

Deep Seabed Mining:

Environmental Risks, Social Consequences, Responsible Governance

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Cover photo: A coastal community disproportionately affected by the negative impacts of deep seabed mining (photo by istock).





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Executive Summary

The emergence of Deep Seabed Mining (DSM) presents a formidable governance challenge with far-reaching environmental, ethical, and institutional implications. At the centre of this debate, the International Seabed Authority (ISA) is charged with managing the seabed beyond national jurisdictions as the common heritage of humankind. However, the ISA faces a growing legitimacy crisis driven by a profound lack of consensus among member states, scientists, and civil society actors concerning the risks and regulatory shortcomings associated with DSM.

We examine the institutional dynamics of the ISA and its ability to reconcile its dual mandate: enabling mineral exploitation while safeguarding the marine environment. Drawing on interviews with stakeholders — including ISA officials, scientists, and NGOs — the analysis reveals deep governance gaps, particularly around transparency, accountability, public participation, and the application of the precautionary principle. Decision-making structures often marginalize affected communities and observers, raising credible concerns over conflicts of interest and the erosion of the “common heritage” ideal under pressure from state and corporate actors.

Our findings contribute to a growing call for a moratorium on DSM until these governance and scientific gaps are meaningfully addressed. This position aligns closely with several United Nations Sustainable Development Goals (SDGs): SDG 14 (Life Below Water), by promoting the conservation and sustainable use of ocean resources; and SDGs 16.6 and 16.7, by advocating for more effective, transparent, and inclusive institutions and decision-making processes at all levels.

Ultimately, the study underscores that legitimate global governance of shared environmental resources hinges on robust safeguards,

participatory mechanisms, and science-based policy. Without these, institutions risk capture by narrow interests and the possibility of irreversible ecological harm. Reforming the ISA is not only a matter of environmental urgency — it is essential to upholding principles of justice, sustainability, and global cooperation.

Background

Deep Seabed Mining (DSM) is an emerging activity that aims to extract valuable mineral resources from the seabed at depths exceeding 4,000 metres. Although still in its early stages, this practice has captured global attention due to the growing demand for critical metals essential for modern technologies (like electric cars and energy generators) and the energy transition. It has sparked an intense debate and concern over its potential environmental impacts and the lack of a robust regulatory framework.

WHAT IS DSM, AND WHAT ARE COMPANIES TRYING TO EXTRACT?

When speaking of the extraction of minerals from the deep sea, people typically refer to three main types of deposits containing significant reserves of copper, cobalt, nickel, zinc, silver, gold, and rare earth elements. These deposits are polymetallic nodules, polymetallic sulfides, and the cobalt-rich ferromanganese crust, from which polymetallic nodules are at the centre of the current controversies and possess most of these minerals. Although they are composed of many minerals, they are sought for their rich contents of manganese, nickel, copper, and cobalt.¹

Polymetallic nodules are potato-sized rocks, mostly between five and ten centimetres in diameter, lying on the abyssal plains of the deep sea, normally between 4,000 and 6,000 metres under the surface of the ocean, half buried.

1 The polymetallic nodules are composed of 29% manganese, 1.4% nickel, 1.3% copper, and 0.25% cobalt. “Polymetallic Nodules,” ISA, 2022. [↗](#)

Polymetallic nodules form through a very gradual process of metal precipitation from seawater into a nucleus (a shark tooth, a rock, or a piece of debris) or an existing polymetallic nodule. This process is extremely slow, with growth rates of just a few millimetres per million years!

The largest nodules (up to 20 centimetres in diameter) can be tens of millions of years old and are predominantly found in regions with low sediment accumulation, which prevents them from being buried over time. One of the most notable of these regions is the Clarion–Clipperton Zone (CCZ) in the Pacific Ocean, located between Hawaii and Mexico.² It contains more nickel, cobalt, and manganese than the entire world’s terrestrial reserves.³ These nodules can vary in their contents and grades of mineral purity depending on the area of the sea in which they are found.

The extraction of these nodules has been tested since the 1970s, on several occasions for research purposes, but the viability of commercial mining has not been explored for multiple reasons. One is that the technology to extract them commercially was not available until recent years because of the deep sea’s conditions, such as high pressure, absence of light, and low temperatures. The CCZ is estimated to contain up to 30 billion metric tonnes of nodules with an estimated value of USD 18.4 trillion. Thus, mining companies have invested time and money in investigating and developing new technologies for their extraction rather than in extracting the materials.⁴

Most current deep-sea mining projects plan to use remotely operated vehicles (ROVs) equipped with suction and dredging systems to collect the nodules from the seabed. These are connected to “riser systems,” vertical pipes

that pump the nodules to the surface using hydraulic or mechanical power. One example is GSR’s *Patania II*, a tracked vehicle with systems for collecting nodules, separating them from sediment, and monitoring operations. This increase in interest has resulted in technology evolving quickly. For instance, Impossible Metals’ *Eureka II* uses robotic claws instead of suction, combined with artificial intelligence to identify and avoid nodules hosting marine life. This approach produces fewer sediment plumes and aims to minimize harm to deep-sea biodiversity.⁵

Even so, this process is also extremely harmful. In interviews we heard that what selective harvesting really does is avoid big nodules. One interviewee told us “that level of sediment, according to their consultancy report, would be 23,000 times the natural sedimentation rate. No organism is going to be able to survive being smothered at 23,000 times the natural rate ... That’s what they’re adapted to. But also, selective harvesting is actually not selective. What it selects for are the very large nodules.” Although the technologies for the commercial extraction of nodules already exist, companies still have to acquire the licenses to proceed legally with commercial mining.

THE ISA

As established in part VI of the 1994 United Nations Convention on the Law of the Sea (UNCLOS), each state party has jurisdiction over its national waters. The extent of these national waters is, in most cases, 200 nautical miles starting from the coast. Everything within this space is called the Economic Exclusivity Zone (EEZ), considered part of the state and thus its property. This also means that national laws apply in the EEZ as do programs for DSM exploration and

2 Other theories might explain how the nodules came to be in the deep sea. See “Polymetallic Nodules,” ISA.

3 “Polymetallic Nodules.”

4 See “Seabed Mining: A \$20 Trillion Opportunity,” Arthur D. Little. [↗](#)

5 Andrew Chin, Katelyn Hari, and Hugh Govan, “Predicting the Impacts of Mining Deep Sea Polymetallic Nodules in the Pacific Ocean: A Review of Scientific Literature,” Deep Sea Mining Campaign and MiningWatch Canada, May 2020. [↗](#)

regulation.⁶ Most of these programs have not been successful.

Papua New Guinea's *Solwara 1* Project, the first DSM commercial project, failed for many reasons: opposition by nearby communities and NGOs, criticism of their environmental impact assessment, and financial defaults on payments. Nautilus Minerals, a Canadian company, went into bankruptcy in 2019, and the government lost CAD 120 million. Papua New Guinea called for a ban on deep-seabed mining, while Fiji and Vanuatu imposed a ten-year moratorium on DSM.⁷

However, most of these resources that mining companies seek are found in Areas Beyond National Jurisdiction (ABNJ), governed by international law. The International Seabed

Authority (ISA) is the United Nations body responsible for overseeing exploration, regulating activities, and granting access to these seabed resources. Established under

Part XI of the 1994 UNCLOS agreement, the ISA advocates that "the Area" (ABNJ) and its resources constitute the common heritage of humankind. Since it was established to regulate the exploration and exploitation of mineral resources that the ABNJ possesses, the ISA's principle on the common heritage of humankind emphasizes equitable benefit sharing and the sustainable management of resources for the welfare of all nations and future generations, with particular attention to developing countries' needs.

The ISA's organizational structure consists of the assembly, composed of 168 members, and the EU, which is the ISA's highest decision-making

body, though most responsibilities fall to the council and its commissions. The council, with 36 geographically and economically representative members, grants licenses and drafts regulations. The ISA also includes 119 nonvoting observers, such as states, NGOs, and UN organizations.

ISA'S ORGANIZATIONAL STRUCTURE

The assembly includes all 168 members as well as the EU and functions as the ultimate decision-making entity. It is responsible for approving budgets, adopting rules and regulations, and overseeing the general distribution of benefits derived from the Area. However, other components of the ISA undertake the majority of these actions and responsibilities, mostly falling under the council and its commissions.⁸

The council implements decisions made by the assembly. With 36 members elected based on geographic representation and economic interests, the council is responsible

for granting exploration and exploitation licenses and drafting operational regulations as requested by the assembly. ISA has 119 observers, including states, NGOs (59), and UN intergovernmental organizations; they can join public meetings but cannot vote. For this research, we conducted interviews with ISA members and NGO representatives.

ISA'S PRINCIPLES AND RESPONSIBILITIES

Part XI of UNCLOS defines the ISA's main responsibilities, which are central to understanding its mandate: organizing and overseeing activities in the Area among member

The ISA's principle on the common heritage of humankind emphasizes equitable benefit sharing and the sustainable management of resources for the welfare of all nations and future generations

6 "United Nations Convention on the Law of the Sea." 

7 The Solwara project has served as a case study on DSM on a national scale. See "The First Deep-Sea Mining (DSM) Project in Papua New Guinea," Source International. 

8 "Organs — International Seabed Authority," ISA, 21 January 2025. 

states, administering resources, granting and monitoring exploration and exploitation contracts, promoting marine scientific research, facilitating technology transfer between states, and ensuring the equitable distribution of benefits from these activities. These responsibilities were a recurring topic in the interviews, with several participants questioning whether the ISA has been effective in fulfilling them.

The ISA faces an important dual mandate: it is tasked with protecting the marine environment — a primary

concern given that the Area and its resources are considered the common heritage of humankind — while at the same time developing frameworks, such as the ongoing Mining Code, to enable the commercial exploitation of those same seabed resources.

These are the main responsibilities and principles ISA has to follow under UNCLOS regarding the Area:

- No one can claim sovereignty over the Area and its resources.
- States are liable for damages to the Area.
- Mining activities in the Area are to be carried out for the benefit of humankind.
- The Area shall be exclusively used for peaceful purposes.
- Benefits from mining in the Area are to be shared equitably.
- Necessary action shall be taken to ensure the effective protection of the marine environment from the harmful effects of mining.
- The effective participation of developing states shall be promoted.

Less than 0.01 per cent of the deep sea, its species, or its interactions within the ocean ecosystem have been explored.

ISA'S LICENSES AND DECISION MAKING

The ISA can give both exploration and exploitation contracts for resources in the Area. These are granted to members or “sponsor states” of private sector actors. So far, ISA has granted 31 exploration contracts, 19 for polymetallic nodules.

No exploitation contracts have been granted because regulations for seabed mining have not yet been finalized. In 2021, Nauru invoked

the “two-year rule” under UNCLOS, requiring the ISA to establish exploitation regulations within two years. Although the deadline passed in 2023, the rules are still under discussion and remain in draft form, facing strong opposition from 32 states calling for a moratorium, as well as from marine scientists, NGOs, coastal communities, and even some companies such as Volvo and Samsung.

There is a general agreement among interviewed stakeholders that commercial exploitation of the deep sea should not proceed under current conditions because of limited ecosystem knowledge, the potential for significant environmental harm, and uncertainty regarding economic viability. This position is rooted in the fact that less than 0.01 per cent of the deep sea, its species, or its interactions within the ocean ecosystem have been explored.

The ISA has decided to interpret the provisions in UNCLOS of the two-year rule by taking into consideration contractors’ applications for exploitation licenses but not necessarily accepting them until the regulations are adopted.

Today, an ongoing debate continues regarding the conditions under which commercial DSM should happen, and even if it should be permitted at all. The ISA’s Legal Technical Commission is currently drafting the Mining Code, even while the ISA’s transparency is being questioned. Observers

are formally included in the decision-making process, but their concerns are often disregarded.

Lack of Information

During the 1990s, the word *transparency* became important in many international organizations' codes of conduct and norms, such as fisheries and the Food and Agriculture Organization of the United Nations (FAO). This was not the case for the ISA, where openness and public access to information were not a priority. A review of ISA documents from 2000 to 2013 by Jeff Ardron found that the concept was barely mentioned, or else entirely absent, in the organization's legal framework.⁹ In our recent interviews with ISA personnel, several dismissed any suggestion of a transparency gap, with one of them stating that "the ISA is the most transparent of all UN bodies currently in operation." This view, however, contrasts with that of interviewees outside the ISA, who generally perceive a lack of transparency in the organization.

One of our interviewees, a recognized oceanographer with expertise on the scientific and governmental discussion surrounding DSM, spoke about governance and transparency within the ISA: "The ISA will have to transform itself to become a regulatory authority. It is not currently a regulatory authority. It does a very poor job of regulating the contractors right now ... If it goes into the exploitation stage, it will have to set up proper regulatory, control, surveillance, and enforcement mechanisms. And it has none of that right now."

When asked about what the ISA could bring in terms of regulation and governance, our interviewee responded: "It's just a typical UN body populated by diplomats. Diplomats are not enforcers; diplomats are not managers. So,

the ISA would have to reinvent itself completely and at least make a dedicated body that would be for monitoring, control, surveillance, and enforcement, which it doesn't have right now."

This perspective was not uncommon among the interviewees. Many believed that if the ISA intended to enforce the law and regulate the exploitation of the marine seabed soon, their capacity to do so is nonexistent, and that proceeding with such little care with the approval of any exploitation code would be a reckless decision.

Although ISA officers and personnel often disagreed with (and perceived as attacks) the statements questioning the organization's ability to ensure transparency and provide information, they acknowledged that there is currently insufficient regulatory capacity and limited knowledge of the marine seabed to make DSM a reality. They also noted that discussions among the various actors involved — states, observers, scientists, and ISA staff have been, to say the least, highly polarized.

A representative from an ISA member state remarked: "The truth is that the ongoing discussion is very heated, something that we can observe in the huge distance between the positions of scientists, activists, and observers within the ISA ordinary sessions, and the officers and specialists who work in the Assembly and the Legal-Technical Commission of the ISA."¹⁰

There is a clear gap between the legitimacy claimed in official statements and the reality of the decision-making process. Observers — including scientists, activists, and NGOs — often disagree with ISA technicians and officials on whether the potential impacts of deep-sea mining are being adequately considered. In many cases, they question whether drafting a mining code should even proceed. These concerns become

9 Jeff A. Ardron, Henry A. Ruhl, and Daniel O.B. Jones, "Incorporating Transparency into the Governance of Deep-seabed Mining in the Area Beyond National Jurisdiction," *Marine Policy* 89 (2017): 58–66. [↗](#)

10 "The Assembly — International Seabed Authority," International Seabed Authority, 26 September 2024. [↗](#)

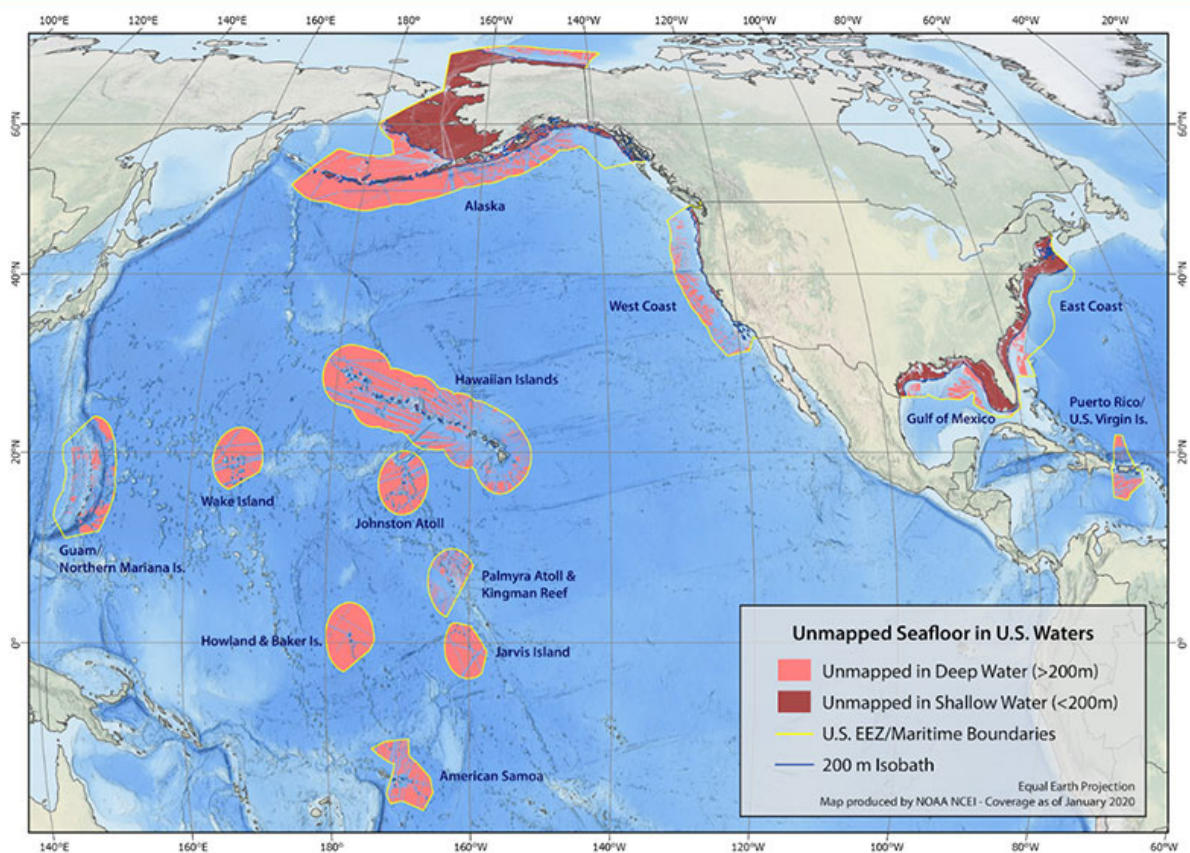


FIGURE 3. This map shows the boundaries of the U.S. EEZ, outlined in yellow, as well as deep and shallow water areas of the U.S. EEZ that have not been mapped as of January 2020. Map created by NOAA's National Centers for Environmental Information" (retrieved from [\[link\]](#))

particularly relevant in the context of agreements between nations and contractors seeking to exploit deep-seabed resources, as observers perceive that current mechanisms are insufficient to ensure a regulated and transparent process.¹¹

Transparency challenges are often present in issues such as land jurisdiction, fiscal responsibility, investment, and project sustainability, making effective monitoring difficult. The ISA holds a high level of responsibility for safeguarding the health and future of the international seabed. Therefore, it should seek to strengthen its capacity to sanction actors who cause damage or withhold knowledge obtained under the terms of the exploration code before even considering exploitation as a possibility. Ultimately, the ISA's

"common heritage of humankind" principle calls for equitable benefit sharing and the sustainable management of resources for the benefit of all nations and future generations, with particular attention to the needs of developing countries.

Perception of Risk, Lack of Trust, Governance, and Consent

Another highly problematic issue is the lack of trust between nonstate observers and the ISA regarding the usage of the marine seabed and its resources. The UNCLOS/ISA framework is

11 Ibid.

state-centric, leaving coastal and Indigenous communities with no formal role in ISA decision-making processes. The current guidelines do not require states to consult their local communities or integrate traditional knowledge and social impact assessments before sponsoring contracts. Although the ISA does include observers in its sessions as a way to consider different perspectives and suggestions, observers (typically nonstate actors) don't possess any capacity to influence the final decision-making process — they can't vote on the sessions, since states are the only actors capable of voting.

The recognized oceanographer who we previously mentioned spoke about this situation:

Even when you know what the ISA is doing, and even when they list the comments received from stakeholders, as they did back in 2016, you never find out if they considered them when taking action. They were transparent, but not accountable. And that's an important link in any transparency process. Transparency without accountability is, frankly, frustrating. People will lose motivation if their participation is not taken into account.

One of the ISA officials gave a reason for why this may be the case:

There are organizations that are confused about which stage we are in. At this moment, we are negotiating a legal text ... Some people are confusing a legal document with a policy itself, and that is different. Public policies will be applied once the legal text is finalized. There is concern from scientists and NGOs who wonder why their proposals are not being included, but in reality, their proposals are public policy matters that will be applied later on in the Standards and Guidelines, which is where those issues should be established.

Another interviewee, a prominent member of a

Pacific Island nation NGO who advocates for the prohibition of deep-sea mining, described ISA meetings like this:

Well, at the ISA, we sit as observers — a collective group alongside numerous other NGOs and members of the private sector. We have very limited time to provide any input into the discussions taking place on the floor. But when it comes to how much of our participation is actually considered compared to that of the states ... Those are issues we've had with the ISA. They have this dual responsibility of collecting environmental data while also drafting regulations at the same time. We try to raise awareness about our concerns with the ISA, but when it comes to making actual changes within the organization, it ultimately comes down to the states — they hold the power.

In practice, coastal communities are excluded from meaningful participation; though they can apply as observers to the ISA's meetings, they have no guarantee of being accepted. To have some degree of influence, these communities and NGOs that represent them have resorted to lobbying states to gain their support.

A member of an important NGO described how, "As in any UN-level conference, there is a lot of lobbying taking place ... Civil society has managed to bring some important aspects to the table for discussion." Another Indigenous community and NGO member also said "Observers do a good job at lobbying states as well to feed in some of the information that observers would like to get tabled on the floor. That is some of the power of observers and ourselves. Rubbing our shoulders with states to table some of what we want on the floor."

Their exclusion is especially troubling given that many coastal populations depend heavily on ocean resources, making the matter of not having any vote an obstacle to their voice on the matter.¹²

¹² Ibid., 7–8.

Also, coastal groups have few formal channels to influence ISA policy. They have responded by forming coalitions or launching NGO campaigns, such as Pacific advocacy networks and fishermen's alliances, to pressure their governments and ISA members. In a few instances, communities have sought legal recourse. For example, some groups in Papua New Guinea have sued their government for access to details of a deep-sea mining license. However, these legal actions occur outside the UNCLOS/ISA framework since the ISA itself lacks a mandate to engage directly with nonstate stakeholders.¹³

Empirical studies on mining and oil projects confirm that coastal Indigenous groups most often bear the brunt of negative social impacts from resource extraction. Terrestrial impacts linked to deep-sea mining — such as the construction of ports and processing plants — can lead to habitat loss and increased housing costs, disproportionately affecting shoreline villages. A UN analysis of Pacific Island States' concerns indicates that the impacts of deep-sea mining are "expected to be felt disproportionately" by these communities, with one report warning that mining "may limit or prevent the harvesting of living marine resources upon which their livelihoods depend."¹⁴

No matter how efficient the ISA practices become internationally, if local-level authorities do not have the necessary strength to support international efforts for institutional strengthening, these efforts will have a diluted impact and will be insufficient to address the potential impacts like those that terrestrial mining has. Furthermore, it seems that the ISA won't grant any voting rights or decision-making capacity any time soon to Indigenous and coastal communities that appoint observers within the ISA, and it seems very likely that this exclusion will continue for decades to come. Therefore, if communities seek to draw

attention to the issue, their most viable choice is to raise their voices through petitions on platforms such as Change.org or Avaaz: organized civil society seems to be how they'll be able to effectively force states and the ISA to consider them within the larger DSM framework.

About Our Research

We conducted 17 semi-structured interviews with policy experts, marine scientists, ISA members, and NGOs that represent coastal and Indigenous communities with the intent of gathering a diverse set of views on the ISA as regulator, its transparency, the impacts of deep seabed mining (DSM), and the involvement of coastal communities in decision-making processes. Through this we identified mostly similar opinions regarding most of the topics relevant to the interviews.

TRANSPARENCY OF THE ISA

Most of the people we interviewed have a similar perspective regarding the ISA's lack of transparency, often referring to the relationship between the ex-secretary general and the companies that seek exploitation contracts. Some of the subjects even went as far as pointing out alleged corruption inside the ISA. The only interviewees who considered the institution transparent enough were members of the ISA itself. They mentioned that all the data are publicly accessible, explaining that the ISA does public consultations, actively publishes research, holds webinars to inform people, publishes draft regulations and other legal documents, and shares other relevant information. Another common comment was regarding the importance of establishing effective protections for whistleblowers and preventing conflicts of

13 Klaas Willaert, "Public Participation in the Context of Deep-sea Mining: Luxury or Legal Obligation?" *Ocean and Coastal Management* 198 (2020): 105368. [↗](#)

14 Masato Abe, Faradh Maharoof, and Mohab Eldacrory, "Policy Implications in Deep-Sea Mining: Opportunities and Challenges for Kiribati," United Nations Micronesia Working Paper Series no. 2, UN Micronesia, 2025. [↗](#)

interest among ISA members. According to the interviewed members of the ISA, there is due diligence for there to be no conflict of interest.

PRECAUTIONARY PRINCIPLE

None of the interviewees denied that DSM would cause inevitable damage to the deep-sea ecosystem, and all of them declared that no one is certain about the amount of the potential damage or the effects that DSM could have on the ocean and its biodiversity. Interviewees generally agree that the ISA should act following the precautionary principle and should not permit DSM, at least not until the effects are understood and can be properly controlled.

However, some of them (activists from NGOs, scientists, and representatives of coastal communities) suggested that the ISA has the duty of “effectively protecting the environment,” and as such, cannot allow DSM to happen. They advocate for a permanent ban on such activities.

VIABILITY OF DSM AND ALTERNATIVES TO IT

Some of the subjects discussed the economic viability of the extraction process of polymetallic nodules and the minerals they contain. They mentioned that demand for these minerals currently does not even exist, and in fact, is a narrative pushed by the mining companies to attract investors. As evidence of this, one of the interviewees mentioned that the biggest mining companies are not invested in DSM for a reason; it is neither reliable nor needed. Participants mentioned that these minerals won’t be required for decades from now, if ever, and new energy sources that do not need these minerals will likely exist in the future.

INDEPENDENT RESEARCH

There’s a strong desire from the scientific community and from NGOs to encourage independent research. Much of the research

about DSM is done and pushed by ISA or with the support of contractors. For this reason, they advocate for more independent research with no interests at play.

GENUINE COMMUNITY PARTICIPATION

Other than the members of the ISA, who base their decision-making and consultation process on a state-centric view, especially in the drafting of regulations, all the interview subjects shared a similar perspective on the involvement of coastal communities and NGOs in the decision-making process. They agree that the ISA does allow observers to participate in meetings and submit comments, but they stress that these comments are not considered or translated into tangible results. In this sense, observers are in the ISA as a “checkbox.” They also believe that the communities that might suffer from the first negative effects of DSM (such as coastal communities) should be involved in the discussions directly, with one of the participants saying that the peer community should be extended to other stakeholders when the scientific knowledge is insufficient (i.e., in scenarios of inherent uncertainty).

ISA STRENGTHENING

All ISA members we spoke with recognized the ISA’s critical role as the regulator of DSM, pointing out the structural deficiencies of the organization at different levels. Some of them mentioned that the ISA is deficient and does a poor job as a regulator of the current contractors.

Hard to Reach: An Unexplored Ecosystem

For a long time, the ocean floor was thought to be a lifeless place, but today we know it is one of the most diverse and fragile habitats on the planet. Its ecosystems, like hydrothermal vents and

seamounts, are home to unique species, many of which have yet to be studied.¹⁵ These organisms live in extreme conditions — total darkness, high pressure, and very low temperatures. Activities like nodule mining directly destroy these habitats, disrupting the balance of ecosystems that have evolved over millions of years.

Since polymetallic nodules take millions of years to form, their removal would cause a permanent loss of marine

habitats; species that live attached to these nodules —

such as sponges and corals — along with those that depend on them, would face a direct threat of extinction. Research shows that mining radically alters the composition of sea floor communities, reduces microbial biodiversity, and disrupts essential ecosystem functions. As one expert explained,

Those nodules are home to, well, a vast array of species because they're the only solid surface on the bottom of the sea floor. And so they become the feeding grounds, the spawning grounds, the sort of harbour for lots of different organisms. And it's actually the micro-organisms that may be arguably the most important for ocean chemistry and planetary balance, because those micro-organisms, which the nodules, of course, would harbour millions of, play crucial roles in marine chemistry.

In 1989, the Disturbance and Recolonization (DISCOL) experiment was conducted to assess the environmental impacts and risks of industrial-scale DSM for polymetallic nodule extraction. The experiment took place within a two-nautical-mile-diameter area near a German mining concession, about 1,000 kilometres off the coast of Peru and Chile in the South Pacific. It simulated mining activities using an eight-metre-wide “plough-

harrow” to remove nodules and disturb sediment structures. Nearly 30 years later, scientists from the National Oceanography Centre (NOC) revisited the site and confirmed that the seabed marks and impacts on marine life remained evident.¹⁶ In other words, the recovery of these ecosystems is extremely slow and may never occur.

Studies predict that a single mining operation could discharge up to 50,000 tons of sediment-laden water per day and may disturb between 300 and 800 square

kilometres per year, with impacts spreading over an area two to five times larger as a result of suspended sediment deposition.

These disturbances are not limited to machinery on the sea floor; impacts are also evident at the surface and midwater column. There are impacts at all levels, from the surface to the sea floor:

- **Surface.** Presence of vessels and semi-permanent support platforms, surface discharges, noise, and light pollution.
- **Midwater column.** Disturbances caused by vertical riser pipes, discharges, water and waste processing, and vertical movement of extraction equipment.
- **Sea floor.** Physical disturbance and habitat alteration from mining equipment, noise and light pollution, sediment displacement, and extraction of polymetallic nodules.

What's known is what could be affected, but what remains uncertain is how. It's uncertain how mining could alter food chains in the open ocean, interfere with the daily movements of species that migrate up and down the water column, or disturb the feeding and movement patterns of fish that rely on deep-sea prey, such as tuna. There is also a limited

What's known is what could be affected, but what remains uncertain is how.

¹⁵ Hydrothermal vents are seabed fractures from which mineral-rich geothermal waters emerge. They have their own ecosystems. Seamounts are isolated volcanic elevations on the ocean floor with unique biological communities.

¹⁶ National Oceanography Centre, 2019; Hjalmar Thiel, Gerd Schriever, Ahmed Ahnert, et al., “The Large-scale Environmental Impact Experiment DISCOL — Reflection and Foresight,” *Deep Sea Research Part II Topical Studies in Oceanography* 48, no. 17–18 (2001): 3869–82. [↗](#)

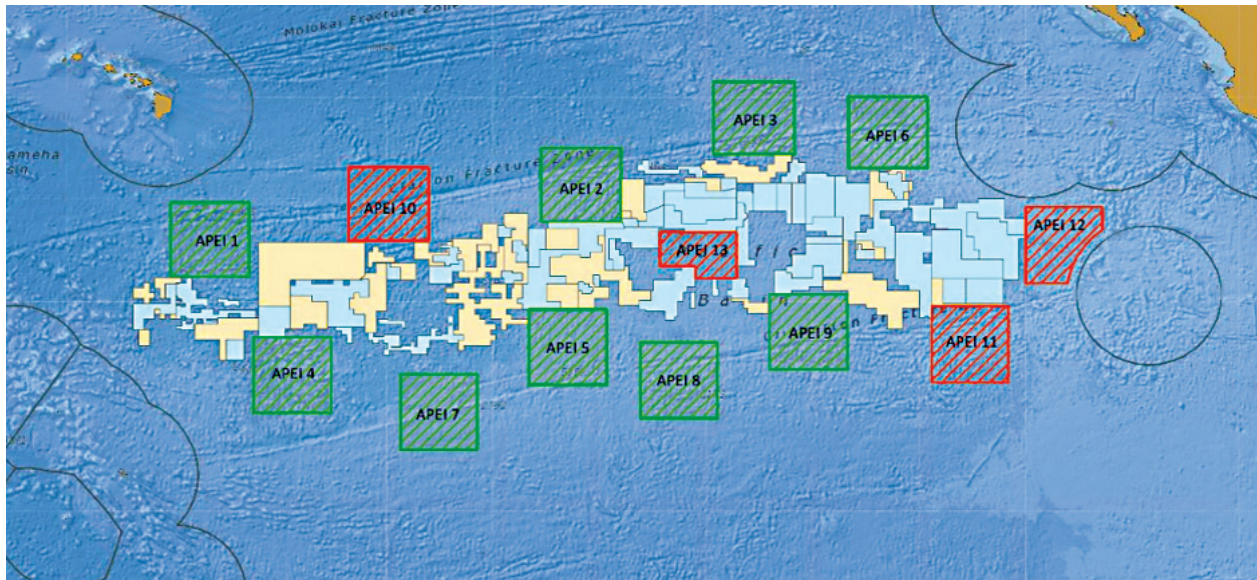


Figure 2. Thirteen areas protected from deep-seabed mining in the environmental management plan for the Clarion-Clipperton Zone (retrieved from [\[link\]](#))

understanding of how artificial light and noise from mining activities might affect deep-sea animals.

Studies in the CCZ have recorded more than 330 species in an area of just 30 square kilometres, half of which were previously unknown. The loss of these species could have irreversible ecological consequences, including impacts on ecosystem functions such as carbon sequestration, whose dynamics on the sea floor remain poorly understood.

An international law expert and member of the Mexican Foreign Service, currently serving as chair of the ISA's Legal and Technical Commission, clarified that within the CCZ there are nine "areas of particular environmental interest (APEI)," which were designated to protect the biodiversity, structure, and performance of the ecosystems in that region.¹⁷ He claims that if exploitation were to occur, it would be in a minimal percentage of the Area, since these APEIs are protected from future mining exploitation activities.

While this designation of APEIs represents an important regulatory step to safeguard

biodiversity, questions remain about whether these measures are sufficient. From our perspective, the protection of ecosystems and the prevention of irreversible environmental harm must remain the foremost priority. It is necessary to recognize that political and economic interests shape how regulations are implemented. Striking a balance between ecological preservation and economic pressures is, therefore, one of the most pressing challenges for the ISA. Deep-sea mining must not proceed without a deeper understanding of what we are dealing with to prevent each of the possible consequences.

One ISA official holds another view. "If there aren't sufficient studies, how do you reach the conclusion that it's devastating? To have more data, you need more exploration, and eventually you're going to need exploitation. Then you'll have data to determine whether it's devastating or not."

FOOD SECURITY, FISHERIES, AND LIVELIHOODS

Fishing, particularly tuna fishing in the Pacific, is an essential source of food, employment, and cultural

17 "Environmental Management Plan for the Clarion-Clipperton Zone," International Seabed Authority, March 2023. [\[link\]](#)

identity for island communities. In 2018, its value reached USD 6 billion, representing a significant portion of many Pacific economies' gross domestic product. DSM places these activities at risk. While limited scientific data on DSM processes hamper a precise evaluation of the risks to commercial fisheries and food security, experts warn that noise and light pollution can significantly disrupt fish behaviour, and toxic metals from mining waste can be ingested by marine organisms and accumulate through the food chain. Tuna avoid turbid waters, so sediment plumes could alter their movement patterns and, consequently, negatively impact fishing communities.¹⁸

Still, there's a significant lack of research on the bioaccumulation of metals and the ecotoxicity of DSM on surface marine food networks. However, metal contaminants in shallower waters could likely be ingested by organisms and subsequently transferred along food chains, potentially affecting commercially fished species and, ultimately, human consumers. While the impacts on fisheries may be immediate, the consequences of deep-sea mining may never be fully observed or understood.

Social Impacts: Cultural Overview

Some argue that DSM may not directly affect coastal communities because many of the exploitation operations are planned to be done in remote areas like the CCZ, far from inhabited territories and current fishing zones. However, this overlooks broader ethical, cultural, and economic dimensions. For instance, the Law of the Sea

contains no provisions regarding social justice, nor does it acknowledge whether it should.

We need to understand and acknowledge how interconnected the ocean is with everything we see — how, throughout millions of years

The destruction of marine ecosystems signifies an erosion of the cultural heritage and spiritual practices of many Indigenous and coastal communities.

of evolution, it allowed life on land to maintain its balance — and how complex the deep-sea environment is, and how it has been

historically separated from humanity. This has led to governance systems that fail to account for the social risks of DSM.

Cultural concerns in the Pacific Islands are not isolated; the ocean is more than a space for resources or economic opportunity; it is part of the community's sense of self. For many, the sea is considered an ancestor, a provider, and a living presence. DSM is not perceived as "just" a disruption of nature but as a violation of cultural integrity and collective memory. The destruction of marine ecosystems signifies an erosion of the cultural heritage and spiritual practices of many Indigenous and coastal communities.

Experiences with terrestrial mining in the Pacific show that cultural losses can often be irreversible and much more difficult to repair than even physical environmental damage. The *Solwara 1* project near Papua New Guinea illustrates these concerns. It met with extensive opposition by the alliance of the Solwara Warriors, a coalition of communities, church leaders, and civil society actors. In the words of a local chief opposing *Solwara 1*, "When they start mining the seabed, they'll start mining part of me."¹⁹ This reflects how deeply intertwined land and sea are for human existence.

Governance gaps and challenges persist. The ISA has faced criticism for advancing regulations

¹⁸ Chin, Hari, and Govan, "Predicting the Impacts of Mining," 3–6.

¹⁹ John Childs, "DSM Threatens Indigenous Culture in Papua New Guinea," *The Conversation*, February 2019. [↗](#)

rapidly without robust environmental and social baselines. The EU-funded MIDAS project, which took place between 2013 and 2016, emphasized the need for precautionary approaches, citing the lack of technological, ecological, and socioeconomic assessments necessary for responsible decision making.²⁰

Environmental and social impact assessments (ESIAs) also often fail to recognize non-economic values like cultural heritage, spiritual meaning, and traditional ecological knowledge. For example, John Childs explains that local opposition to *Solwara 1* was fueled by the belief that copper from the seabed held ancestral and spiritual significance, challenging the notion of mineral extraction as a neutral act.²¹

Activists, organizations, local communities, and many scientists advocate for a more holistic framework that includes the cultural and spiritual connections, since ESIAs usually prioritize economic metrics over traditional knowledge, sacred sites, and vulnerable fishing areas. By contrast, Indigenous worldviews require legal recognition of free, prior, and informed consent (FPIC) and the establishment of binding frameworks that ensure that affected communities, even if geographically distant, are included in decision making.

Environmental leaders and spokespeople such as Jeff Ardron and Asterios Tsioumanis, team leader, writer, and editor of the IISD Earth Negotiations Bulletin (ENB) (a reporting service on UN environment and development negotiations), have said that mining should not happen until environmental damage can be avoided.²² Nonetheless, some legal advisors

and representatives, experts on the matter with extensive experience in international law, specifically the ISA, have stated that it is more complicated than that. “The ISA is in urgent need of reinvention” — a process that, according to a Mexican diplomat and Law of the Sea expert we interviewed, is already beginning to take shape.²³ Details on a guarantee and compensation plan are currently being discussed within ISA negotiations. He explained that the basis of these regulations is two main framework principles: the protection of the environment and the overall benefit of humankind as a whole. The challenge is to balance these two principles by evaluating the minimum acceptable damage based on scientific research and testing, and figuring out how to distribute the royalties generated from the exploitation activities.

Each contractor has to present environmental assessments and evaluations, which undergo the Legal and Technical Commission’s revision to determine the granting of an exploitation license.²⁴ This plan aims to better manage the economic benefits obtained from these activities, where the money acquired would be directed to this fund controlled by the ISA, which, hopefully, will distribute a percentage of the royalties, prioritizing developing countries.

Beyond the environmental and economic dimensions, governance of DSM also faces significant social equity challenges. In many coastal communities, women play a central role as knowledge holders and subsistence providers, yet they are systematically excluded from consultation and decision-making processes. This exclusion exacerbates gendered inequalities and denies communities the full range of local expertise.

20 “Managing Impacts of Deep-sea Resource Exploitation — Final Report Summary — MIDAS (Managing Impacts of Deep-sea Resource Exploitation),” CORDIS: European Commission. [↗](#)

21 Childs, “Deep Sea Mining Threatens.”

22 Interviews with Asterios Tsioumanis (4 March 2025) and Jeff A. Ardron (23 May 2025).

23 Interview with Marcelino Miranda, 19 June 2025.

24 Pradeep A. Singh and Maila Guilhon, “A Reflection of the EIA Process for Exploration Activities at the International Seabed Authority in Light of the Recent Nori,” DSM Observer, December 2022. [↗](#)

Scholars and policy advocates call for DSM governance that includes human rights, health, gender equity, and fair resource distribution. Without these considerations, DSM risks repeating the exploitative patterns of terrestrial mining, undermining both environmental and social sustainability. An international policy expert suggested in an interview that the ISA could include a “body of Indigenous people” to institutionalize their involvement and give them more tangible power in the decision-making process.

More than one scientist we interviewed for this research argued that deep-sea mining is fundamentally an ethical and moral issue, and the law remains silent on that.

Another of the policy experts we interviewed gave us the next example.

I can just note that, for instance, in the Arctic Council they have, Indigenous people have a formal role as permanent participants. They are as important as Canada or Norway in the decision-making structure there. A similar mechanism could help the ISA to live up to its promise to represent humankind, not just governments, not just companies.

Communities and activists are already responding with concerns about the risks they perceive around DSM, concerns that are just as relevant as the proven impacts. These perceptions are generated not only by uncertainty but also by long histories of harm caused by terrestrial mining, where environmental and social promises were not fulfilled.

The ocean is part of the common heritage of humankind. DSM — proposed under the current international frameworks — prioritizes industrial interest over long-term ecological and cultural well-being. These impacts, either indirect or immediate, threaten international justice, and communities today are not only defending their environments but also their right to preserve knowledge, identity, and a sustainable future for themselves and their next generations.

More than one scientist we interviewed for this research argued that deep-sea mining is fundamentally an ethical and moral issue, and the law remains silent on that. For instance, the international policy expert stated in an interview that we should “find a way to answer these questions in favor of humanity.” He was very explicit about the need for deep and substantial research on the matter before any type of talk regarding mining exploitation activities or sharing economic benefits.

In Need of a Global Collaboration

To date, there is no resolution on how to mitigate or prevent environmental damage in ecosystems that may never recover. Agreements have yet to be reached on how contractors will be held accountable — or even whether they will be held accountable for environmental harm. While financial responsibility for environmental damage appears likely to fall on contractors through the implementation of a guarantee fund, important questions remain about whether this is truly viable. Can a monetary value be assigned to ecological loss? And how can environmental damage be repaired in an ecosystem we do not yet fully understand?

It is essential to ensure that contractors are held accountable for their actions, but what mechanisms will the ISA implement to guarantee legal compliance throughout the long lifespan of a deep-sea mining project? This is a profoundly significant matter involving the ocean and the current governance model.

Although one of the ISA’s commitments is to work for the “benefit of all humankind,” there is still

a need to deepen the understanding of social impacts and to develop methodologies that ensure participation and diverse dialogue among scientists, states, organizations, and activists. Beyond the supposed obligation of states to consult communities at the national level, the ISA also publishes calls for proposal reviews and conducts public consultations online, webinars, and other in-person sessions to consider public interests and opinions. However, the boundaries, criteria, and minimum distances from coastal communities to determine whether they are of interest have not yet been clearly defined.

One of the major challenges posed by these issues is that, given the highly technical nature of the subject, even when information is made public and transparent, coastal and Indigenous communities may not fully understand it. Collaboration with these groups and the inclusion of traditional knowledge are of utmost importance to diversify the debate and better understand mining's implications. A methodology that integrates all types of knowledge without prioritizing one over another, to engage legitimately, has not yet been established.

While these communities hold a certain responsibility to participate and show interest, it is the ISA's responsibility and obligation to ensure access to information. For a more democratic and inclusive approach, more virtual sessions should be organized.

It is also crucial to highlight the urgent need for global collaboration. Given the transboundary nature of marine ecosystems and the legal complexity of deep-sea mining, this debate cannot be addressed through isolated efforts or fragmented regulatory tools. Multidisciplinary and global cooperation is essential to ensure environmental protection and to uphold the

principles of equity, justice, and intergenerational responsibility.

Mechanisms for cumulative impact assessment, continuous environmental monitoring, and the establishment of a social and economic planning commission within the ISA are necessary and important steps toward building a comprehensive governance structure. Without the active participation of all stakeholders — Indigenous communities, developing states, civil society, and the scientific community — these mechanisms will lack a multidimensional perspective that is not only scientific but also political, ethical, and social.

Recommendations

Generally speaking, the main challenge the ISA faces lies in the way its internal sessions are conducted. While observers such as NGOs and civil society representatives are allowed to attend, they are not granted meaningful roles in decision making. This has fueled growing concerns about the ISA's legitimacy and transparency, especially given the limited access to discussions held between the ISA and community representatives regarding exploration procedures. Additionally, there's a persistent lack of consensus among key stakeholders, leading to tensions between state representatives and advocates from environmental NGOs, the scientific community, and civil society activists. Although the ISA has framed this as an external matter under the responsibility of individual states, its broader relevance becomes evident when considering cases like Papua New Guinea's ten-year moratorium on seabed mining, prompted by advocacy efforts led by Jonathan Mesulam.²⁵

²⁵ Jonathan Mesulam, a former teacher and UN worker from New Ireland, emerged as the leading voice of the Solwara Warriors Alliance — a coalition of coastal and faith-based communities opposing the *Solwara 1* deep-sea mining project. Through grassroots mobilization and strategic advocacy, he brought attention to the ecological and cultural risks of seabed extraction, sparking national and international debate. His efforts played a decisive role in securing Papua New Guinea's 2019 decision to impose a ten-year moratorium on deep-sea mining. John Cannon, "PNG Communities Resist Seabed Mining: Interview with Activist Jonathan Mesulam," *Mongabay Environmental News*, 1 March 2024. [🔗](#)

Observations	Recommendations
Observers, including NGOs, civil society, and representatives of coastal communities, have limited influence within the ISA. This is further undermined by the authority's internal discord and contested legitimacy.	• Include alternate mechanisms of citizen participation in ISA discussions. • Incorporate observers in tangible contributions, like votes. This involves active discussions alongside the observers about what is and is not approved. • Decisions should not rest solely with states; affected communities must also be consulted, and the results of these consultations should be publicly disclosed. This ensures alignment between a state's official position and the will of its citizens.
Lack of consultations with communities and scientists when discussing the exploratory processes.	• Publish on ISA's website any survey applied, its conditions, methodology, and results. • Prioritize communities' and scientists' opinions, especially if they don't agree with the process. Moratoriums and international dispute settlements through the ITLOS and UNCLOS are highly advised.
The decision-making focus is often based on a positivist, traditional view of facts as unchangeable and certain. But in the case of DSM, this limited view is very treacherous when considering the possible environmental and social implications of such a complex activity.	• Recognize uncertainty as an intrinsic characteristic of complex systems like the international seabed. The ISA should incorporate uncertainty rather than eliminate it from decision making. By applying sensitivity analyses to explore how varying assumptions affect outcomes, particularly regarding exploitation and its multifaceted impacts, this approach aligns with postnormal science principles. • Regularly re-evaluate methods, assumptions, and content of the reports, allowing for a more pivot-based study based on the most recent observations and trends on the international seabed (submarine ecology, availability of minerals, species migration patterns, etc.) • Plan for contingencies to improve the risk management of DSM on the international seabed. This can ensure that the field studies made by ISA and other agencies stay relevant to future changing scenarios, as it considers various potential futures.

These recommendations are directly aligned with several SDGs. By advocating for a moratorium and the strengthening of environmental protections, they support SDG 14 (life below water), aiming to conserve and sustainably use the oceans, seas, and marine resources. The proposed reforms to enhance transparency, accountability, and stakeholder participation are central to SDG 16.6 (develop effective, accountable and transparent institutions at all levels) and SDG 16.7 (ensure responsive, inclusive, participatory, and representative decision making at all levels). Implementing these changes would not only improve the governance of the deep seabed but also reinforce the global commitment to building peaceful, just, and strong institutions through the ISA.

Lessons Learned

As our research progressed, one of the most important insights that emerged was the complexity of the governance and regulations regarding deep-sea mining. The ISA has a significant responsibility in the regulation of activities that affect the ocean sea floor and humanity's well-being.

We acknowledge that the ISA is still an evolving organization, with many gaps in areas where its regulatory framework could be improved, especially in terms of inclusivity, enforcement mechanisms, and accountability. However, it has also provided a structured platform for states, civil society, scientists, and other stakeholders to come together in one forum to negotiate and shape the future of the seabed in a controlled manner. Although it is one of the few international institutions that tries to be transparent, transparency alone might not be enough. Real participation from and open information for groups at stake is of utmost importance.

Coastal and Indigenous communities are often the most vulnerable to the impact of deep-sea

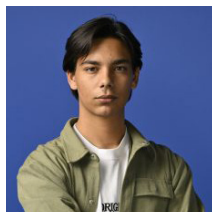
mining, not only economically but culturally as well. Today, there is no institutional mechanism within the ISA framework to ensure their involvement in a meaningful and sustained way. Establishing such a mechanism would not only provide legitimacy to these communities' concerns but would also strengthen the credibility of the entire governance system. As one NGO member put it: "Trust in the ISA will depend on whether it can actually prioritize environmental stewardship and public accountability over commercial pressure."

As one of the oceanography experts noted, "communities have a responsibility to participate and be interested, but ISA is also responsible for allowing access to information." Practices such as virtual sessions could be key to a more democratic, cost-effective, and inclusive way to approach this issue. Participation will remain strong only if people feel heard and if they understand the complex, often technical implications of what is being discussed. If the process feels obscure or disempowering, motivation to engage will not last and will eventually lead to more systemic gaps and a lack of community involvement.

This precautionary principle must be central to any regulatory decisions. No mining activity should be approved without complete, peer-reviewed, and transparent scientific data on the potential environmental and social consequences. At the same time, sanctions and enforcement mechanisms must be agreed upon to stop any member state from profiting without a collective agreement or in breach of the established rules.

Ultimately, the ISA's path forward will require rethinking how benefits are defined, whose voices are heard, and how they are regarded. Priorities should shift toward decision making that is inclusive, grounded in human rights, and informed by science. People should have both the power and the right to shape the future of the deep ocean, a shared heritage that belongs to us all.

Research Team



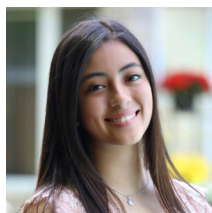
Emiliano Bondani Rahme is an undergraduate student in law and international relations at Tecnológico de Monterrey. His academic focus lies in the regulation of emerging technologies and upcoming industries. He is particularly interested in how international legal frameworks can balance innovation and social responsibility. Through his participation in global governance and technology policy dialogues, Emiliano has developed a multidisciplinary perspective that combines law, science, and ethics. He aims to contribute to the creation of regulatory approaches that foster technological progress while safeguarding the environment and social interests.



Santiago Colin is an undergraduate student studying public transformation and governance and international relations. He is passionate about philosophy, culture, and nature, and is deeply interested in developing public policies for environmental protection and conservation. He has worked on digital transformation academy initiatives such as the South School of Internet Governance and has participated in the development of human resources projects for companies such as Grupo Bocar.



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