BRIEF OF THE SCIENTIFIC ADVISORY BOARD ON:

DEEP-SEA MINING

WHAT IS DEEP-SEA MINING?

Deep-Sea Mining (DSM)[1] refers to the practice of exploiting mineral deposits from the deep seabed (400 meters to 6.5 kilometers below sea level). DSM targets three main sources of minerals: (1) **Polymetallic nodules**, containing manganese, nickel, copper, cobalt, and trace amounts of rare minerals; (2) **Colbalt-rich crusts**, containing cobalt, manganese, nickel, lithium, and rare earth minerals; and (3) **Polymetallic sulfides** containing copper, zinc, silver and gold.[2] While the technologies and impacts for each are different, all involve some form of destruction of the seabed and discharges within the surrounding waters.

Many low carbon energy technologies are at present heavily reliant on the kind of minerals found in high concentrations in the deep-sea bed. The transition towards renewable energy is driving increasing demand for these resources and a potential acceleration of efforts to scale up deep-sea mining.[3]

However, a growing body of scientific evidence indicates that DSM poses significant direct and indirect risks to fragile submarine ecosystems, with potential impacts on biodiversity, fisheries, water quality, and other connected ecological systems.[4] This brief provides an update on recent developments, an assessment of these risks, and considerations for the UN system.

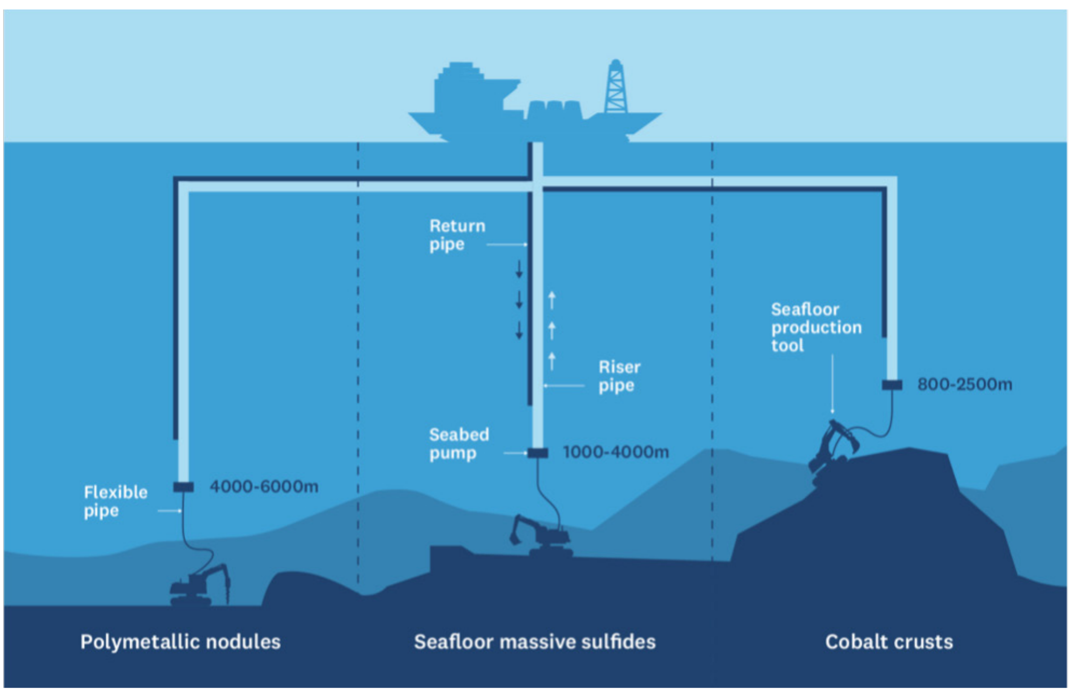


Diagram of the Deep-Sea Mining Process (George Shouha)

WHY IT MATTERS?

Deep-sea mining could have wide-ranging, long-lasting, irreversible effects on marine ecosystems, with global impacts. If demand for critical minerals grows, pressures for large-scale DSM are likely to increase.

WHAT ARE THE LATEST DEVELOPMENTS?

While commercial DSM has not yet started, several countries have taken steps to regulate exploration and/or exploitation in national waters.[5] In 2022, the Cook Islands approved three exploration permits in its exclusive economic zone, while Japan began testing rare earth extraction off its coast in 2023 after a significant deposit was discovered.[6] In January 2024, the Norwegian parliament approved a law permitting exploration of the deep sea within Norway's exclusive economic zone, but the government paused the process in November 2024 following strong public pressure and calls for restraint by many scientists.[7] In the US, legislation was recently introduced to support deep-sea mining activities, emphasizing the strategic importance of securing critical minerals necessary for the energy transition.[8] In contrast, in 2022 the European Parliament committed to prohibiting DSM until "scientific gaps are properly filled" and the marine environment is effectively protected.[9]

Efforts are also underway to begin DSM in "the Area," which is the seabed and subsoil beyond national jurisdiction governed by the UN Convention on the Law of the Sea and within the ambit of the International Seabed Authority (ISA). As of December 2024, 31 contracts have been issued by the ISA for deep sea exploration.[10] In 2021, the Government of Nauru, in partnership with The Metals Company, sought the ISA's approval for deep sea exploration, aiming to be the first company to begin operations in The Area.[11] This triggered the so-called "two year rule," which would allow Nauru to request an exploitation license at any time from 2023 onwards. In the summer of 2024, The Metals Company announced that it would request such a license in June 2025.[12]

While the ISA has already designated some no-mining zones called "Areas of Particular Environmental Interest," no international regulations have been approved so far to regulate exploitation of mineral resources in the Area.[13] In 2024, the ISA hosted Member State deliberations on possible regulations for deep-sea exploration and exploitation, aiming for agreement and adoption by the end of 2025.[14]

WHAT ARE THE RISKS?

There remains significant uncertainty about the full range of potential environmental impacts of DSM. According to some estimates, only about one-quarter of the deep seabed has been adequately mapped thus far, though scientific studies of possible environmental impacts of DSM are rapidly scaling up.[15] Recent research has highlighted that each area of the deep seabed has a unique set of characteristics; each DSM technique may affect ecosystems in very different ways; and mining is not the only impact on the deep seabed.[16]

What is known is that deep-sea ecosystems are rich in unique biodiversity, many are strongly interconnected and extend well beyond the deep sea (e.g. fisheries), and many are highly susceptible to external shocks.[17] Based on existing scientific research, mining of the deep seabed likely will generate the following **direct impacts:**

- A vast diversity of organisms, some representing unique branches of the evolutionary tree of life and many yet to be discovered, would be killed by the destruction of their habitats.[18] Further potentially irreversible biodiversity loss in the areas surrounding mining sites is very likely.[19]
- Sediment plumes produced by some forms of mining (depending on scale and technology) would impact many organisms in the immediate mining vicinity, potentially also having far-reaching direct impacts on biodiversity, water quality, and fisheries for hundreds of kilometers in all directions.[20]
- Toxins released by mining could enter the water column, killing some marine life in the immediate vicinity.[21]

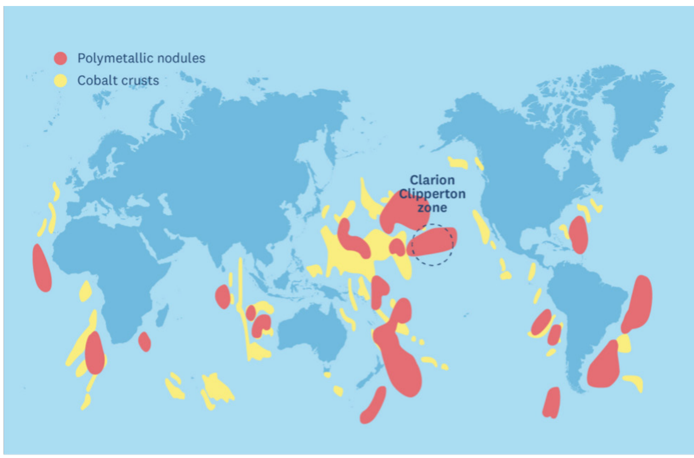
The UN Convention on the Law of the Sea and the International Seabed Authority

UNCLOS is an international treaty providing a legal framework for activities on the oceans and seas. It defines zones of maritime jurisdiction and asserts that the seabed and ocean floor beyond national jurisdiction (known as The Area) are the "common heritage of mankind." The treaty aims to ensure equitable resource sharing, and the sustainable use of marine resources while protecting the marine environment.

The International Seabed Authority (ISA) is the organization through which States Parties to UNCLOS organize, carry out, and control activities in The Area. The Authority is mandated to adopt appropriate rules, regulations and procedures to ensure effective protection of the marine environment from harmful effects which may arise from activities in the Area, and to promote marine scientific research. This mandate includes the authority to offer exploration and exploitation licenses for deep-sea mining, and for developing regulations to avoid harm to the environment.

The **indirect impacts** on the environment are potentially far more extensive. The creation of sediment plumes may spread harmful substances and disrupt interconnected marine ecosystems far beyond extraction sites.[22] Noise, light, and vibration from some mining techniques may impact hundreds of miles beyond the exploitation site, disrupting marine habitats and affecting migration patterns of fish and marine mammals.[23] Damage to mid-water ecosystems above the deep-sea mining sites could also be extensive.[24] Bioaccumulation of hazardous substances in fisheries has not yet been comprehensively studied, but could affect human wellbeing.[25]

Some of the areas with high mineral concentration also harbor disproportionally high, unique and poorly understood species diversity as compared to other areas of the seabed, and represent key food and resting resources for pelagic fish, turtles and mammals. A recent survey has found more than 5,000 animal taxa and estimated their total species richness in the order of 6,000 to 8,000 in the Clarion Clipperton Zone alone.[26]



Map of High Mineral Concentration Zones (George Shouha)

If damaged, many ecosystems and mineral deposits on the deep seabed likely will be **very slow to recover, if at all.** The same biological characteristics that allow organisms to cope with extremely harsh conditions (e.g. low growth and reproduction rates) also make them disturbance-intolerant and slow to recover.[27] Nodules, for example, form over millions of years. Marine life depending on nodules as a habitat may never return or go extinct if the nodules are destroyed or damaged. Corals living on cobalt crusts take thousands of years to form but would be destroyed immediately by many DSM techniques.[28] Deep sea hydrothermal fields are home to some of the most unique biodiversity on the planet.[29] The full scale of the impacts of their destruction are impossible to know with certainty based on today's knowledge.[30]

Much of the marine life in these areas is unique and has been used to produce **important solutions for human wellbeing, including cancer treatments and vaccines.**[31] The destruction of an unknown number of life forms – many of which have not been discovered or tested – could close off one of the most important sources of medical breakthroughs to date. The utility of these organisms to human wellbeing is only part of the story; they are also essential parts of broader marine ecosystems and their destruction could have impacts far beyond the local mining areas.

There is emerging evidence that DSM could **disrupt the carbon capture process of the oceans**, potentially contributing to global warming.[32] Marine sediments store more than twice as much carbon as land-based soils. Disruption of the deep seafloor has already been shown to reduce its carbon capture methane absorption capabilities. While it appears unlikely that large-scale "remineralization" of carbon back into the atmosphere will occur, the effects on the carbon sequestration function of the oceans is uncertain.[33] There is some new and as yet unverified evidence of "dark oxygen", or oxygen produced in the deep ocean without sunlight, challenging long-held assumptions about how oxygen is created on Earth. This oxygen production, particularly on the surface of nodules, points to the still unexplored potential of these ecosystems. [34]

In fact, **we may be severely underestimating the broader impacts of DSM.** Conceptions about the limited impact, small mining areas, and abundance of unexplored deep seabed areas may obscure the enormous "cascade" effects of localized disruptions on connected ecosystems.[35] Some risks may be mitigated, including by designing less disruptive mining tools, filtering the sediment for toxic substances, or reducing the noise and light generated.[36] The designation of protected areas (such as Areas of Particular Environmental Interest), or establishing independent monitoring or well-designed "reference" or "baseline" zones to evaluate the impacts of mining, could also play a role in limiting the risks posed by mining. Active or unassisted restoration options for areas damaged by mining could also limit the broader environmental impacts, if they prove effective and the obstacles of prohibitive costs are overcome.[37]

However, given the scientific evidence available today, it appears that exploitation of the deep seabed presents enormous risks across a wide range of areas, with far-reaching implications for environmental sustainability, biodiversity, healthy ecosystems, and human wellbeing. **In this context, the dominant characteristic of DSM is uncertainty:** We have enough evidence to anticipate very serious ecological impacts, but we simply do not know how destructive it might be and we have insufficient scientific evidence that available mitigation measures would be sufficient to ward off the most serious impacts, some of which are likely to be long-lasting or irreversible.[38]

EXISTING REGULATIONS

Article 145 of the UN Convention on the Law of the Sea requires States Parties to protect the marine environment from any harmful effects of their activities, for the benefit of mankind as a whole.[39] Other international agreements also contain clear commitments to protect and preserve marine biodiversity.[40] However, the ISA process has not yet agreed clear environmental preservation goals, or what levels of harm would be considered serious enough to prohibit or limit DSM, nor has it carried out a global assessment of the full range of DSM's potential effects.[41] Indeed, as of today, there are no globally-agreed terms to describe what "protection of the marine environment" means, or what thresholds of harm should be used to guide regulations, though exploration permits have already been granted. While the most recent session of the ISA was in part focused on agreeing eventual DSM regulations and definitions of environmental harm, it is unlikely any will be adopted or ratified before the end of 2025 at the earliest. Even regulations eventually agreed under the ISA would only affect "the Area" beyond national jurisdiction and would not restrict the ability of states to conduct DSM within their exclusive economic zones.[42] In this context, momentum for undertaking mining operations to meet the growing demand for critical minerals could lead to a scenario in which mining begins prior to the finalization of scientifically-based definitions of serious environmental harm and/or related regulations.

CONSIDERATIONS

Based on the current scientific understanding of the potential impacts of DSM, the Board notes the following considerations:

1. **Application of the precautionary principle.** The precautionary principle or approach is a guiding principle in international law and is expressly found in numerous international agreements and instruments.[43] Where there are threats of serious or irreversible damage, the precautionary principle holds that lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation. Based on the scientific evidence known today, the case of DSM falls squarely into such a scenario of high risk and high uncertainty. Given the risks, the potential irreversibility of some impacts, and the growing efforts of mining companies to begin operations in the short term, a growing number of scientists, environmental organizations, governments and businesses have called for some form of "pause" or moratorium on DSM until there is greater evidence-based clarity on the extent of the risks and there is clear scientific evidence that serious harm will not be caused. There is no consensus amongst the scientific community on this matter.[44]

2. **Comprehensive assessment of DSM impacts.** One of the most complex challenges is uncertainty about the potential impacts of DSM. To address this, a recent report by the UN Environment Programme has called for a comprehensive and independent assessment of activities and potential impacts of DSM.[46] From a scientific standpoint, such an assessment would play an important role in establishing a baseline understanding of the direct impacts of mining, and also the indirect effects via disruption of interconnected ecosystems. This could enable a scientifically-based comparison of the environmental impacts of DSM as against terrestrial mining practices, and could generate actionable recommendations to limit environmental harm, including specific recommendations for mitigation measures.[48]

3. **Environmental goals and definitions.** From a scientific standpoint, avoiding the above risks via regulation of DSM in The Area would require a globally accepted and scientifically grounded definition of environmental harm relevant to Article 145 of UNCLOS, preceded by an agreed set of environmental preservation goals.[50] The above proposal for an independent, scientific assessment of the seabed and its vulnerability to DSM would be necessary in setting those goals and defining environmental harm, given the many indirect impacts of mining. To ensure rigorous evidence of impacts is produced, many experts have pointed to the need to broaden the stakeholders involved, for example to include the views of a wider range of independent scientists, Indigenous communities, coastal fishing communities, and others.[51]

4. **The need for DSM.** As of today, there is no scientific consensus on whether DSM is necessary to meet the demand for critical minerals. Some estimates suggest that anticipated mineral needs could be met by land-based extraction and/or more efficient use of existing capacities (though it is important to note that all forms of mineral extraction have environmental consequences).[52] A science-based assessment, drawing on the best available independent sources of information, could support a more evidence-based evaluation of the trade-offs required to meet the growing need for minerals, land- and sea-based resources, and other options to reduce human contributions to climate change.[53]

5. **Recycling of critical minerals.** From a technical standpoint, the undersupply of minerals for meeting demand can be addressed in part by better use, re-use, and recycling of existing supplies.[54] The Board takes note of proposals to develop a global regulatory framework that incentivizes recycling of critical minerals to help reduce commercial demand for DSM and other mining practices.[55] Some proposals focus on inefficiencies in use and re-use of minerals, as well as technologies to reduce demand for critical minerals.[56]

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