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Harmful Marine Extractives:

Understanding the risks & impacts of financing non-renewable extractive industries

Deep-Sea Mining

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List of abbreviations and acronyms

CCZ	Clarion-Clipperton zone
CO_2	Carbon dioxide
CH_4	Methane
CRC	Cobalt-rich crust
DPSIR	Driver, pressure, state, impact and response
DSM	Deep-sea mining
EEZ	Exclusive Economic Zone
ETP	Endangered, threatened and protected species
GHG	Greenhouse gas
H&M	Hull and machinery [insurance]
ICES	International Council For The Exploration Of The Sea
IMO	International Maritime Organisation
IFI	International Finance Institution
IPCC	Intergovernmental Panel On Climate Change
IRP	International Resource Panel
ISA	International Seabed Authority
IUCN	International Union For Conservation Of Nature
ODA	Official development assistance
OECD	Organisation For Economic Co-Operation And Development
P&I	Protection and indemnity [insurance]
SDG	Sustainable Development Goal
SMS	Seafloor massive sulphides
SIDS	Small Island Developing States
UNEP	United Nations Environment Programme
UNEP FI	United Nations Environment Programme Finance Initiative
UNEP-GEAS	Unep Global Environmental Alert Service
WEF	World Economic Forum
WOR	World Ocean Review

Executive summary

The ocean covers the majority of earth's surface, holding 97 per cent of all our water and 80 per cent of all life forms. Major ocean sectors such as fisheries, ports & shipping, marine renewable energy and coastal infrastructure, collectively contribute to a "blue"economy.

According to estimates prepared by the Organisation for Economic Co-operation and Development (OECD), ocean-related sectors contributed approximately USD 1.5trn of global gross value-added in 2010, a figure that is projected to increase to USD 3trn by 2030, with some ocean industries set to grow faster than the global economy.

However, ocean health is under increasing stress, faced with the triple crises of climate change, nature loss, and pollution—leaving the industries, businesses and livelihoods that rely on the ocean exposed to serious risks. While many existing ocean-linked sectors have the potential to contribute positively to a sustainable blue economy, this is not true for all sectors. The extraction of non-renewable marine resources such as oil & gas and seabed mineral deposits in particular poses a significant risk to the ocean and cannot be considered sustainable.

Recognizing that a significant amount of investment and financing continues to be directed towards the exploitation of non-renewable marine mineral resources, UNEP FI has prepared a series of sector-specific briefing papers[1] to explore their social and environmental impacts, with particular reference to the development, operation and closure of each of these sectors, the risks to financial institutions of continued association with these activities, and managing the transition to more sustainable alternatives.

This briefing paper discusses the potential risks associated with plans to mine the deep seabed of minerals, and how financial institutions should respond to the deep-sea mining sector.

Key takeaways

- The deep sea contains many of the most pristine, biodiverse, poorly studied, and evolutionarily remarkable ecosystems on our planet, which provide a broad range of critical ecosystem services.
- There is currently a paucity of data to support a detailed understanding of ecological relationships and impacts associated with deep-sea mining. Despite the fact that

1 The sectors addressed are: (i) offshore oil & gas; (ii) dredging and marine aggregates extraction; and (iii) deep-sea mining.

commercial deep-sea mining has not yet commenced, current scientific consensus suggests that deep-sea mining will be highly damaging to ocean ecosystems. Furthermore, the combined potential impacts from mining and other stressors on the marine environment (such as climate change, unsustainable fishing, and pollution) increase the level of uncertainty and may exacerbate disturbance from mining.

- It can therefore be argued that, at present, no robust, precautionary approach exists to safeguard the ocean against the potential ecological impacts of deep-sea mining.
- As a result of these high levels of scientific uncertainty, the prospect of deep-sea mining continues to attract significant opposition, with scientists, environmentalists, the European Parliament, and some national governments calling for a moratorium until its ecological consequences can be better understood. Increasingly, these concerns are also being supported by a broad range of private sector organizations.
- Significant challenges must be overcome before the sector can be recognized as economically viable or as a responsible industry that can make a positive economic contribution. These challenges present potential investors with significant risks.
- In the context of ongoing work being undertaken by UNEP FI with respect to financing the sustainable blue economy, **there is no foreseeable way in which the financing of deep-sea mining activities can be viewed as consistent with the Sustainable Blue Economy Finance Principles**, or compatible with the spirit and intent of the Sustainable Blue Economy.
- Instead of supporting the nascent deep-sea mining sector, financial institutions wishing to finance the extraction of necessary rare earths and metals and support the transition to a sustainable blue economy could focus efforts on alternative strategies that would: (i) reduce the environmental footprint of terrestrial mining; and (ii) support the transition toward a circular economy that promotes the reuse of raw materials in the economy, making current minerals demand obsolete and setting us on a path to a circular resource economy.

Introduction

Context

The ocean is a vital driver of planetary systems and a source of economic activity, livelihoods and food security. The Intergovernmental Panel on Climate Change (IPCC)'s 2019 special report on the ocean and cryosphere in a changing climate states: "In addition to their role within the climate system, such as the uptake and redistribution of natural and anthropogenic carbon dioxide (CO_2) and heat, as well as ecosystem support, services provided to people by the ocean and/or cryosphere include food and water supply, renewable energy, and benefits for health and well-being, cultural values, tourism, trade, and transport)" (IPCC 2019 pp 15). This dependence on the ocean as a major source of resources and services is projected to continue growing as human populations increase, which by 2050 is projected to reach nine billion.

At the same time, the health of the global ocean is under threat from human activity, with increasing pollution, overfishing, invasive species, physical damage to ocean habitats, unsustainable coastal development and climate change all contributing to the loss of biodiversity and ecosystem services, and to the decline in the environmental health of the ocean. Finance for a sustainable ocean remains limited, with SDG 14 (Life Below Water) receiving the least official development assistance (ODA) of all the SDGs in 2017 (Pincet, Okabe and Pawelczyk 2019). Nevertheless, awareness of the key services and provisions provided by the ocean is increasing, as well as the recognition that continued ocean health decline inhibits prosperity (Laffoley *et al*. 2019).

The sustainable blue economy is an approach put forward by the international community to take into account the health of the ocean as it strives to balance the three dimensions of sustainable development: economic, social and environmental. It is an economy based on circularity, collaboration, resilience, opportunity and interdependence. Its growth is driven by investments that reduce carbon emissions and pollution, enhance energy efficiency, harness the power of natural capital and the benefits that these ecosystems provide, alongside halting the loss of biodiversity.

A "sustainable blue economy" can be defined as one that: "provides social and economic benefits for current and future generations; restores, protects and maintains diverse, productive and resilient ecosystems; and is based on clean technologies, renewable energy and circular material flows".

With appropriate planning, governance and decision-making that involves the broad range of relevant stakeholders, many existing ocean sectors have the potential to contribute positively to a sustainable blue economy. However, this is not the case for all sectors. The extraction of non-renewable marine resources—particularly: (i) offshore oil & gas, (ii) dredging, marine sand & gravel extraction, and shallow marine mining, and (iii) the potential future development of deep-seabed mining—and the inherent impacts of these sectors on environment and society pose a significant risk to the ocean and therefore cannot be considered sustainable.

Given the critical importance of the ocean as a driver of socioeconomic development, it is becoming increasingly important that future investment in those ocean sectors that present the greatest social and environmental risks is replaced by investment in sectors of the blue economy that are rapidly transitioning towards sustainable pathways. In this regard, banks, insurers and investors have a key role to play in financing the transition to a sustainable blue economy, helping to rebuild ocean prosperity and restore biodiversity. Through their lending, underwriting and investment activities, as well as their client relationships, financial institutions have a major impact on ocean health and hold the power to accelerate and mainstream the sustainable transition of ocean-linked industries.

With a significant amount of existing financing still largely directed towards the unsustainable extraction of non-renewable marine mineral resources, UNEP FI considers it important to provide financial institutions with science-based and decision-useful information to support those financial institutions wishing to transition away from or avoid any involvement in non-renewable, marine extractive activities. Given the substantial differences within the three broad sector categories (oil & gas, dredging, and deep sea mining), UNEP FI has prepared a series of sector-specific briefing papers to explore their social and environmental impacts, with particular reference to the development, operation and closure of each of these sectors, the risks to financial institutions of continued association with these activities, and managing the transition to more sustainable alternatives.

About this briefing paper

Purpose and scope

These briefing papers are a practical working resource for financial institutions to assess their potential exposure to social and environmental risk factors associated with non-renewable marine extractive industries and recommend actions based on indicators of the social and environmental pressures in each sector. They summarize the key relationships between pressures and their associated impacts following a modified Driver-Pressure-State-Impact-Response (DPSIR) framework, building on this understanding to highlight how and why these pressures are material to financial institutions and the types of risk they represent.

The approach taken for these briefing papers is based on:

- How financial institutions should view these sectors, particularly in terms of managing and accelerating the transition away from unsustainable economic activity;
- The avoidance of new financing for the sectors;
- Challenging the existing finance approaches (where these exist) for some of the above activities to minimize harm and mitigate their impact as far as possible; and
- The search for sustainable alternatives and divestment from these activities.

This briefing paper discusses the potential risks associated with plans to mine the deep seabed of minerals, and how financial institutions should respond to the deep-sea mining sector.

Intended audience

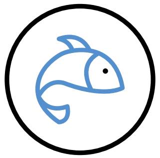
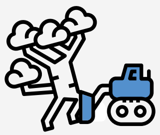
The primary audience for this briefing paper is financial institutions (banks, insurers and investors) with exposure to harmful and non-renewable marine extractive industries and those seeking to support the transition away from unsustainable activity towards a sustainable blue economy. The briefing paper aims to provide an initial framework for this broad variety of institutions to consider how sustainability impacts and risks specific to harmful and non-renewable marine extractives manifest within their own portfolios, as well as the potential business risks arising from financing such activities. Given the breadth of this subject matter and the relevance of sustainability considerations to a broad array of stakeholders, this information may also be valuable to the public sector, intergovernmental organizations, academia, civil society, commerce and industry.

Approach

The information and recommendations in this paper were developed using a bottom-up approach grounded in extensive literature review and expert interviews. Based on this and the latest available science, the drivers of impact in the sector were determined, the pressures exerted by the sector were identified, and these pressures were linked to categories of social and environmental impact. This approach is consistent with the DPSIR[2] framework developed by L'Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) in 2004.

Table 1 outlines the meaning of the environmental and social impacts discussed in this briefing paper, and provides examples of where they may materialize—these impacts are further explored in the chapter on key environmental and social impacts and dependencies.

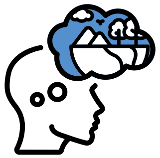
Table 1: Table of impact definitions

Environmental impacts		Description	Examples
	**Loss or reduction in marine biodiversity including loss of endangered, threatened and protected species**	Loss or reduction of populations of a given species, or of a species as a whole, due to human impact. This includes endangered, threatened and protected (ETP) species as defined by the IUCN Red List of Threatened Species and protections under applicable jurisdictions.	This may result from the impacts of noise or other disturbance that causes individuals to change their behaviour or may result from impacts to the habitats that support these organisms.
	**Loss of ecosystem resilience and provision of ecosystem services**	Loss or reduction in the ability of an ecosystem to provide specific benefits. These benefits, termed ecosystem services, include provisioning services such as oxygen production and carbon sequestration, as well as regulating services for the climate.	The introduction of pollutants (including suspended sediment) may exacerbate existing impacts and impact key services such as primary production.

2 DPSIR (Driver, Pressure, State, Impact, Response) is a framework to systematically approach impacts and describe the relationship between human activity and impact. It allows for a more precise assessment and understanding of how actions and activities affect the environment. It is based on a model originally developed by the Dutch National Institute of Public Health and Environment and later adopted by the European Environment Agency (EEA) (IFREMER 2004).

Loss or degradation of coastal and marine habitats	Changes to the physical environment on which life depends.	This may result from physical damage to the seabed as a result of dredging or mineral extraction.
Reduction in animal welfare	The consequences of human activity on the health of individual animals, both wild and farmed. It complements the impact on biodiversity, which looks at impacts on groups of animals and species. These impacts are closely linked and often appear together.	Reduction in animal welfare includes sources of stress for many organisms—including noise pollution from vessels and construction activity.
Increased GHG concentrations	The role of greenhouse gas (GHG) emissions in contributing to climate change. While human activity affects the climate in many ways, as well as the capacity to offer resilience or adapt to climate change, this impact covers the output of GHG emissions into the atmosphere itself, raising concentrations that result in a changed climate.	This results from a broad range of human activity, including emissions from vessels and offshore mineral extraction activity (including flaring and venting of gas from offshore installations).
Changes to marine biological, chemical and geological cycles	The consequences of changes to biogeochemistry—the natural processes within the ocean that play a role in regulating the planet, such as the water, carbon and nitrogen cycles. While dependent on water chemistry, marine life also plays a role in these cycles. As such this is closely linked to loss of ecosystem services—though the consequences differ, focusing specifically on these global chemical regulation processes.	This may result, for example, from removal of specific mineral layers from the seabed or from the release of contaminants such as heavy metals to the water column.

Social impacts	Description	Examples
Violation of human rights including rights of indigenous communities	The violation of any human right, including the rights of indigenous communities, in the process of development or financing of a given sector. This includes both specific and clear examples of human rights violations as well as more systemic human rights violations such as the impact of inequality of opportunities between social groups and genders.	This may result, for example, from the exclusion of local communities from sites of specific cultural significance due to the occupation of the site for mineral processing purposes.
Reduction or loss of access to sustainable and inclusive livelihoods	The consequences of development on an individual or community's ability to attain and maintain livelihoods.	This impact may cover the consequences of pollution preventing a community's ability to harvest living marine resources upon which their livelihoods depend, or the construction of mineral processing infrastructure physically preventing coastal communities' access to the marine environment.
Increased likelihood of injury, disease or loss of life	The consequence of an activity on the short- and long-term physical health of an individual or community as a result of development.	This may include the risks of injury or fatalities associated with high-risk offshore extractive industries as well as the impacts of increased levels of atmospheric pollution on coastal communities and workers.
Economic damage and loss of productivity	While all these impacts ultimately lead to some form of economic damage and loss of productivity, this impact specifically examines the direct, proximate consequences of a given pressure on the economic output and productivity of an individual or an enterprise.	This may include economic damages and losses because of a loss of livelihoods or a reduction in attractiveness of a coastal community due pollution or the development of new infrastructure.

	**Inequality of opportunities on the basis of age, sex, disability, race, ethnicity, origin, religion or economic or other status**	Closely linked to the impact of human rights violations, this impact looks more specifically at those instances where the development of a sector reinforces or establishes inequality of opportunities within and between communities and between individuals.	This may include gender imbalances in corporations across blue economy sectors, or racial discrimination in employment. This may also include unequal distribution of costs or benefits associated with a development.
	**Perceived degradation in cultural value of the environment**	The degradation of cultural value perceived by communities because of development or operation of a sector of the blue economy. This is distinct from the economic implications of the impact, and covers changes to the non-monetary value of an environment for local stakeholders.	This may include, as an example, the destruction of coastal sites of cultural or historical significance to make way for coastal development of mineral processing facilities.

On the basis of the identification of these pressures and impacts, the potential risks of financing deep-sea mining are explored.

Sector overview

Deep-sea mining (DSM) refers to the extraction of mineral deposits from the deep sea (the area of the ocean below 200m, which forms over 95 per cent of the biosphere of our planet). Although the presence of major reserves of mineral on the deep seabed has been known for several decades,[3] commercial extraction at these depths has not yet begun. Anticipated rising demand for minerals and metals, including for use in the technology and green energy sectors, as well as increased geopolitical interest in securing strategic reserve of key metals has led to increased interest in exploration of mineral resources located on the deep seabed (WOR 2011). At the same time, the increased demand for metals in the global market has resulted in an increase in metal prices. These factors together serve as the market logic behind developing the industry of seabed mining (FFI 2020).

To be competitive, DSM would rely on the presence of greater concentrations of certain valuable elements on the ocean floor than can be found in most terrestrial sites. The most important/valuable of these elements are copper, cobalt, manganese, nickel and zinc, as well as silver and gold. (Pew Charitable Trust 2018). Mineral extraction has been proposed from three main deep-sea mineral deposit types (Table 2), within which many of these elements occur together in concentrations that make them highly attractive to mining companies (Levin, Amon and Lily 2020).

Table 2: Main deep-sea mineral deposit types

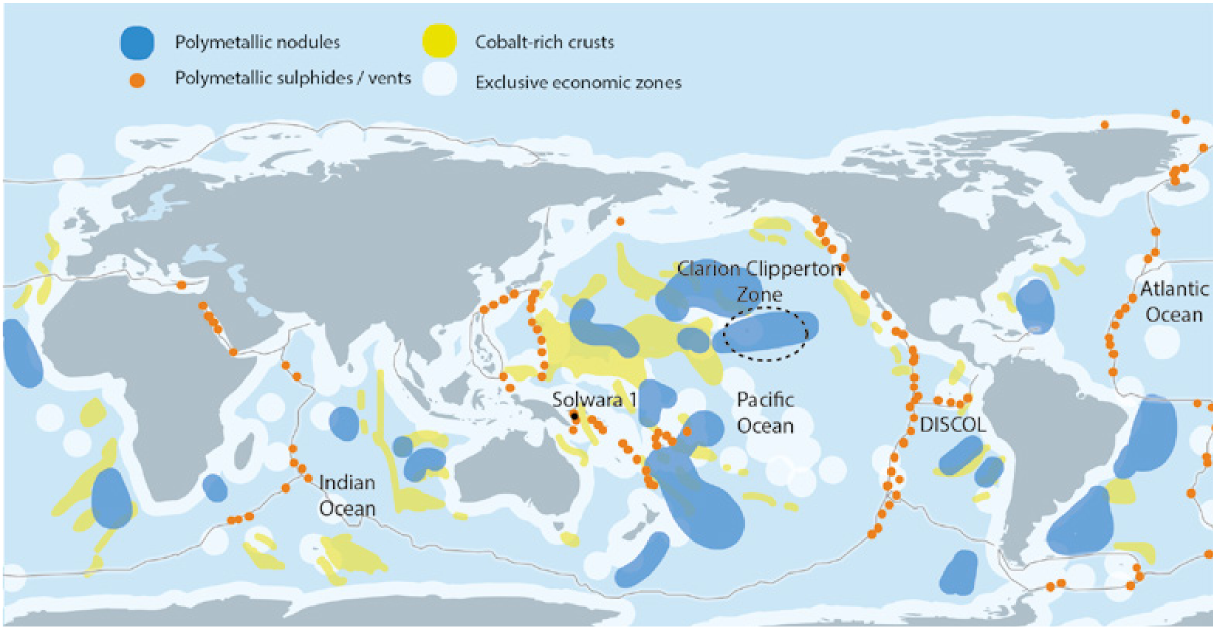
Seafloor Massive Sulphides (SMS)	Bodies of metallic sulphides precipitated at and near the sea floor where hydrothermal fluids (in excess of 350°C) are being emitted on the seafloor. SMS may be found at both hydrothermally active vent sites and dormant vent sites. Among the most valuable metals found in SMS are copper, lead, zinc and gold. Hydrothermal venting and seafloor massive sulphides deposits have been found in all the world's oceans associated with oceanic plate boundaries—mid-ocean ridge-spreading centres, volcanic arcs and back arc basins.

3 The first manganese nodules were identified in 1868 during the Challenger research expedition.

Polymetallic (Manganese) Nodules	Concretions of iron and manganese hydroxides (usually 5–10cm in diameter) that occur in extensive fields in the abyssal areas of the ocean (4000–6500m water depth). Nodules contain significant concentrations of manganese, iron, nickel, copper, cobalt and other metals in smaller quantities, such as titanium. Nodules of commercial interest have been found in parts of the Clarion-Clipperton Zone (CCZ) of the equatorial eastern Pacific, around the Cook Islands in the SW Pacific, and in an area of the Central Indian Ocean Basin.
Cobalt-rich (Ferromanganese) Crusts (CRCs)	Precipitation of manganese and iron from cold seawater forms crusts up to a thickness of 25cm on the flanks and tops of seamounts at depths as shallow as 600m. Crusts usually grow on hard rock surfaces on seamount flanks, ridges and plateaus at water depths that vary from 400m to 7km. The crusts contain commercially important metals such as cobalt, nickel, tellurium, and rare earth elements. Crusts of commercial interest are found principally at water depths between 800–2500m on the flat tops of guyots in the western Pacific. There are about 1,200 seamounts and guyots that may be of commercial interest in the western Pacific Ocean. They may also be found on Arctic and Antarctic seamounts.

Source: ECORYS, 2014a

Figure I: A world map showing the location of the three main marine mineral deposits: polymetallic nodules (blue); polymetallic or seafloor massive sulphides (orange); and cobalt-rich ferromanganese crusts (yellow).



Redrawn from a number of sources including Hein et al. (2013).
Source: Miller et al. (2018).

Some countries—including some Small Island Developing States (SIDS)—have identified potential mineral resources within their continental shelves (UNEP-GEAS 2014b). Indeed, a small number of Pacific island states (e.g. Fiji, Tonga, Solomon Islands, Papua New Guinea and Vanuatu) have previously issued licences for seabed mineral exploration on their respective continental shelves, although, for various reasons, none of these remain active. Some SIDS, including Fiji, Papua New Guinea and Vanuatu, are now calling for a moratorium or a ban on DSM.

Deep-sea mineral resources are also found in areas beyond national jurisdiction. The exploration and potential exploitation of these are regulated by the International Seabed Authority (ISA). The ISA also has a challenging and potentially conflicting mandate to ensure the "effective protection" of the marine environment, and to guarantee that any mining activities in the area are carried out for the "benefit of (hu)mankind". To date, the ISA has entered into a total of 31 exploration contracts with 22 contractors. Of these 31 contracts, 19 are for exploration for polymetallic nodules, seven are for polymetallic sulphides and five are for cobalt-rich crusts (International Seabed Authority [ISA] 2021). Contractors are entitled to explore for minerals over a designated area of the seabed for a period of up to 15 years (although several of the contracts have been extended for further 5-year periods). Exploration contracts for polymetallic nodules cover up to 75,000 km^2, for SMS cover up to 10,000 km^2, and for cobalt-rich ferromanganese crusts cover a maximum 20 km^2 (Miller *et al.* 2018).

Commercial DSM has not yet commenced and many of the techniques proposed for use for seabed mining remain at the conceptual level and are untested. That said, the development of components of deep-sea minerals mining technology is underway, with at least one prototype crawler (Apollo II) being tested under the auspices of the EU's Blue Nodules project. Some techniques assume modifications of existing techniques such as those used in terrestrial surface mining or the oil & gas industry (ECORYS 2014a). Although mining strategies will vary significantly between the three mineral resource types (and perhaps between contractors), all proposed mining operations are broadly based on a mining concept involving some combination of seafloor collector vehicle, with a vertical transport system to carry the ore and sediments to a surface vessel, shipboard separation of ore-bearing materials (dewatering), and subsequent discharge of sediments and water either back into the water column or at the seabed (Drazen *et al*. 2020).

Due to the nascent nature of the DSM sector, characterizing the financing mechanisms is difficult. The current cost estimates, lack of proven track record of the industry, and lack of regulatory certainty may make raising capital to support DSM projects very challenging. That said, it is possible to identify those entities that have an economic interest in the sector and through which finance may flow, including:

Countries holding ISA exploration contracts: The largest number of exploration contracts in the area beyond national jurisdiction are held by states sponsoring DSM ventures, including China, France, Germany, India, Japan, Poland, Russia and South Korea. As such, these states are directly funding DSM activity, often through state-owned enterprises.

Countries that have deep-sea mineral deposits of commercial interest within national jurisdictions: As noted above, many countries have mineral deposits within their continental shelves. With the possible exception of Japan, which has explored for SMS deposits within its EEZ, although no countries are currently directly supporting DSM activities under their jurisdiction, there is the potential for states to enter into shared equity partnerships to finance seabed mining activities. To date the one example where this has occurred is Papua New Guinea, which entered into such an agreement with the mining company Nautilus Minerals. In this case, the government of Papua New Guinea invested approximately US$115 million in the *Solwara 1* mining venture. Nautilus Minerals subsequently went into administration, leaving major creditors, including the government of Papua New Guinea, holding significant realized losses. Other countries are certainly also providing indirect support for DSM activities within the limits of their continental shelfs.

DSM companies that hold licences to explore: A small number of private and publicly listed firms, which either hold licences directly or through subsidiaries to explore within EEZs or are sponsored by states to hold ISA exploration contracts, are also currently engaged in exploration activities. These companies may offer potential investors high-risk/high-return investments and typically appeal to high-wealth private investors and venture capital firms. Some of these companies are fully owned subsidiaries of larger multinational companies or may be fully listed on the capital markets themselves.

Key environmental and social impacts and dependencies

Exploration and production impacts

The deep sea contains many of the most pristine, biodiverse, poorly studied, and evolutionarily remarkable ecosystems on our planet (Smith *et al.* 2020), which are globally important for: earth system regulation; climate regulation and climate change mitigation services; fisheries and other ecosystem services; genetic and evolutionary processes; and the maintenance of ocean chemistry and primary productivity (FFI 2020). Although no actual DSM activity currently occurs, the broad scientific consensus to date indicates that DSM will be highly damaging to deep-sea ecosystems and the broader ocean ecosystems with which they interact as well as causing a significant loss of biological diversity (Niner *et al.* 2018).

The scale at which these impacts may occur is largely unknown and most of the effects remain unstudied (FFI 2020). The highly connected and dynamic nature of the ocean and the complex biochemical and physical processes that drive ecosystem function implicate widespread impacts that are likely to be very difficult to control and contain. Furthermore, the cumulative impacts from mining combined with climate change add to the levels of uncertainty and may exacerbate disturbance from mining (Smith *et al*. 2020).

DSM is planned to occur in areas that are generally poorly known, especially with regard to their ecology and sensitivities. This leads to great uncertainty in the estimation of impacts (Jones *et al.* 2019). Most deep-sea ecosystems targeted for mining have some combination of ecological characteristics that make them particularly sensitive to anthropogenic disturbance, such as being largely pristine, highly structured, very diverse, dominated by rare species and (extremely) slow to recover from disturbance (Niner *et al.* 2018).[4] These traits make them particularly vulnerable to environmental change (Chin and Hari 2020). Furthermore, the connections of these habitats to the wider global functioning are poorly understood (Levin, Amon and Lily 2020), raising concerns about the broader impacts on global ocean system function.

4 In some cases rates of recovery will be measured in terms of decades—or even centuries—depending on the resource and the extent of mining activity.

The lifecycle for DSM would follow a number of sequential development phases (Figure II).

Figure II: Stages in the potential DSM life cycle

Prospecting	Exploration	Exploitation	Mine site closure
▪ Search for mineral deposits, including estimation of composition, distribution and value of resources (without exclusive rights to exploit those resources).	▪ Search for mineral deposits, including analysis of those resources, use and testing of recovery systems and equipment, processing and transportation systems (with exclusive rights to exploit those resources).	▪ Large scale extraction and recovery, for commercial purposes, that would include mine site construction, mineral extraction activities, on-site processing of mined material and transportation of processed ore.	▪ Mine site closure would include activities related to the closure and abandonment of a mine site and facilities at the end of its economic life, including the proper abandonment of installations and post-mining monitoring.

In most cases the "prospecting" stage is either part of the "exploration" stage or is simply analogous to marine scientific research. It is also unclear what activities would be associated with mine site closure, since there appears to be no realistic potential for the environmental damage resulting from mining activity to be rehabilitated or remediated in any way. Thus, although impacts would occur at each of these stages, by far the biggest impacts would be associated with the mineral extraction, which may, as in the case of nodules, last for several decades.

The major impacts from mining would be similar for the three types of mineral deposit considered here, namely:

i. irreversible loss of substrate and its carbon storage potential and function as animal habitat;

ii. physical disturbance to the seabed, resulting in an operational plume and resedimentation, likely to result in smothering of biota, and clogging for filter-feeders;

iii. the discharge plume and its effects on pelagic and/or benthic fauna depending on the depth of discharge, as well as on the carbon pump, which forms a critical component of the ocean's carbon sequestration capacity;

iv. noise, light and the release of toxic metals, which may affect animals in the water column; and

v. the potential damage to underwater cultural heritage.

There will also be impacts that are unique to each deposit, depending on the geomorphological setting, differing physical conditions, the scale of operations, and the technology used for extraction. (ECORYS 2014b).

Direct impacts

By far the greatest projected impact associated with mining activity is the destruction of seabed habitats and the mortality of associated fauna that grow on these substrates (e.g. deep-water corals and sponges, which are both exceedingly slow-growing and long-lived), as well as fragmentation and modification of remaining habitat through altered mineral and sediment composition, geomorphology, and biogeochemical processes (Niner *et al.* 2018). In many cases, organisms associated with specific mineral deposits (e.g. hydrothermal vent systems and nodule fields) are unique due to geographic isolation. Any mining activity may lead to extinction of those organisms and the permanent loss of unique deep-sea genetic material, which experts believe could one day be used to create new antibiotics, anti-cancer drugs and nutritional supplements (see for example Tortorella *et al*. [2018]).

In the case of nodules, this habitat loss is twofold since, in addition to the removal of the underlying seabed material, the nodules themselves provide a unique habitat for specific assemblages of organisms. Because nodules take millions of years to form, the loss of such habitats would essentially be permanent (Chin and Hari 2020).

Indirect impacts

The main indirect impacts of mining are likely to be associated with plumes of sediment, created either at the point of excavation of the sea floor or at the point of discharge of excess water and sediment from the surface vessel. These impacts, which are likely to occur both within and beyond directly mined areas, would be diffuse and difficult to predict.

Large amounts of sediment disturbed during seafloor mining activities would give rise to sediment plumes that may remain in suspension for extended periods (existing models suggest that this could last for up to a year in the case of nodule fields) and may disperse widely, impacting areas many tens of kilometres away from the mining site. Potential impacts of such plumes, both within and beyond the directly mined area, include the smothering of benthic habitat and biota, interference with feeding activities, and the release and spread of nutrient-rich and toxin-laden water (Niner *et al.* 2018).

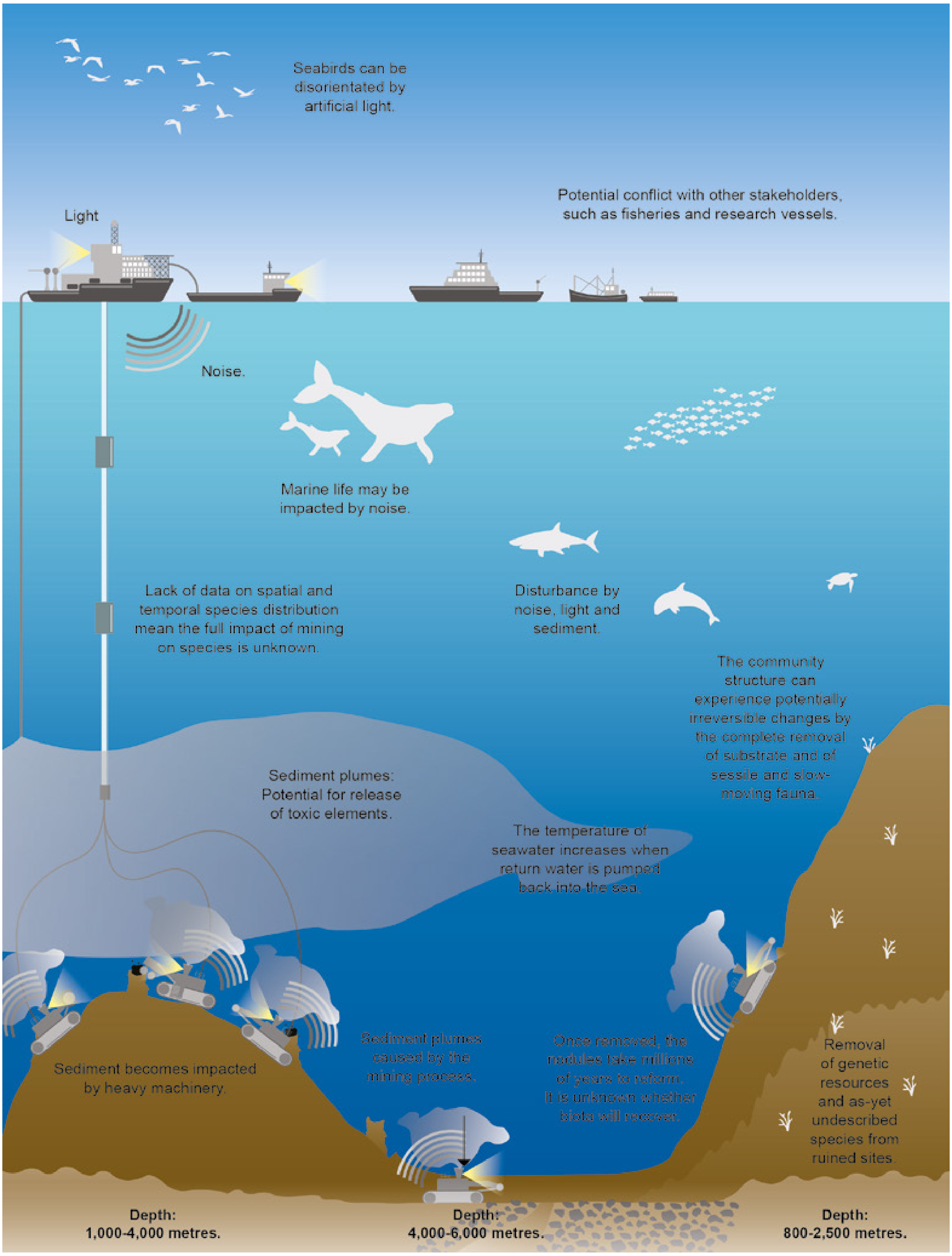
Of particular importance for the water column would be the discharge of the tailings (likely to comprise largely seawater with some mineral traces and sediment) from the mining vessel back into the water column, which would introduce sediment and dissolved metals over potentially large areas (Drazen *et al*. 2020). The impacts are likely to vary depending on the depth at which that discharge is made, and experiments are underway in this regard to identify optimal depth to minimize impacts.

Dewatering may have a clouding effect, resulting in localized impacts on primary productivity and potentially reducing oxygen levels. In addition, the released seawater will be different in composition from when it was collected with the ore and is likely to contain different levels of salinity, temperature and trace amounts of toxic chemicals. Ingestion of the contaminated water by organisms may create a potential for bioaccumulation through the food chain (UNEP-GEAS 2014b). In addition, concerns have been raised about the impact of mid-water discharges on broader level global ocean ecosystem services such as fisheries, carbon cycling and climate regulation, detoxification and nutrient cycling whose values in the high seas and deep ocean are not yet fully understood or quantified but are potentially significant.

A further potential concern relates to the release of stored carbon from seabed sediments. According to recent research, marine sediments store approximately twice as much organic carbon as terrestrial soils. Sediments in abyss/basin zones account for 79 per cent of global marine sediment carbon (Atwood *et al*. 2020) and, as such, represent a large and globally important carbon-sink. However, the lack of protection for marine carbon makes it vulnerable to human disturbances that can lead to their remineralization to CO_2, further aggravating climate change impacts (Atwood *et al*. 2020). A recent study published in the journal *Nature* (Sala *et al*. 2021) has also suggested that significant amounts of stored carbon can be released from the seabed sediment into the water, as a result of seabed disturbance (in the case of the Nature study—bottom trawling). In the current context of global climate change, the implications for seabed mining contributing to carbon emissions is a cause for concern.

Given that mining operations operate on a continuous 24-hour basis, several impacts common across the extraction of the three types of deposits include those associated with elevated levels of underwater noise, the introduction of artificial light to deep sea environments that are normally light-deprived (both of which may attract or deter some fish species, and may alter normal feeding and reproduction behaviours) and the impacts associated with the presence and operation of mining ships and supply vessels above the mine site. Other concerns include the introduction of oxygen-rich water into low-oxygen environments and the release of toxic metals in the plumes (Figure III).

Figure III: The potential impacts of deep-sea mining on marine ecosystems. Schematic not to scale.



Source: Miller et al. 2018.

Furthermore, the combined potential impacts from mining and other stressors on the marine environment (such as climate change, unsustainable fishing and pollution) increase the level of uncertainty and may exacerbate disturbance from mining (Smith *et al*. 2020). Simply put, if mining was to go ahead with the current state of knowledge, species and functions could be lost before they are known and understood (Levin, Amon and Lily 2020). For this reason, there are increasing demands for a moratorium to be placed on DSM, at least until more is known and understood about the potential impacts and how to manage them (see for example the *Marine Expert Statement Calling for a Pause to Deep-Sea Mining* that has been signed by 622 marine science and policy experts from more than 44 countries).[5]

Transportation impacts

Following initial preprocessing and dewatering on the surface mining vessel, mined material is expected to be transported by ship to shore-based facilities. Therefore, in addition to the normal environmental impacts that are associated with maritime transport (as reported in *Turning the Tide*) such as marine pollution, atmospheric emission, underwater noise and physical disturbance, transporting mineral ore from the mining site also has potential impacts associated with accidental discharges of mineral ore to the marine environment during the transfer phase from the mining vessel to the transporting vessel.

Impacts associated with processing and utilization

Based on current metal processing technologies, the downstream processing of deep-sea minerals is expected to take place entirely on land. Based on metallurgical approaches applied to terrestrial deposits, this will involve processes to separate and extract the valuable minerals including crushing and chemical extraction of specific elements (Ochromowicz, Aasly and Kowalczuk 2021). However, the final choice of processing plant will strongly depend on economic and technological considerations. As with offshore petroleum, where new coastal facilities are constructed as a specific component of an overall mining project, the impacts of these facilities on the coastal environment should be considered by investors.

In addition to environmental impacts such as habitat damage, pollution of rivers and coastal waters and air emissions, perhaps the greatest impacts will be socioeconomic impacts on local communities.

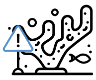
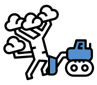
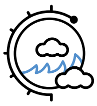
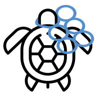
For example, large-scale developments may result in a loss of access to certain coastal areas directly impacting livelihoods through, for example, loss of access to sites of cultural significance or the inability to carry out economic activities. Construction may cause damage to culturally important heritage sites and the disturbance caused by construction lights, noise and dust may cause a nuisance.

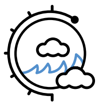
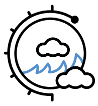
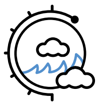
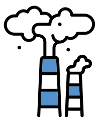
5 seabedminingsciencestatement.org/. Accessed 20/01/2023.

The pressures and their impacts on environment and society discussed in this section are listed in Table 3 below.

Table 3: Pressure and impacts of the deep-sea mining sector

Pressures	Impacts	Explanation
Seabed disturbance and disruption of habitat		The physical removal of seabed material and mineral deposits results in the destruction of benthic habitats. Mining polymetallic nodules will permanently remove nodules as a habitat for attached species, such as sponges, sea anemones and xenophyophores, as they will not regenerate. It is expected that there may be many other species using nodules as a preferred habitat. The mining of seamounts for cobalt crusts and hydrothermal vents would have similar permanent impacts.
		The removal of mineral deposits and the underlying sediments will result in a direct loss of organisms from those habitats and may cause local extinction of genetically isolated species that may have (as yet undiscovered) bio-active properties that may be beneficial to humankind.
		High rates of physical disturbance and indirect impacts arising from mining may make those ecosystems far less resilient to other types of change. Their ability to recover from such damage is extremely limited due to their slow production rates.
		Removal of mineral deposits and the discharges of metals associated with sediment may lead to disruption of the biogeochemical processes of deep ocean ecosystem with potential consequences to the nutrient balance and associated life cycle of species.
Increased turbidity of water above the seafloor		The discharge of sediments during mining and initial processing of product may also cause changes to adjacent benthic habitats through increased sedimentation, smothering and changes to the sediment structure. This may result in altered sediment fabric and habitat structure that would vary depending on the intensity, method, and duration of mining.
		Increased turbidity may adversely impact the surrounding benthic fauna, which are likely to be poorly adapted to cope with disturbance. Large amounts of disturbed sediment can also have a smothering effect on certain sea floor residents.
		As well as directly impacting benthic communities through deposition of sediment, other impacts to marine life may include impacts to behaviour from poor visibility, impacts of chemicals made bioavailable through disturbance and impacts to free-swimming organisms such as zooplankton and micronekton in the water column.

Discharge of fine sedi-ments and metals to the water column		The discharge of processing slurry will result in plumes that may travel over large distances and remain in suspension for extended periods. Discharge within the water column may result in localized impacts on primary productivity and potentially reduce oxygen levels. In addition, the released seawater will be different in compo-sition from when it was collected with the ore and is likely to contain different levels of salinity, temperature and trace amounts of toxic chemicals.
		Impact of mid-water discharges on broader level global ocean ecosystem services such as fisheries, carbon cycling and climate regulation, detoxification and nutrient cycling whose values in the high seas and deep ocean are not yet fully understood or quantified.
		Discharge plumes may have higher temperatures compared the water in which they are discharged. Over time there is a risk that this might change the temperature profile of certain pelagic layers, thereby impacting pelagic biota associated with those layers. Discharge plumes may also include higher oxygen levels than the receiving environment, with possible harmful effects to low-oxygen biota.
		Discharge within the water column may result in localized impacts on primary productivity and potentially reducing oxygen levels. This may have significant impacts for pelagic food chains, although the scale of these impacts is unknown. This may have particular implications for pelagic mega-fauna (such as tuna) that feed in the pelagic zone.
		Large amounts of disturbed sediment can also have a smothering effect on certain sea floor residents. It may also have a significant effect on gelatinous zooplankton and micronekton in the water column.

Disruption to wildlife		The mining activity will create underwater noise from variety of sources including operation of seabed crawlers and the pumping of nodules up and down the risers. This may result in changes in the behaviour of some animals, with some organisms entirely avoiding an area that may be critical to their life cycle (e.g. a feeding or breeding ground). Physical damage to hearing and disruption to communications may also result from high levels of noise.
		Vessel movements within and to/from mining sites can result in collisions with marine life, notably large fish, turtles and marine mammals, as well as noise that may result in changes in the behaviour of some animals, with some organisms entirely avoiding an area that may be critical to their life cycle (e.g. a feeding ground). Physical damage to hearing and disruption to communications may also result from high levels of noise.
		High light levels at the seafloor might impact on those organisms that are poorly adapted to such light levels. For mobile species this might change their behaviour or result in displacement. For benthic species, this might directly affect their ability to survive. There is some evidence that the high levels of lighting associated with mining vessel operations can affect the behaviour of seabirds.
Pollution and water contamination	 	Metals released during deep-seabed mining will occur in different physical states. Metals may enter solution/aqueous phase and be taken up across the gills, body wall and digestive tracts of exposed animals. Alternatively, metals may adsorb onto sediment particles or flocculates and be ingested; this may be particularly the case for metals released during dewatering of the ore slurry.
	 	Handling and use of fuel oil/diesel/hydraulic fluids may give rise to minor spills of fuel. In more extreme cases, collisions between mining vessels and other ships may result in breaches of fuel oil tanks allowing fuel oil to spill into the marine environment. Spills of oil may significantly impact marine living resources (e.g. fisheries) making them unavailable for exploitation. Similarly, oil pollution may impact other economic sectors of the blue economy such as tourism beaches and infrastructure.
Air pollution		The discharge of air pollutants to the atmosphere in emissions from dredging vessels may change the chemical composition of the sea and the health of all marine life. Pollutants that alter marine biochemistry include CO_2, SO_x, NO_x, untreated ballast water and fuel residue.
		All ships burn fuel to generate power. GHG emissions from fuel combustion contributes to global warming and acidification, resulting in storm surges, sea level rise, and coastline erosion.

Use conflicts		Temporary loss of access to marine areas may directly impact other users' ability to carry out their own economic activities effectively resulting in lower economic returns than normal. Damage to habitats and the resulting losses of biodiversity in those areas reduce their ability to support other productive sectors.
		The construction of new facilities may result in a temporary or (more likely) permanent loss of access to those areas for local communities. Loss of access might impact livelihoods in a number of ways including loss of access to sites of cultural significance or the inability to carry out economic activities.
Social and economic conditions		Construction of mineral processing facilities may permanently damage or destroy sites of cultural significance (e.g. burial sites or middens).
		High rates of pay associated with construction work may distort local economies including raising the price of property, land and everyday commodities. The loss of labour force may also directly impact other economic sectors.
		New economic opportunities in at-sea work, mining projects and construction—if following past trends—are likely to be more available to men, leading to greater income disparities between men and women. Access to deep-sea resources may be more readily achievable for technologically and financially advantaged groups, which could cause inequities in participation benefits,
		The construction of new facilities may result in a temporary or (more likely) permanent loss of access to those areas for local communities. Loss of access might impact livelihoods in a number of different ways including loss of access to sites of cultural significance or the inability to carry out economic activities. The influx of new sources of certain metals with limited markets may undercut the prices for existing on land mineral producers]

Relationship to sectors of the blue economy

In addition to the impacts outlined above, DSM activities may have negative effects on blue economy sectors, including:

Fishing: sedimentation and pollution into the water column may disrupt pelagic fishery stocks (e.g. tuna). Any mining activity on seamounts has the potential to conflict with fishing activities. There may be further, unanticipated consequences to fishery life cycles caused by seabed damage and sediment plumes.

Shipping: mining activities have the potential to conflict with shipping if mining occurs in or close to key shipping routes.

Subsea cables: Submarine cables, which form the backbone of international telecommunications, extend across many areas of the deep seafloor, where exploratory mining licences have been granted by the ISA. The liability and legal implications that would be triggered by mining activities that inadvertently damage such cables are unclear and untested.

Pharmaceutical and scientific research: Deep-sea mining could potentially cause as yet undiscovered species to become extinct, potentially removing possibilities for finding novel drugs.

Potential risks of financing deep-sea mining

Consideration of the full scope of ecosystem risks from deep-sea mining requires comprehensive evaluation of impacts on both benthic and midwater ecosystems. Despite some existing general knowledge, broadscale ecological baselines for midwater ecosystems do not exist and the data collected by contractors to date appears to be very limited (Drazen *et al.* 2020). With the current absence of a detailed understanding of ecological relationships, the only conclusion that can be drawn is that, at present, no robust, precautionary approach exists to safeguard the ocean against the potential ecological impacts associated with deep-sea mining.

As a result of serious concerns over the impacts on ocean ecosystems, DSM has attracted, and continues to attract, significant opposition. According to the World Economic Forum (WEF) (2021), more than 90 civil society organizations, which manufacturers might count among their stakeholders, have voiced concerns over the potential environmental effects of deep-sea mineral extraction and the associated regulations and compliance systems that are currently under consideration. Scientists, environmentalists, the European Parliament, and some national governments are now calling for a moratorium on deep-sea mining until its ecological consequences can be better understood. The European Commission also states that "marine minerals in the international seabed area cannot be exploited before the effects of deep-sea mining on the marine environment, biodiversity and human activities have been sufficiently researched, the risks are understood and the technologies and operational practices are able to demonstrate no serious harm to the environment, in line with the precautionary principle" in the EU Biodiversity Strategy (European Commission 2020). Calls for a moratorium were given added impetus during the 2021 IUCN World Conservation Congress, which voted almost unanimously to adopt Motion 069 calling on all state members to support and implement a moratorium on deep-seabed mining,[6] thereby signalling a clear lack of social licence to operate for this activity.

Increasingly, these concerns are also being supported by a broad range of private sector organizations. For example, the BMW Group, Google, Patagonia, Philips, Samsung SDI, Scania, Triodos Bank, Volkswagen Group and Volvo Group have all joined a public statement supporting a moratorium and committed not to use metals produced from

6 iucncongress2020.org/motion/069.

deep-sea mining until the environmental risks are "comprehensively understood" (World Wide Fund for Nature and Deep Sea Conservation Coalition 2022). In addition, a growing number of companies[7] and financial institutions[8] are explicitly distancing themselves from deep-sea mining by excluding deep-sea metals from their procurement policies and/or investment policies.

There are, therefore, significant challenges to overcome before the deep-sea mining industry is recognized as economically viable or as a responsible industry that can make a positive economic contribution (Roche and Feenan 2013). These challenges present potential investors with several significant risks.

With global calls for a moratorium on DSM increasing, it must be understood that companies seen to be engaging in or supporting DSM may suffer serious reputational harm. Moreover, with an increasing number of companies distancing themselves from deep-sea mining, those organizations actively supporting DSM may find that they are excluded from the supply chains of such companies.

A second critical risk relates to the current lack of a comprehensive regulatory framework. The development of environmental regulations for seabed mining is hampered by profound gaps in basic knowledge about deep-sea ecosystems and in our ability to predict responses to stressors. As a result, ongoing concerns over the environmental risks associated with DSM may still result in changes to existing or proposed regulatory frameworks governing the activity. This lack of regulatory certainty creates significant risks for miners and investors alike. It is conceivable, or even highly likely, that if any future deep-sea mining activity were to cause significant environmental damage, legal action would be taken to hold those responsible legally liable for those damages. The insurance market for deep-sea mining may not yet have developed due to the nascent stage of the industry, but initial indications are that regulators may have particular requirements for insurance policies from operators, as a precondition to granting mining licences.[9]

Finally, from an operational perspective, consideration needs to be given to the risks associated with the operations of the actual mining company, since further complications can arise if official mining approvals do not translate to community consent or a social licence to operate (Roche and Feenan 2013). Civil society has already demonstrated the willingness and capacity to engage in direct protest against marine extractive industries. This may translate directly into operational risks.

As recently highlighted by the High Level Panel for a Sustainable Ocean Economy, until the need for—and potential consequences of—DSM are better understood, it is hard to

7 For example, Microsoft has established a moratorium on using minerals sourced through deep-seabed mining until the proper research and scientific studies have been completed; Ford, General Motors, Daimler, Tiffany & Co. and many other companies are members of IRMA (Initiative for Responsible Mining Assurance), meaning that they will only source metals from IRMA-certified mines. IRMA does not allow its system of certification to be used by deep-sea mining companies.

8 To date the following international lending institutions have also created explicit policies excluding financing of deep-sea mining: Lloyds Banking Group, ABN Amro, NatWest, BBVA Bank and Standard Chartered.

9 For example, the Draft ISA Regulations on Exploitation of Mineral Resources in the Area require that all contractors of ISA obtain and maintain, and cause its subcontractors to obtain and maintain, in full force and effect, insurance with financially sound insurers satisfactory to ISA.

arrive at any other conclusion than that **DSM is conceptually difficult to align with the definition of a sustainable blue economy** (Stuchtey *et al*. 2020). Furthermore, in the context of ongoing work being undertaken by UNEP FI with respect to financing of the sustainable blue economy, there is currently no foreseeable way in which investment into DSM activities can be viewed as consistent with the Sustainable Blue Economy Finance Principles.

It is widely accepted that demand for metals for use in clean energy and emerging technologies will increase in the next decades, raising the likelihood of supply risk (International Energy Agency (IEA) 2022). While closing the loop on metals use is possible—since in theory all metals are recyclable—we are some years away from achieving this. Indeed, current recycling rates of many metals from end-of-life product are very low, sometimes less than 1 per cent (UNEP, 2011, International Resource Panel [IRP] 2020).

Instead of supporting the nascent DSM sector, financial institutions wishing to support the transition to a sustainable blue economy could focus efforts on alternative strategies that would: (i) reduce the environmental footprint of terrestrial mining; and (ii) support the transition toward a circular economy that promotes: recycling and reuse of components from products at the end of their life cycle so that raw materials are fed back into the economy, investments in innovation in battery technology, mass transit systems, telecommunication and computer systems, making current minerals demand obsolete and setting us on a path to a circular resource economy (Ali *et al*. 2017).

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