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Heading to the Deep End Without Knowing How to Swim:
Do We Need Deep-Seabed Mining?

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Summary

The deep seafloor is regarded as a potentially large source of the minerals needed to produce batteries to fuel the transition to a low-carbon energy system, but rapid, unrestrained mining would impose severe impacts to deep-ocean ecosystems and should be avoided. We propose alternative pathways forward.

Keywords

hydrothermal vents, cobalt-rich ferromanganese crusts, polymetallic nodules, seamounts, polymetallic sulfides, policy, International Seabed Authority

Draft Text

In this warming world, humankind must curb carbon emissions and meet net-zero goals by 2050 [1]. This requires transformation of our energy and transport systems to low carbon technologies (renewable energy and electric vehicles), which requires the use of batteries to store energy due to the intermittency of solar and wind. At present, battery designs typically use lithium (Li), nickel (Ni), and cobalt (Co). By 2015, battery production required about 31,500 tonnes of Li, 2,280,000 tonnes of Ni and 126,000 tonnes of Co [2]. Estimates of global demand for Li, Ni and Co by 2050 vary by technology choices, scenario targets (e.g., 2050 net zero), and battery chemistry, but commonly range up to more than ten times 2015 levels (e.g., World

Bank Group [2]). However, there is little consensus on where these minerals will come from, especially considering the desire for responsible mining to meet sustainability needs, with the deep ocean being portrayed as one major potential source [3,4].

Deep-seabed mining (DSM) could cause significant damage to near-pristine and important ecosystems on enormous scales. This could potentially be permitted within two years in Areas Beyond National Jurisdiction (ABNJ). Here we argue this rapid, unrestrained expansion of mining into the deep ocean may not align with sustainable development objectives based on the scope and scale of potential impacts. We ask whether humankind needs to dive into the deep ocean for minerals at all and propose alternative pathways forward.

Jeopardizing the depths

Mining of the seabed for minerals required for batteries is being explored in polymetallic nodules on the abyssal seafloor (Ni, Li, Co), polymetallic sulfides at active and inactive hydrothermal vents (copper, zinc, silver, gold, although not ‘primary’ in battery chemical design, are used in renewable energy and battery technology), and ferromanganese crusts on seamounts (Ni, Li, Co) within Exclusive Economic Zones and in ABNJ globally [3].To date, 31 exploration contracts covering more than 1.3 million km^2 of deep seafloor globally have been granted in ABNJ by the International Seabed Authority (ISA) (https://www.isa.org.jm/exploration-contracts). However, there are concerns from many scientists, environmental NGOs, businesses including battery producers and consumers, local communities, and Indigenous Peoples that the emerging industry of DSM does not promote equitable net-zero transition and socio-ecological sustainability [3].

The projected intensities and methodologies, as well as spatial scales, of DSM would cause significant environmental impacts [4-6], such as direct removal and destruction of seafloor habitats along with their unique fauna. Sediment plumes created from seafloor disturbance and return of sediment-laden wastewater will extend the impacts of DSM horizontally and vertically for tens to hundreds of kilometers [5]. Additionally, there will be contaminant release, changes to water properties, and increases in noise and light.

DSM is predicted to cause intense damage to some of the most pristine habitats on the planet, many of which are also biodiversity hotspots, vulnerable marine ecosystems and/or ecologically and biologically significant areas. For example, all eleven known active vent fields on the northern Mid-Atlantic Ridge are in exploration contract areas despite meeting multiple criteria for protection, including uniqueness or rarity, critical habitat, and importance for threatened, endangered, or declining species and/or habitats [7]. Seamounts often support productive benthic and pelagic assemblages designated as biodiversity hotspots [4]. The Clarion-Clipperton Zone (CCZ), which has the most mining interest for battery minerals currently, also shows extraordinary diversity, with most of the many thousands of species still undescribed [8]; a clear demonstration that not only do we have little knowledge, but what we do know is concerning.

Mining impacts through ecosystem degradation have the potential to damage ecosystem services such as climate regulation, fisheries, elemental cycling, provision of marine genetic resources, and the culture and well-being of local communities [9]. For example, because northern Mid-Atlantic Ridge mining exploration claims substantially overlap areas managed by the North East Atlantic Fisheries Commission, mining may displace or spatially concentrate fishing effort, yielding reduced catch or local fisheries depletion [10].

These DSM impacts might be considered inconsequential on small scales of 10s-100s of kilometres, but the scales of potential disturbance are enormous. In the CCZ alone, some industry projections are to directly mine seafloor habitats over a total area of ~500,000 km^2 [11]. Plume disturbances and noise pollution will at least triple this areal impact to $\geq$1,500,000 km^2 [4,5], yielding a footprint the size of Spain, Portugal, France, Belgium and Germany combined and 300 times the area of the Grand Canyon (Figure 1). In addition, these disturbances will be three dimensional, potentially extending throughout the ~4500-metre-high water column to disrupt $\geq$6,000,000 km^3 of ocean, a volume 1000 times that of the Grand Canyon and three times larger than the entire Himalayan Mountain Range (Figure 1) [4]. This DSM footprint increases when considering the remaining 13 exploration contract areas covering <85,000 km^2 in the West Pacific Ocean, West and Central Indian Ocean, and the North and South Atlantic. Importantly, impacts will also extend beyond the depths given the connected nature of the ocean, and onto the land where processing will occur.

A management and mitigation abyss

Managing and mitigating the impacts of DSM present some daunting challenges. A comprehensive understanding of the structures and functions of deep-sea ecosystems is necessary to assess whether DSM can avoid causing ‘serious harm’ to the marine environment [12]. Publicly available scientific knowledge is far too limited to enable evidence-based decision-making on DSM in targeted regions [13]. The lack of a strong regulatory framework, combined with nascent mining technology and monitoring approaches, as well as undefined enforcement of protocols, are of grave concern and should prompt a precautionary approach.

Deep-sea ecosystems are not only highly vulnerable to disturbance and extremely slow to recover, but habitat restoration also appears inconceivable. These characteristics leave little room for error. Recovery of ecosystems depends on population replenishment, which will not be successful if source populations are destroyed or too distant. For instance, the high biodiversity associated with the large heterogeneity of habitats in the CCZ is unlikely to be represented in potential recruits because not all species are able to move across its vast area [14]. Also, the recipient habitats will have been profoundly altered across huge scales and may no longer be suitable. The large distances and new physical barriers to dispersal (e.g., by plumes) will make natural recovery on ecological timescales nearly impossible.

The targeted polymetallic sulfides were formed over millennia, and associated ecosystem dynamics may have evolved similarly lengthy timescales [4]. For seamounts and nodule biotas, recovery is expected to be essentially nonexistent because nodules and crusts regrow very slowly (1 - 250 mm/My) [3,4]. Additionally, DSM will interact with other anthropogenic stressors on deep-sea ecosystems, including climate change, bottom trawling and pollution, likely further reducing the probability of recovery [10].

Because mined deep-sea habitats are unlikely to recover naturally, habitat restoration might seem desirable. However, assuming very conservative restoration costs of abyssal seafloor habitats similar to coastal ecosystems [15], restoration of just 10% of 500,000 km^2 of abyssal seafloor would cost US$50 billion, and are still likely inadequate to prevent substantial species extinctions. Furthermore, because abyssal communities recolonize very slowly, it would take decades to determine whether a particular restoration approach was truly effective [6].

Securing battery minerals from the deep seafloor to achieve net zero poses a sustainability conundrum given the significant and wide-ranging impacts that will occur on spatial and temporal scales not yet seen in the ocean. This, combined with the inadequate knowledge to inform management and the lack of technology for effective environmental monitoring, casts serious doubts on the wisdom of proceeding with DSM at the current pace (i.e., within the next few years) and urges us to explore alternative approaches for the development of renewable energy resources.

Is exploitation of the depths needed?

As it stands, the expected environmental impacts of DSM are not aligned with many intergovernmental and national policy agendas worldwide, which seek to halt biodiversity loss. The goals of the post-2020 Global Biodiversity Framework include no net loss by 2030, maintenance of the integrity of freshwater, marine and terrestrial ecosystems, and placing biodiversity on a trend to recovery by mid-century. The UN Sustainable Development Goal (SDG) 14 “to conserve and sustainably use the oceans, seas and marine resources” includes targets on the reduction of pollution and the increase of scientific knowledge and development of research capacity to improve ocean health (sdgs.un.org/goals). DSM even seems at odds with some of the ISA’s own guiding principles, e.g., Article 145 of the United Nations Convention on the Law of the Sea, which calls to ensure effective protection for the marine environment from harmful effects that may arise from activities in ABNJ. Yet, and despite its irreparable environmental impacts, plans for DSM are forging ahead.

Often DSM is justified based on the assumption that land-based metal reserves are being depleted rapidly. Yet, extensive research shows the opposite is true. In mining, reserves refer to the components of a mineral deposit which can be mined in 1-2 decades at a reasonable profit, while resources refer to those which are less certain economically, environmentally, or socially and are always far greater than reserves. In 2018, when global extraction of Ni was about 2.4 Mt/year, the United States Geological Survey estimated global Ni reserves at 89 Mt [16], but global resources were at least 335.3 Mt Ni (excluding reported nodule resource estimates) [17]. Similarly for Co, global production was 0.15 Mt/year, global terrestrial reserves were estimated at 6.9 Mt [16] and global resources at 33.6 Mt . Resources of Ni and Co already identified on land could therefore meet global demand for many decades to come [17]. Additionally, known reserves and resources invariably expand with further exploration, improvements in technology, discoveries of new deposits and rising market prices supporting the costs of mining. Moving forward, the path for extracting the resources needed should be done in the most sustainable manner possible – and the deep ocean does not meet this goal.

An obvious way to avoid expansion of mining into the deep ocean is embracing a circular economy of those minerals, reusing, repurposing, reforming, remanufacturing, and recycling them to the greatest extent possible. Recycling needs much less energy, water, and chemicals, leaves considerably less waste than mining, and provides greater security over the resources needed for modern technology and infrastructure. The trajectory to achieve high recycling rates for minerals is complex as many parts of the world still need to build stocks in their urban and industrial systems to facilitate metal flows for recycling (e.g., rare earths, Li, Co). However, there is widespread agreement on the overall need to move to a circular economy framework, as evidenced by such numerous government policies globally, and increasingly, the corporate sector. A shift to such a circular system would be the best way to satisfy the needed metal resources for batteries in our path to net-zero, while protecting ecosystems to reach conservation targets.

DSM will likely be impossible to stop once it commences as has been seen with other resource industries, even if it proves to be environmentally damaging. Societal dependence is partially responsible, but the demands for returns on major investment of capital is another. For example, there is every reason to halt deep-ocean oil and gas exploration and extraction; it does not represent a large part of global energy reserves and is wreaking havoc on the climate (especially suspected methane leaks as a plausible explanation of rapidly growing atmospheric methane levels). Yet this continues with new activity around the world. DSM, which may require start-up capital expenditures of nearly US$2 billion for a single venture, is also unlikely to stop easily once started, even if battery innovations reduce demand for Co and Ni, ecosystem damage is substantial, and unforeseen problems emerge (e.g., Deepwater Horizon). Also, given the constant evolution in battery design and improvements in performance for different uses, it can be expected that battery chemistry will continue to change in response to market drivers, supply issues, costs, and environmental and human rights concerns. Thus, it would be unwise to justify a new industry, such as DSM, solely based on the short-term need for currently-used battery minerals.

There are opportunities to alter the current trajectory of this nascent industry. Elevating the role of science and placing trust in scientists is an integral component of evidence-based decision making. Scientists have requested that time be given to generate the evidence required to effectively preserve and sustain ocean ecosystems. Amon *et al.* [13] project that it will likely take several decades for adequate research to be completed for all DSM resources in all regions, indicating that a push to begin DSM within two years is scientifically unwise. And hundreds of scientists have joined environmental NGOs in calling for a delay to the initiation of DSM (https://www.seabedminingsciencestatement.org/).

A more specific opportunity is for the ISA itself to become a champion of deep-sea science and conservation, with precedent already set for this among other resource-oriented UN bodies. The International Whaling Commission, established to manage international whaling, declared a moratorium on whaling 36 years after its formation and since has refocused its efforts on the science and preservation of whale stocks. While not without controversy, these events were driven by the scientific reality of the unsustainability of whaling. Given the ISA’s core missions, especially related to marine research, capacity development, and the protection of the marine environment, a similar pivot in its primary focus led by the 167 Member States would be feasible. Coincidentally, thirty-six years after the formation of the ISA would be 2030; a new ISA emphasis would be a fitting goal for the United Nations’ Decade for Ocean Science for Sustainable Development.

The role of batteries in transitioning towards a low carbon energy system in undebatable, but we caution against the rapid, unrestrained expansion of mining into the deep ocean to obtain the required materials, as it will not support the targeted sustainable use of natural resources and ecosystems. We call on the global community to consider the proposed alternatives while enough scientific evidence is gathered and a strong regulatory framework is established.

Figure

Figure 1: A comparison of the spatial scale of impacts from deep-seabed mining in the Clarion-Clipperton Zone (CCZ) with well-known terrestrial features.

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