outside them. Thus, the governance system is under visible pressure.

The deep sea is not the first global commons in this way. The 1987 Montreal Protocol has successfully protected the ozone layer in the stratosphere, been universally ratified, and achieved measurable recovery of the ozone layer. It is a typical case of the first cooperation in environmental governance.

Based on the above, this paper examines whether the structure of the Montreal Protocol can be replicated in the context of deep-seabed mining. The answer matters for two reasons. First, it shows whether the problems at the ISA are due to diplomatic failures that can be resolved through better negotiations, or whether they are deep-seated structural issues. Second, it identifies parts of the system that will change and how such changes affect the feasibility of cooperation.

The paper proceeds as follows. Section 2 reviews scholarship on the governance of the commons, the Montreal Protocol and the ISA. Section 3 presents the empirical background. Section 4 presents a four-condition model. Section 5 applies the framework to the two cases. Section 6 discusses implications. Section 7 concludes.

2. Literature review

2.1. Global commons and international environmental regimes

Hardin's problem of incentives at the beginning of the discussion on global common resources [2] was whether individuals had an incentive to use the shared resource and whether collective interests could be pursued. Hardin believed that without property rights or other limits, rational people would use a common-pool resource too intensively. Ostrom rejected the earlier view and documented communities that managed common-pool resources (CPRs) successfully without privatisation or top-down imposition, provided certain design conditions were met [3]. According to Ostrom's framework, CPRs are goods that are rivalrous but difficult to exclude others from; pure public goods are non-rivalrous and non-excludable. The two are distinct; therefore, they are not the same kind of common resources.

Parallel literature studies when international environmental agreements have actually altered state behaviour. Mitchell integrates these ideas and identifies recurring factors—scientific consensus on the problem, availability of substitutes that reduce compliance cost, alignment of interests among major participants, and design features such as monitoring and differentiated obligations [4]. Mitchell believed that the impact of regimes was less due to legal provisions and more about the organisation of the problem and its political economy.

2.2. The Montreal Protocol as a governance reference case

A typical case of successful cooperation among the countries is the Montreal Protocol. Parson has shown how scientific data on chlorofluorocarbons (CFCs) and ozone depletion, the discovery of replacements by large-scale chemical enterprises, and the Vienna-Montreal diplomatic approach were united to create a widely ratified agreement that has phased out over 99 per cent of controlled substances [5]. Albrecht and Parker consider the protocol to be an "excellent policy achievement" and point out the three enabling conditions—a strong scientific signal, technological alternatives that reduced phase-out costs, and a configuration of state and industry interests that did not oppose the regime after the stabilisation of science [6]. Both works indicate that the protocol is not a general template, and the features for cooperation may not exist in all parts.

2.3. Research on ISA governance and deep-seabed mining

An increasing number of studies have explored whether the ISA can serve the same purpose for the seabed. Jaeckel's monograph is the most organised introduction to the responsibilities of the ISA and the use of the precautionary principle in the development of deep-sea mineral resources [7]. Recently, scholars have been studying the institutional pressures that have arisen in the Republic of Nauru after it invoked the so-called "two-year rule" in 2021, which obliged the ISA Council to consider exploitation applications without finalized regulations [8]. Singh, Jaeckel and Ardrion explore the legal routes for an ISA pause or suspension under UNCLOS [9]. Amon and others have listed the remaining scientific deficiencies and believe that the current knowledge is not yet suitable for evidence-based environmental management [10]. Collectively, the above studies have indicated a fragile situation.

3. Background: the deep seabed and its governance regime

3.1. The resources at stake

Three mineral deposits are commercially viable. Polymetallic nodules at the bottom of the ocean floor, especially in the Clarion-Clipperton Zone (CCZ) of the middle part of the Pacific Ocean, contain manganese, nickel, copper and cobalt at a depth of 4,000-6,000 metres [11]. Cobalt-rich ferromanganese crusts on seamounts have a high concentration of cobalt and rare earths. Seafloor massive sulfides at hydrothermal vents contain copper, zinc, gold and silver. As shown in the International Energy Agency's forecast, several of these metals will see an increase in demand by 2040 under a certain policy scenario due to electric vehicle batteries and electricity grids [1].

The deep-sea floor is also a high-biomass region. CCZ hosts large numbers of megafauna, and many shallow-water areas also have this feature; nodules, seamounts and abyssal hills provide various habitats for separate communities [11]. The recovery period of the damaged deep-sea environment will be long.

3.2. The UNCLOS–ISA regime

The 1982 UNCLOS set forth the various zones of the sea and their respective jurisdictions in 1994. Coastal areas have full sovereignty over the territorial sea and the exclusive economic zone up to 200 nautical miles, and other continental shelves where they apply. The seabed beyond national jurisdiction, referred to as the "Area" in the UNCLOS text, is subject to Part XI, which designates it as the common heritage of mankind and establishes the ISA to manage it.

The two purposes of the ISA are to organise and coordinate the work carried out in the Area, and to protect the marine environment from pollution. Jaeckel shows that these create an internal contradiction, and the ISA has addressed it by issuing exploration contracts and developing a separate Mining Code for commercial exploitation gradually [7]. By mid-2025, more than thirty exploration contracts have been signed with state-owned or state-affiliated entities across all major regions, and the final exploitation regulations are yet to be determined.

3.3. Recent developments

Three changes since 2021 have been applied to the ISA regime unexpectedly. First, in June 2021, the Republic of Nauru invoked the two-year rule under Section 1, paragraph 15, of the 1994 Implementation Agreement to oblige the Council to "consider and provisionally approve"

applications for exploitation within two years, whether or not there were final regulations. Singh thinks that the appeal created a tight time limit, and therefore the Council had to choose between granting it an exception or delaying in a political way [8].

Second, the Marine Biodiversity Regime has also developed simultaneously. The Agreement on Marine Biological Diversity of Areas Beyond National Jurisdiction (BBNJ Agreement), which entered into force on January 17, 2026, in line with the decision of the UN General Assembly in June 2023, has established a system for Marine Protected Areas and environmental impact assessments in the high seas [12]. The link between BBNJ and the ISA mandate is unknown, but the two systems now have overlapping areas of authority for the deep sea.

Third, several countries have begun to authorize seabed mining outside the scope of the ISA in their EEZs or through national licenses. In January 2024, the Norwegian Parliament voted to open a section of the Norwegian Sea for exploration; in April 2025, Executive Order 14285 in the United States ordered federal agencies to speed up both exploration and commercial recovery license approvals inside and outside of national jurisdiction [13]. By 2025, the number of members in the coalition calling for a precautionary pause or moratorium had increased from around 12 in 2022 to over 30. Singh, Jaeckel and Ardron say that the regime has both centrifugal and centripetal forces at the same time [9].

4. Analytical framework: four conditions for effective global commons governance

Good cooperation in the global commons is not limited to diplomacy. Combining Ostrom's division of CPRs and public goods [3] with Mitchell's research on regime effectiveness [4], four conditions appear in the successful cases.

Condition 1—Scientific consensus on the nature and scope of harm. Collaboration will be more effective if the reasons for the problems are well-known and consensus holds that human activity is responsible for these issues. Uncertainty expands the political room for delay.

Condition 2—Availability of a viable substitute. It is more feasible to form an alliance if the restricted operation can be carried out by a suitable and affordable substitute technology. Regulation has no substitute and is thus an absolute cost that strongly incentivises defection.

Condition 3—Alignment of major economic and political interests. Cooperation will be relatively easy if the leading economic powers and their main industries lack a strong material basis for opposing the regulation. Misalignment can be corrected, but it will require a higher side payment and a longer-drawn-out negotiation.

Condition 4—Structural characteristics of the resource. Cooperation is more feasible for public goods; the benefits of protection are shared by all participants, regardless of their contribution, whereas for rival CPRs, what one actor extracts cannot be taken by another [3]. Public goods have reduced the incentive for competition; CPRs have induced competition.

These four conditions are not all of them, but they are indicative. A regime that meets the above four conditions will be suitable for the foundation of cooperation, even if there are problems with diplomacy. A regime meeting infrequently is structurally prone to fragmentation, even with good diplomacy.

5. Comparative analysis: the ozone layer and the deep seabed

5.1. Scientific consensus on harm

The Montreal Protocol followed the release of new research. In 1974, it was proposed that CFCs were causing a reduction in the ozone layer of the stratosphere, and by 1985, scientists had observed the Antarctic ozone hole; this provided real-life proof of the first theory and spurred the effort to reduce emissions [5]. By the 1987 talks, most of the scientists had agreed on the reason for the cause. The next round was based on the previous evaluation and reduced the risk.

The Deep-seabed case is different. CCZ studies have reported high megafaunal diversity and slow recovery speeds, but baseline surveys are still scarce in the area under contract [11]. Drazen and others have focused the impact discussion on the seafloor, and the effects of sediment plumes from collector vehicles on midwater ecosystems several hundred to thousands of metres above the bottom have been less understood [14]. Levin, Amon and Lily have found that the uncertainties in community recovery, connectivity and downstream ecological links have not been addressed yet [15]. The first in terms of systematisation is Amon and others' gap analysis, which determined that only two out of 180 required categories of scientific knowledge for evidence-based management were necessary in any region under contract [10]. Condition 1 is satisfied for ozone and only weakly met for the seabed.

5.2. Availability of viable substitutes

The Montreal Protocol provided a replacement route that became available in the years after its signing. Hydrofluorocarbons and other alternatives to CFCs have allowed large-scale users of refrigeration and electronics to comply at a moderate cost [5]. The replacement reduced the absolute economic loss due to regulation and the political foundation for opposition.

The case of seabed minerals is relatively complicated. Demand for nickel, cobalt and copper is expected to increase multiple times by 2040 under the stated policy scenarios [1]. But cathode chemistry has moved to a lower-cobalt form, such as lithium iron phosphate, and battery recycling rates are increasing. Tunnicliffe and others do not believe that the relevant comparison is seabed mining versus no mining; rather, they believe that seabed mining should be compared with continued, better-regulated terrestrial extraction, and in this comparison, the contribution of seabed sources to addressing supply gaps is less than sometimes stated [16]. Substitution therefore exists, but it is not as complete as that for ozone. Condition 2 is well satisfied for ozone, and only partially met for the seabed.

5.3. Alignment of major economic and political interests

At the time of the Montreal Protocol, the major CFC producers, such as DuPont, had already invested heavily in substitute chemistry and agreed to a regulated phase-out. The first industrial leader and the first regulatory state moved in the same direction [5, 6]. No other industrial interests had been unified against the government.

The deep-seabed case has a divided arrangement. ISA exploration contracts have been supported by states in all the major regions, such as China, Russia, India, Japan, the Republic of Korea, Germany, France, the United Kingdom, and several Pacific Island Countries. Many sponsors have the materials to keep exploitation as an option. At the same time, more than 30 states have formed a coalition and called for a precautionary pause; some important industrial units have also withdrawn.

The national-level changes are also divided this way. In 2024, the Norwegian Storting voted to open part of the Norwegian Sea for exploration, and in April 2025, Executive Order 14285 in the United States directed federal agencies to develop both domestic and extraterritorial licensing tracks [13]. Singh, Jaeckel and Ardrøn have presented a system that includes both a centripetal force for multilateral rules and a centrifugal force towards national rules [9]. Condition 3 is met to a certain extent for ozone and barely for the seabed.

5.4. Structural character of the resource

The ozone layer is close to a pure public good; that is, all people benefit from protection regardless of whether they pay for it, and a state's ozone-friendly technology does not diminish the ozone available to others [3]. Protection is a coordination problem with a clear collective benefit, and the main risk is free-riding rather than direct competition.

Deep-seabed minerals are different. Polymetallic nodules, cobalt-rich crusts and sulfide deposits are in direct competition, and the first to extract them will deny others the opportunity. They are also too expensive to exclude given the scale of the Area. They are the prototypical common-pool resources [3]. Hardin's prediction of competitive over-exploitation is structurally more likely for CPRs than for public goods [2]. Cooperation is not out of the question, but it must be high enough to overcome the motivation to compete and not just to free-ride. Condition 4 is met for ozone, but it does not occur at the seabed.

5.5. Summary

All four conditions were met for the ozone regime in 1987, and at most one of the four conditions for the ISA regime in 2025 meets full requirements (Condition 2, only partially). Table 1 is the comparison.

Table 1. Four conditions applied to the two cases

Condition	Ozone (Montreal Protocol, 1987)	Deep seabed (ISA regime, 2025)
1. Scientific consensus on harm	Strong; supported by 1985 ozone-hole evidence	Weak; major gaps in baseline and impact knowledge
2. Availability of viable substitutes	Strong; HFCs and related substitutes available	Partial; recycling and chemistry shifts emerging
3. Alignment of major interests	Strong; leading industrial actor aligned	Weak; sponsoring states and pause coalition divided
4. Structural character of resource	Public good; protection benefits all	Common-pool resource; extraction is rival

Based on the above comparison, the problems at the ISA are not primarily due to a lack of diplomatic skills. They are due to some other reasons.

6. Discussion: implications for the ISA regime

Three implications follow for the ISA regime.

First, it will change the connection among the multilateral and the national. National licensing decisions in the Norwegian Sea in 2024 or under Executive Order 14285 in the United States in 2025 [13] are better understood as manifestations of structural pressure rather than causes of regime

fragmentation. When Condition 3 is only weakly met and Condition 4 is structurally absent, states with material interests are highly motivated to keep the national option open.

Second, it finds what changes in these conditions. Condition 1 is the most feasible—continuous scientific research and study of the effects on midwater environments at a base level can reduce uncertainty over the next ten years [14]. Condition 2 is partially endogenous to the energy transition—changes in battery chemistry and recycling capacity will alter the demand for cobalt and nickel at the same time [1, 16]. Conditions 3 and 4 are more difficult to move. Condition 4 is fixed by the physical attributes of the resource. Condition 3 responds to economic and political shifts that the ISA cannot control.

Third, the comparison reduces the feasible choices for the ISA. Singh, Jaeckel and Ardron have identified several legal ways to obtain a precautionary suspension under UNCLOS [9], and Albrecht and Parker have shown that the adaptive mechanisms in the Montreal Protocol—including periodic scientific assessments, differentiated obligations and a multilateral fund—have all been necessary for its extended success [6]. The deep-seabed regime will not be able to achieve all of these characteristics in time, but standing scientific advisory bodies and more explicit rules for the ISA-BBNJ arrangement are within reach. None of the above would solve the problem of the underlying CPR structure, but they could slow down fragmentation and preserve the multi-cornered nature of the system under Conditions 1 and 2.

Applying the ISA to the standard of the Montreal Protocol may misunderstand both systems. The ozone case was an easier problem than its diplomatic success made it look. The seabed case is, by the same standard, a harder problem than its diplomatic difficulty makes it look.

7. Conclusion

This paper has inquired why cooperation for the ozone layer has been relatively successful so far, but cooperation in deep-sea mining seems to be facing many more difficulties. Based on the literature for common-pool resources and international environmental regimes, a four-condition framework has been established to compare the two cases—scientific consensus, substitute availability, alignment of major interests, and resource character. The ozone regime meets all four, and the ISA regime meets at most one in full. The reasons for the different diplomatic abilities are not due to poor foreign-country relations.

The framework has three limitations. Only two cases are compared, risking overfitting. The four are considered independent unless they are linked. It is based on secondary literature and does not contain original data of the ISA negotiations. Future research could extend the comparison to other ocean regimes, such as regional fisheries management organisations and Antarctic Treaty arrangements, to determine whether the same four conditions distinguish between successful and contested cases.

Although there are some constraints, it is clear from the comparison that this regime would be closer to the ozone regime. Two conditions, scientific consensus and substitute availability, will be partially realised in the next decade. The other two are not. There is an asymmetry that imposes a feasible upper bound on the results of cooperation, and it is estimated that, even with good diplomatic relations, the current system will be plagued by structural defects.

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