Deep sea mining poses an unjustifiable environmental risk

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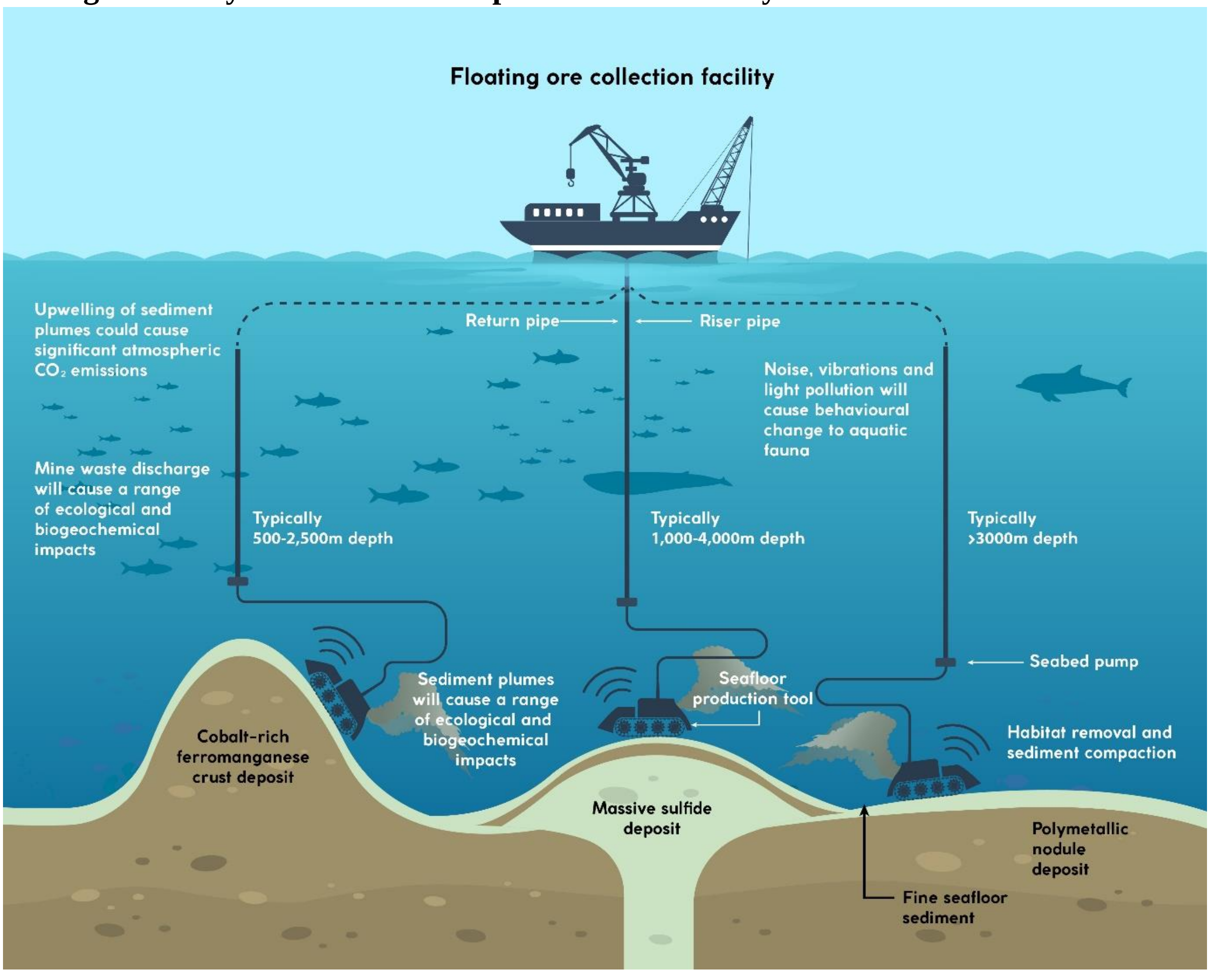
Standfirst: Deep sea mining could provide a globally significant supply of metals we urgently need to decarbonise our society, yet its environmental impact remains intractable. We argue that considering the abundance of on-land resources, and lower environmental risk of terrestrial mining, deep marine mining cannot currently be justified.

The international seabed is host to a globally significant mineral resource, however the prospect of deep-sea mining (DSM) in this environment is a controversial proposition. In recent years substantial advances in DSM technology have been realised but its large-scale application has not yet been demonstrated and environmental regulations remain unresolved. Despite these challenges there are a variety of positions on DSM within the 167 International Seabed Authority (ISA) member states; only 24 currently support a moratorium on the granting of DSM exploitation licenses. This raises the alarming prospect of commercial mining in the deep ocean without adequate environmental impact assessment, transparency, scrutiny or accountability. We contend that the magnitude and gravity of this consideration requires a more precautionary approach; the environmental risks which large-scale DSM currently poses are simply too great.

Schematic diagram of the three main ore deposit types currently proposed for deep-sea mining and likely environmental impacts of such activity



At present three main types of DSM are proposed: polymetallic nodules from deep-sea abyssal plains; cobalt-rich ferromanganese crusts from seamounts, and polymetallic sulfides formed at hydrothermal vents near mid-ocean ridges and back-arc basins[1]. While DSM is mostly planned for beyond national exclusive economic zones (EEZs), a significant fraction of both ferromanganese crusts and polymetallic sulfides are located within EEZs, such as the Norwegian Sea. Though any moratorium on DSM in international waters would not directly apply to these locations, it would protect huge

expanses of the deep ocean and stimulate greater environmental scrutiny and accountability within and adjacent to EEZs.

Here we set out three main questions that must be addressed before any DSM takes place: (1) Is there a coherent economic and net zero carbon argument for DSM? (2) What are the likely environmental impacts? and, (3) Can the impacts be mitigated sufficiently to justify the risks?

Is there a coherent economic and net zero carbon argument for DSM?

Much of the current debate centres around the Clarion-Clipperton Zone (CCZ), a stretch of the North Pacific between Hawaii and Mexico hosting polymetallic nodules on the seabed. Notable technology metals within CCZ polymetallic nodules include Mn, Cu, Ni and Co, with concentrations typically approximately: 30, 1, 1 and 0.2 wt.%, respectively[2]. Although the total potential resource within the CCZ is globally significant, with conservative estimates approximately 20 Gt[2], such grades are not considered particularly high. As a result, given on-land resources of such metals remain abundant, with total Mn, Cu, Ni and Co reserves currently approximately 1700, 890, 100 and 8 Mt respectively[3], a compelling resource argument for DSM is lacking.

Proponents also argue that DSM is needed to allow sufficient upscaling of metal production for timely decarbonization of our society. However, the total global annual production of Mn, Cu, Ni and Co is currently approximately 20, 26, 3 and 0.2 Mt respectively[3], which is only a fraction of the available on-land reserve mass. Indeed, while profound further expansion of Mn, Cu, Ni and Co supply must be realised to achieve the Paris Agreement with existing net-zero technologies, environmentally and socially responsible development of our abundant existing on-land resources, and investment into new and geographically distributed processing facilities, can achieve this future without DSM.

CCZ polymetallic nodules also lack the raw material diversity required for net zero carbon. Elements which are either absent or at relatively low concentrations include: He, Li, Be, C (namely graphite), Al, P, Cr, Pd, W, Sn, Bi, U[2]. If DSM is adopted, even at large-scale, it will therefore have to occur alongside terrestrial mining. Future demand for certain metals within CCZ nodules may also prove lower than currently predicted, e.g. due to the mass adoption of $LiFePO_4$ batteries, which do not require Co or Ni. In this scenario, future generations would inherit quasi-permanently disrupted deep-sea and wider ocean ecosystems which has liberated metals that were only considered temporarily vital for net-zero carbon.

Instead, redirecting investment from DSM into responsible terrestrial metal mining may afford better results because the latter is technologically mature, predictable and is therefore likely to be upscaled more quickly, using well understood methods and risk management. Although it has been suggested that DSM may generate lower direct climate change impacts[4], waste production and freshwater usage[5] than terrestrial mining, such models must be reevaluated as DSM technology matures and the environmental impacts are better quantified. To date, no large-scale DSM trials have been completed, so key operational parameters remain unverified[6].

There are also plenty of alternative terrestrial ore deposits, many of which are high grade but small, such that they do not offer an adequate return on investment in the current economic mining paradigm[7]. If DSM does not get the go-ahead, these deposits could be developed with a smaller spatial footprint, provide direct social community benefit, and be more readily held accountable. In this scenario, we must carefully balance the need for expansion of terrestrial metal mining whilst maintaining the highest environmental, social and governance (ESG) standards.

There is wide agreement that environmentally responsible primary ore mining must continue to provide sufficient raw material mass to tackle the Climate Emergency[8]. However, the industry remains responsible for profound environmental and social damages worldwide. Our ultimate goal is to displace such activity with a circular economy. Metals are infinitely recyclable; we may never need to resort to DSM.

What are the likely environmental impacts of DSM?

When considering likely DSM impacts, it is important to appreciate the magnitude of what is proposed. Since 2001, 31 DSM contracts have been signed spanning all the major ocean basins, including 19 in the CCZ, which cover a total area of over 1.3 million km^2[9]. If implemented such activity would directly impact several thousand km^2 of ocean floor per year[1]. This footprint, combined with the inherent world-wide connectivity of the ocean, means impacts, using current DSM technology, will be felt over large distances and across international borders.

It is now well documented that biological impacts to benthic communities in DSM-impacted regions will be severe, including extinctions of rare and geographically restricted species[10]. Such change is predicted to be irreversible on human timescales, due to the slow growth of both the organisms and the substrates being mined. While these ecosystems may be far removed from human civilization, they are amongst the largest on Earth. DSM would perturb these systems, with unpredictable and possibly severe consequences for wider ocean health and function, causing impacts that propagate into terrestrial environments.

Beyond the direct ecological impact, it is important to consider the change that large-scale DSM could pose to natural oceanic biogeochemical systems. By virtue of their deep-water setting, proposed DSM locations are invariably floored by fine-grained sediments that loft upwards to form turbid plumes when disturbed. Published models of DSM sediment plumes have typically focused on their proximal impacts following a single disturbance event[11]. However, disturbance of the ocean floor in multiple continuous mining operations will result in incremental, cumulative increases in sediment flux transported by deep ocean currents over potentially thousands of km, and high into the water column[12]. This effect would be compounded if tailings from DSM are also released. Ecological impacts may include oxygen depletion, release of toxic metals, gill clogging and physical disruption of mesopelagic assemblages that play a major role in the movement of carbon from shallow to deep waters[13].

The cumulative geochemical impacts of widespread DSM on bottom waters are significant, but currently unconstrained, because deep ocean currents operate as complex conveyors of heat, oxygen, carbon and nutrients. Deep marine sediments also exhibit total organic matter content generally less than 0.5%, albeit with significant local variability[14]. Despite this relatively low concentration, the substantial mass of sediment which large-scale DSM could mobilise through upwelling has the potential to perturb the carbon cycle. This possibility has not yet been adequately addressed by science or acknowledged by industry or the ISA.

Can the impacts of DSM be mitigated sufficiently to justify the risks?

Should DSM be given the green light it will be imperative that such activity is phased in gradually and causes the least environmental harm. There is a scientific consensus, however, that uncertainties in both predicting and monitoring the environmental impact of DSM remain intractable[6]. Effective design of remediation or no net loss strategies are therefore not currently possible.

The scope of environmental impact statements relating to DSM often consider individual mining operations in isolation, and for a limited number of impacts. However, approval of a first deep sea mine is likely to lead to much greater development as entrepreneurs and governments seek to enter new markets and gain access to resources in a competitive arena. The scope of DSM impact assessment modelling should therefore be based on diffuse and widespread contamination across larger volumes of deep-water circulatory systems than often considered[12]. Any approach towards DSM that does not consider the planet-wide implications of plural mining projects occupies a high-risk, immature safety culture with potential repercussions for all Earth inhabitants.

Effective monitoring of DSM may prove difficult. Whilst terrestrial mining operations are highly visible and accessible, it will be much harder for environmental damage to the sea floor or the overlying water column to be monitored; we will likely be more reliant on companies monitoring their own impacts. The ISA has many nation members and so has the potential to set strong global standards, but the present inclusion of those with a direct financial incentive to promote DSM does not provide the impartial framework required for robust compliance and enforcement. To mitigate this the ISA will require exclusive access to ocean-going vessels or submersibles to allow robust and independent monitoring of DSM environmental impacts.

The urgent case for a global moratorium rests on the following: if DSM is allowed, it will be very hard to reverse that decision. The importance of the oceans to the processes that regulate planetary habitability demands a precautionary approach. We must ensure decisions are taken in the interests of everyone on Earth, not just a narrow constituency of a few mining companies or countries. DSM will affect ecosystems that are less understood than those on land, but whose intrinsic characteristics make them highly vulnerable. Further study is urgently needed to address this knowledge gap; DSM should not be initiated until a reliable and acceptable mitigation hierarchy can be established. Precaution is of the utmost importance. We urge all nations that have not yet joined the moratorium on DSM to do so without delay, and that the United Nations adopt this position within international law.

Acknowledgements
The authors are grateful to the anonymous reviewers for their constructive feedback.

Competing interests

The authors declare no competing interests.

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Competing interests: Authors declare that they have no competing interests.