DEEP SEA MINING

A COMPREHENSIVE REVIEW

IWDG

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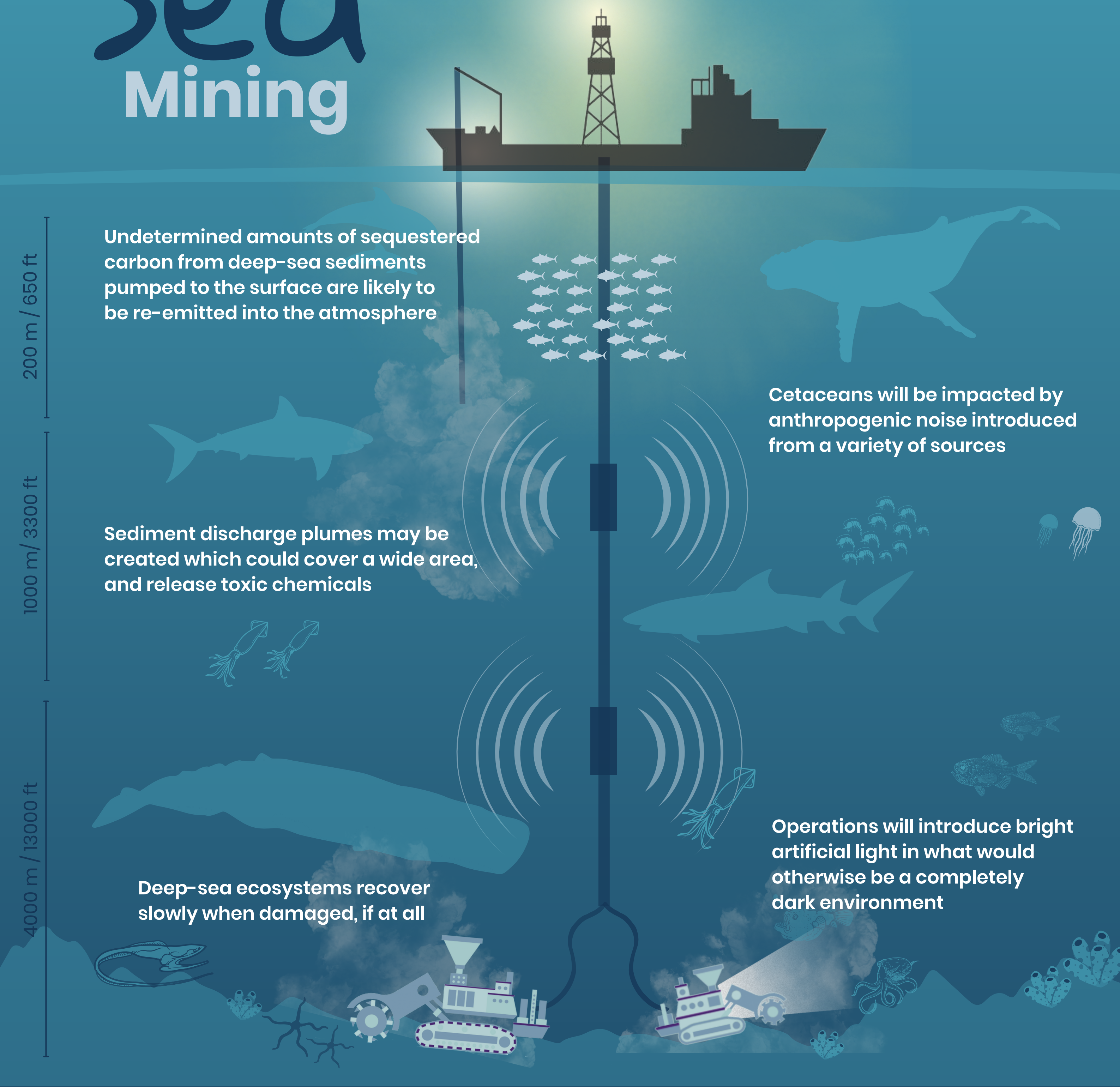

Mining types

- Cobalt-rich crusts
- Polymetallic sulphides
- Polymetallic nodules
- Other forms of deep sea mining

Environmental impacts

- Noise pollution
- Light pollution
- Sediment plumes and resuspension of toxic chemicals
- Climate change

Deep Sea Mining: A schematic showing some of the potential impacts on marine ecosystems. Schematic not to scale.

Psychropotes semperiana- aka blue gummy squirrel 5000 m W CCZ- DeepCCZ Project

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FOREWORD

There are a number of different resources for which Deep Sea Mining (DSM) is proposed. DSM systems will have varying impacts depending on the resource to be mined and the depth and environment in which such deposits are located. However, deep-sea ecosystems show extremely slow recovery rates and there are no existing methods to assist with habitat recovery.

Mitigation aims as much as possible to limit impacts within the zone to be mined, but benthic habitat destruction is currently an inevitable consequence of DSM. It is also highly likely that sediment plumes and noise will far exceed the limits of any commercial licence and impact a far greater area than is licenced to be mined. Adequate Baseline data does not exist for deep-sea habitats and measuring the impacts of mining is currently impossible. Therefore, the Irish Whale and Dolphin Group does not currently support commercial DSM even on a limited scale.

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Cover photograph : Sperm whales in the Rockall Trough (Photo Irish Air Corps Maritime Squadron)

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INTRODUCTION 01

The increasing demand for scarce minerals and trace elements used in technologies such as smart phones, electric cars and green energy is putting greater demand on existing land-based sources of these minerals. Evermore attention is being turned to opportunities in the deep seas (>200 m), where mineral deposits can be retrieved from the sea floor through Deep Sea Mining (DSM).

"The potential catastrophic impact of mining operations on deep-sea habitats is undeniable."

With an estimated value of $15.3 billion dollars by 2030, the development of DSM would be some of the largest planned mining operations in history. Current exploration licences cover an area of 1.5 million km^2 alone, which if mined commercially to entirety, would be the equivalent to mining the combined area of France, Spain, Portugal, and Germany.

Deep sea ecosystems are largely unexplored, and our knowledge of them is extremely limited. Areas which have been explored are rich in biodiversity as their unique physical and geological characteristics provide a range of different habitats. The deep sea also supports key biophysical processes, such as carbon sequestration, and plays a key role in the provision of food and genetic resources.

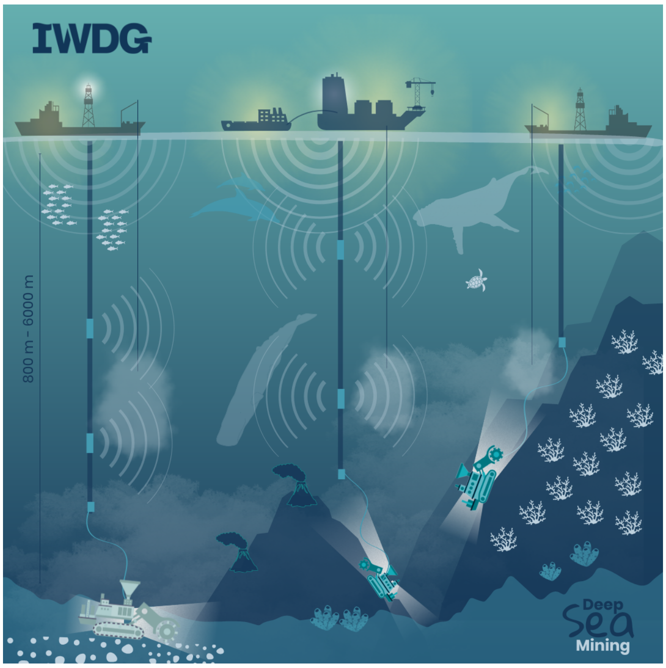
Ireland has an extensive Exclusive Economic Zone (EEZ), with rich and diverse marine ecosystems, including poorly studied deep water ecosystems and species. Ireland could experience emerging deep sea mining interests in the coming decades. The Irish Whale and Dolphin Group is committed to protecting cetaceans and their habitats in Ireland and have identified DSM as a potential threat to our oceans.

In this Comprehensive Review we take a dive into the deep to investigate the potential impacts that deep sea mining could have on cetaceans and their habitats.

DIFFERENT MINING TYPES

02

Extraction of minerals from the deep sea has been projected at several different habitats including seamounts, hydrothermal vents, and abyssal plains.

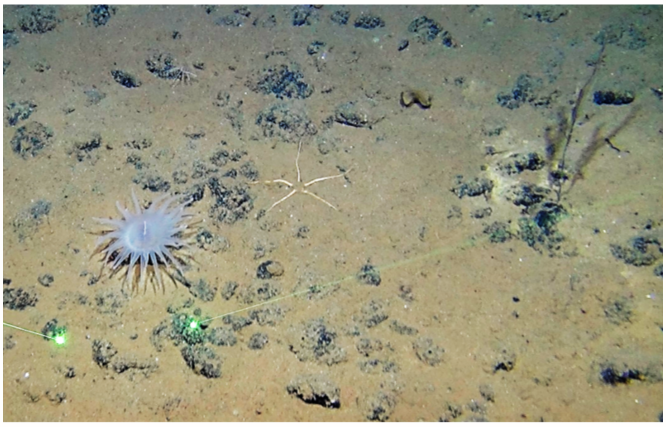


An infographic showing the processes involved in deep sea mining for the three main types of mineral deposit. Schematic not to scale.

2.1 Cobalt-rich Crusts

Cobalt crusts (also known as polymetallic or ferromanganese crusts) develop as layers coating the summit and flanks of seamounts and continental slopes, growing at 1 to 5mm every million years [1]. Cobalt crusts are deposited as delicate lamina onto rock on the seafloor by the precipitation of constituents directly from the surrounding seawater [2]. Mining of cobalt crusts is challenging as they are firmly attached to the rock substrate and cannot be simply picked up, but instead need to be laboriously broken from the underlying rock. Older oceanic crust areas have the greatest deposits and the highest potential for mining. Seamounts in the Pacific Ocean, with the oldest deposits, are currently the most attractive. The Atlantic is a younger ocean and therefore cobalt crust formation has been more limited. However, several seamounts have been highlighted as having mining potential.

While much data on deep water mineral deposits in Ireland is largely absent, and the extent of cobalt crusts are not known, deposits have been identified close to the Irish Exclusive Economic Zone (EEZ). Therefore, it is highly likely similar deposits are present within the Irish EEZ, and the wider Irish Declared Area out to 350 nm. The occurrence of cobalt crusts on seamounts, which are often also hotspots for cetacean activity and biodiversity, are likely to lead to a conflict of environmental interests against those of mining companies.



4200 m depth eastern CCZ - Diva Amon and Craig Smith - ABYSSLINE

2.2 Polymetallic Sulphides

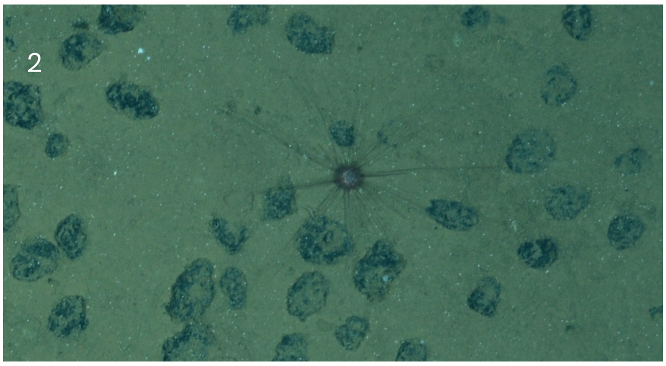
Polymetallic sulphide deposits (also known as Seafloor Massive Sulphides (SMS)) are formed by the precipitation of metals from super-heated fluids expelled at hydrothermal vents. They are typically found along spreading margins and subduction zones of the earth's oceanic crust, often associated with volcanic activity, with the majority of vent systems concentrated along mid-oceanic ridge systems in the Pacific.

In the North Atlantic, considerable investigation has been carried out along the Mid-Atlantic Ridge, where 11 known active vent fields have been identified, all of which are located in areas where exploration contracts have been granted by the International Seabed Authority (ISA) [3].

In Irish waters, while some active hydrothermal vents exist, they are relatively few and old vents are not known to exist in large numbers. Therefore, this particular type of mining is not likely to be significant in Irish waters but may occur in adjoining international waters.

Hydrothermal vents. White smoker.
Images courtesy of the NOAA Ocean Exploration

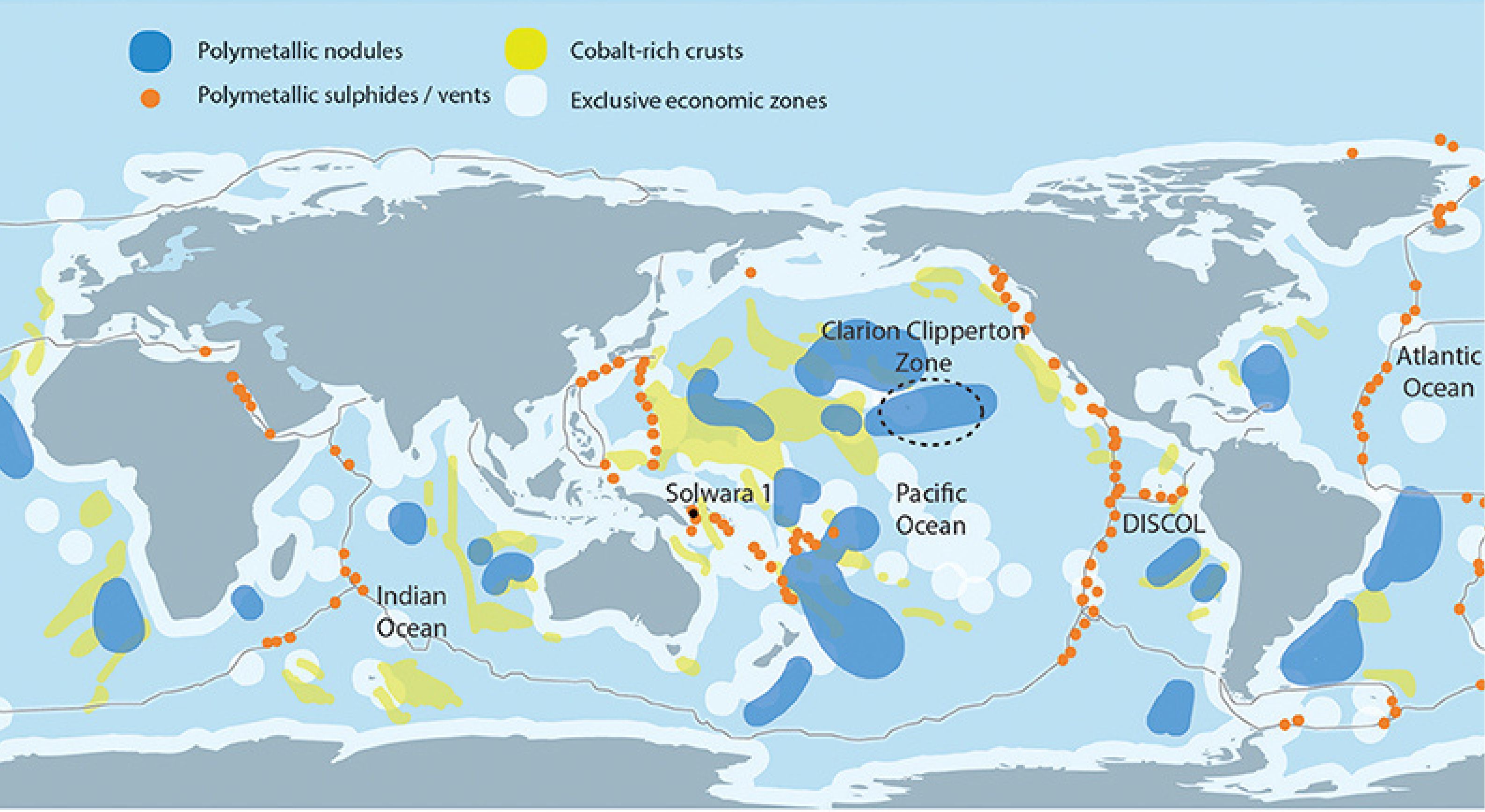
2.3 Polymetallic Nodules



(1) Nodules recovered from box core sample from 4200 m depth in eastern CCZ - ABYSSLINE Project
(2) Urchin on nodules 5000 m W CCZ - DeepCCZ Project

Polymetallic nodules (often termed Manganese Nodules) are found in deep abyssal plains. They range in size but are generally 10 to 50 mm at their longest dimension [4]. The removal of the nodules themselves, which were formed over millions of years, will represent a permanent change of habitat. Manganese nodule mining plans to use large tractors or crawlers to plough and remove seabed material before it is transported to the surface for processing. The metallic nodules are then removed and the sediment is deposited at an agreed depth.

This type of mining will possibly remove a greater amount of fine sediment and unrequired seabed material than other mining techniques. Consequently, sediment removal and redeposition is of major concern.



A world map showing the location of the three main marine mineral deposits: polymetallic nodules (blue); polymetallic or seafloor massive sulfides (orange); and cobalt-rich ferromanganese crusts (yellow) [5]. Original data from [4] Copyright © 2018 Miller, Thompson, Johnston and Santillo .

2.4 Other Forms of Deep Sea Mining

Apart from the main three mineral deposits of interest there are several other potential mineable deposits. Metalliferous sediments in brine pools are known only from the Red Sea and are devoid of fauna, but mining will still have indirect environment effects. Mining of phosphate nodules is of interest due to their high phosphate content and potential use in fertilizers. They are found in the upper continental slopes at 200m to 400m water depth [6]. Additionally, several countries are examining the extraction of gas hydrates from deep-sea sediment to produce methane [5].

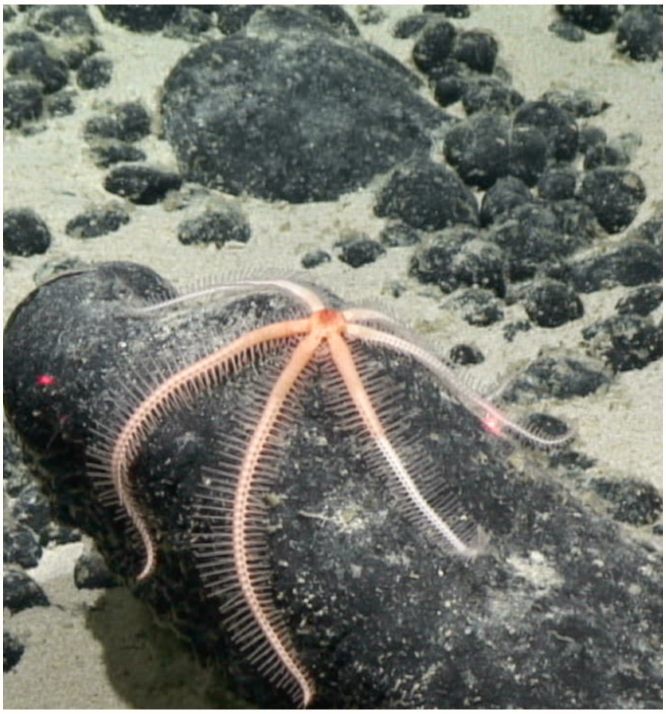
Dissociation of methane hydrates to form free methane could release large quantities of methane gas into the atmosphere, adding to ocean acidification and/or global warming [7].

REGULATION OF DEEP SEA MINING 03

In 1994 the International Seabed Authority (ISA) was established through the United Nations Convention on the Law of the Sea.

In 1994 the International Seabed Authority (ISA) was established through the United Nations Convention on the Law of the Sea. The ISA is responsible for the regulation of all mining activities in international waters and is required to ensure effective protection of the marine environment and human life, as well as promote and encourage scientific research. The ISA is made up of 168 members, comprising of 167 member states (including Ireland), with the European Union as the 168th member. For each mining company to acquire a licence they need to be sponsored by a member state. The ISA assumes the position of regulator but will not take on liability for mining activity, which is instead assumed by the sponsoring state, which must ensure effective legislation to cover this liability. It has been reported that 13 exploration licences have been issued to states with no relevant laws in place to cover liabilities from DSM, while those that have laws in place currently appear to have numerous inadequacies in their legislation [8].

Current exploration companies are required to submit reports to the ISA secretariat, but these reports are not disclosed to the public and there has been no action taken against companies for breaches of exploration conditions. The exact nature of the reported breaches is not known or disclosed and there is a lack of transparency in how the ISA operates. The ISA appears committed to the development of DSM on which its existence and revenue depends. With other regulatory bodies in national jurisdictions, it is normal to give environmental monitoring and regulatory responsibility to an independent body to avoid a conflict of interest.



Brisingid asteroid on manganese encrusted rock with nodules around - 4400 m western CCZ - DeepCCZ Project

KNOWLEDGE OF CETACEANS IN DEEP SEA MINING SITES

04

Irish waters support a rich diversity of cetacean species, both inshore and offshore, including resident (breeding) and migratory populations. To date, 26 species have been recorded within the Irish EEZ, nearly one-third of all the known species of cetaceans worldwide. However, our knowledge of the ecology and habitat requirements of cetaceans in Irish waters is still relatively poor, and especially so for deep-water and oceanic species. There remains much to do to determine reliable abundance estimates, temporal trends, and the location and timing of breeding for most Irish cetacean species. All cetacean species and their habitats are protected under Irish, EU, and international legislation. To protect these species, and their habitats, we need to understand more about their population dynamics and ecology.

Sowerby's Beaked whale @obSERVE Acoustic, GMIT. Photo taken by Anna Cucknall

Lack of baseline knowledge of pelagic ecosystems has been highlighted as a particular deficit [9], with huge deficiencies in species and habitat information and a dearth of published scientific material on which to base assessments. Acquisition of baseline data in the high seas is rare. Therefore, much more needs to be done to establish baseline data for environmental impact assessment of deep-water cetacean species with which we are less familiar.

Beaked whales. Photo taken by Simon Berrow

An increased level of research is needed on cetaceans in deep water areas in Irish waters so that, should mining or other new exploitation requirements develop in the future, there is baseline knowledge of cetacean distribution, abundance, population structure and stock identity. This will allow impacts on cetaceans to be quantified in Irish waters. This should also be applied in international waters where mining activity is likely to take place. Site-specific surveys must be completed to establish baseline data on all marine mammal species occurring at and in waters adjoining mining sites.

ENVIRONMENTAL IMPACTS 05

5.1 Noise

Noise produced during DSM could have far reaching effects on the marine environment. Potential elevated noise comes from a variety of sources, ranging from mining equipment to pumps and thrusters, to a range of acoustic geophysical and undersea communication equipment.

Noise from DSM will be introduced from the surface to the seabed during all phases of the DSM process.

Exploration licences currently issued by the ISA place no temporal or threshold limits on the noise of mining operations.

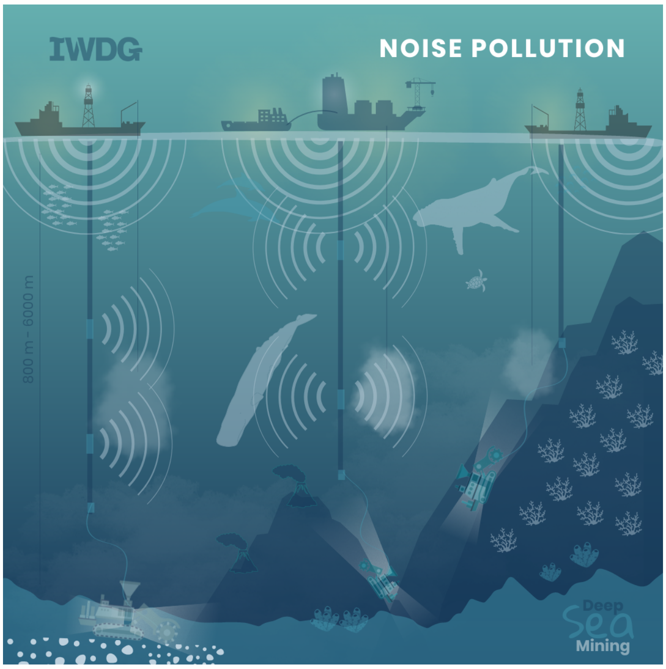
Surface Noise

Noise produced from surface vessels will come from hydro-acoustic and geo-acoustic methods used in exploration of mining sites. Equipment may include deep water multibeam echo sounders, and high-resolution seismic reflection [10]. Depending on the mining operation, it may be necessary to perform geophysical work before each location is mined using sub-bottom profilers (SBPs) or seismic airguns.

During mining operations, a variety of other geophysical equipment to image the seabed from the surface will be used for protracted periods 24/7.

Additionally, an array of sub-bottom profiling equipment may be used, from pingers to chirpers, to boomers and sparkers, as well as airguns. This equipment will vary in frequency and source level depending on the type and location of operations.

Noise will also originate from production vessels during mining operations which will use Vessel Dynamic Positioning (VDP), thought by various experts as the noisiest component of DSM [11]. VDP uses thrusters to maintain a constant position for the mining production vessel. Other sources of noise at the surface include supply, monitoring and research vessels, onboard machinery, and treatment facilities.



An infographic explaining surface noise pollution. Schematic not to scale.

Mid-water

Mid-water noise emissions will mostly come from riser systems, which are used to pump material to the surface vessel, although information on their current noise levels is not available [11].

'Hidden Gem' is an Allseas fleet vessel, fitted with state-of-the-art deep sea mineral collection and transport systems. Photo by: E. van Werd

Seabed

At the seabed removal techniques for mined material will be the most significant source of sound at depth, although the noise produced will be highly variable depending on the resource being mined. Using known noise emissions from dredging activities used in current industrial practices it has been estimated that DSM noise levels through dredging, booster pumps, and surface vessels would be above ambient noise levels to a range of over approximately 500km for just one mining operation [12].

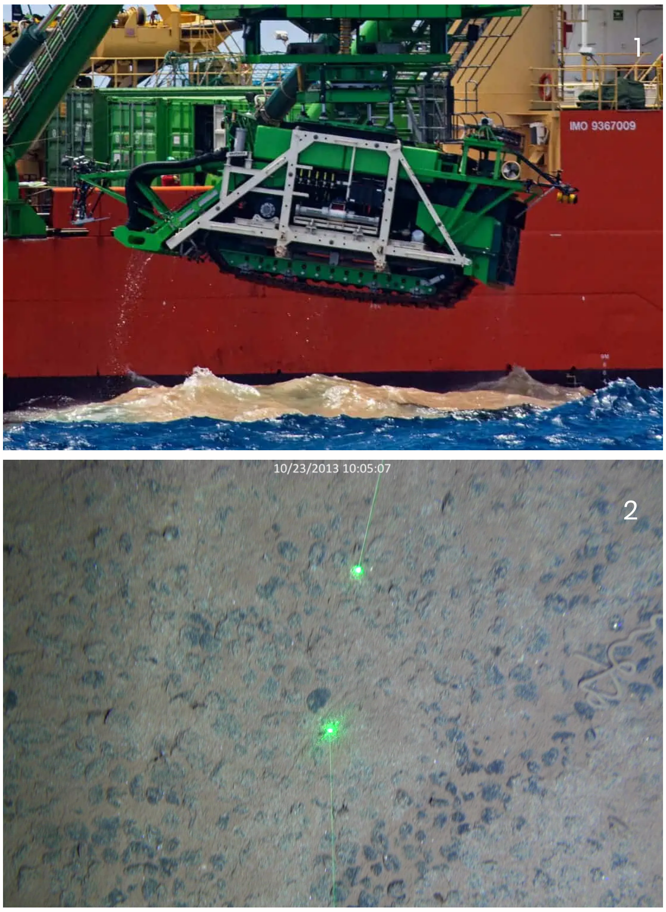
These estimates are to be considered conservative and at the low end of expectations. Additional noise at the seabed will also be produced from acoustic exploration, and communication with submersibles [11].

Impacts

Anthropogenic noise may exclude some species of cetacean and other species of unstudied marine life from large areas of the deep sea where light is excluded, and sound becomes the primary sense for feeding and social or reproductive communication. This includes deep-sea fish species which use low frequency sound to communicate (<1.2 kHz) [13], and may use acoustics to detect food falls up to 100m away [14].

Anthropogenic noise is known to decrease survival and fitness of individuals and populations of certain fish species through a variety of different impacts [15]. Negative behavioural and physiological responses, as well as mortalities have also been evidenced in some invertebrate species [16], which are a crucial prey source for many cetaceans [17].

Walking sea urchin at 5000 m - DeepCCZ.



(1) Mining machine. Photo credit Greenpeace, (2) Holothurian cleaning off nodules AB01 10-23-2013_095656 244

Cetaceans are particularly vulnerable to noise pollution, having adapted to use hearing as their main sense. Increased anthropogenic noise can have a number of negative impacts on cetaceans including physical injury, physiological responses, behavioural disruption, and communication masking. These impacts can in turn affect cetaceans at the individual, group, or population level [18]. Physical injury can take the form of permanent or temporary deafness, and in extreme cases may result in death.

It is clear as we move into deeper and deeper waters that lower frequencies and/or higher source levels from mining equipment will be required during exploration and production.

Much of this equipment operates within the range identified as typical for mid-frequency naval sonar, and like naval sonar, some of this equipment also uses a frequency modulated signal (change in frequency in the signal). Therefore, it might be expected that reactions to signals of this type may invoke a response from some cetacean species similar to reactions to mid-frequency naval sonar. This type of sonar has been widely associated with whale strandings [19] and has already been shown to induce altered behaviour in beaked whales [20].

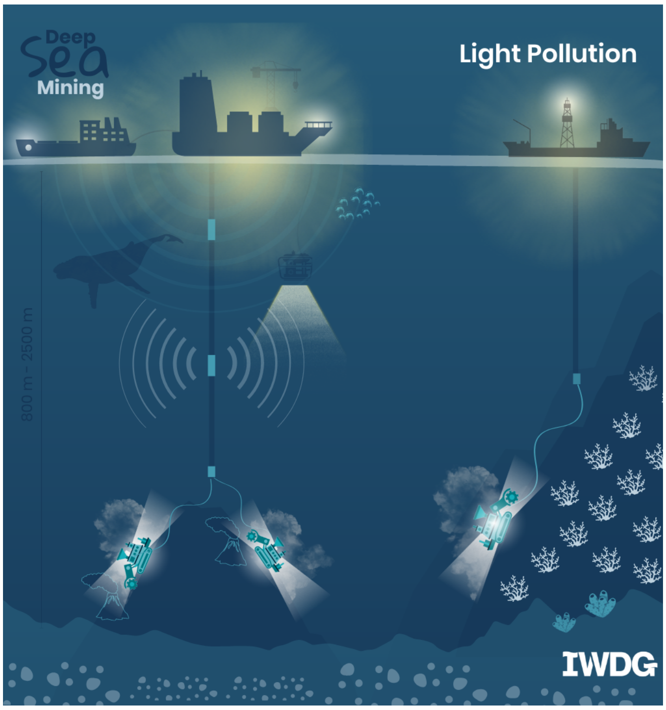
DSM may also introduce sound into the SOFAR (Sound Fixing and Ranging) channel, a horizontal layer of water at about 1000m depth which transmits low frequency sound very effectively, with minimal loss of amplitude over thousands of kilometers. This could have a significant impact on some species of cetaceans. Introduction of sound into the SOFAR channel may mask mating call dispersal across ocean basins for low frequency cetaceans, such as fin and blue whales, which are still recovering from over-exploitation from commercial whaling. Sound levels from DSM into the SOFAR channel must be modelled, measured, and mitigated or prevented where possible.

5.2 Light Pollution

Light pollution from surface vessels involved in DSM will become a long-term feature in an otherwise dark ocean far from land.

Light will be introduced into a dark environment in a number of ways and at a number of locations during mining operations.

At the surface, mining vessels will be stationary or moving very slowly with all deck lights on during night-time operations, producing significant light pollution on the ocean surface, and impacting marine species in the vicinity to a varying degree. Below 800m there is no penetration by sunlight and DSM operations will introduce bright artificial light in what would otherwise be a completely dark environment.



An infographic explaining light pollution. Schematic not to scale.

The impact on cetaceans of bright lights has not been studied. Because of exposure to the sun at the surface, it may be that retinal damage by bright lights is avoided. This, however, may be less likely in the case of fish in the deep ocean who have adapted to extremely low light levels. There is also currently no information available on the use of visual perception by deep-diving cetaceans and whether they may be directly impacted by light pollution or indirectly through light impacts on prey at depth or at the surface.

5.3 Sediment Plumes and Resuspension of Toxic Chemicals

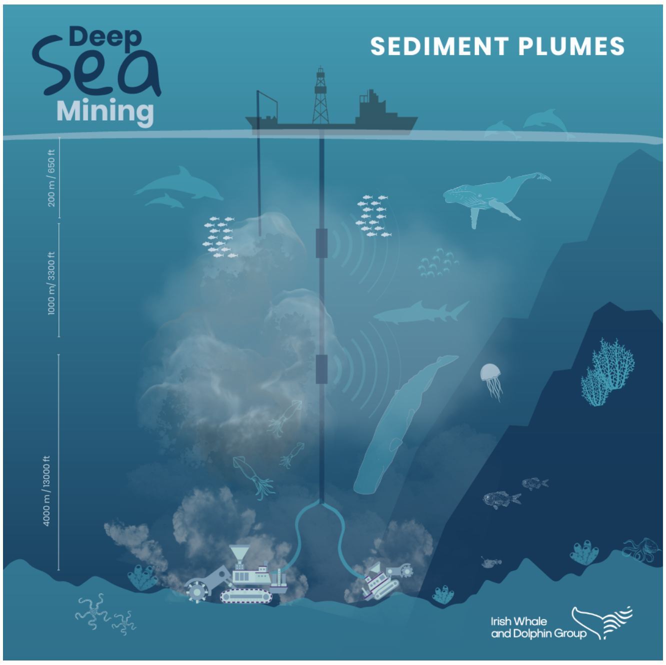
Mining of the seabed will create plumes of fine particles at depth, particularly through dredging. In addition, rock and sediment transported through riser pipes to the surface will be dewatered, and spoil or unwanted material is removed. This water, along with the unwanted sediment and rock material, will be returned to the water column at a currently unknown depth.

Sediment discharge plumes may cover a wide area of ocean as fine particulate matter may take a considerable time (several weeks or months) to settle. The blanketing effect of such plumes may leave large areas of the seabed unable to support the same range of lifeforms.

This may then impact on larger more mobile species who will be forced to leave the wider area to find food.

The discharge of sediment and re-suspension of material may result in a number of other problems. The deep ocean serves to accumulate and dispose of pollutants over many decades. Dredging of sediment from the seabed without proper analysis may serve to release and re-suspend many dangerous chemicals and compounds which will then bio-accumulate, potentially impacting entire world ecosystem, from oceans to humans.

The mining of sulphides is expected to have the greatest potential for metal toxicity due to oxidation of associated sulphide minerals with such metals as arsenic, antimony, lead and mercury [21].



An infographic explaining surface noise pollution. Schematic not to scale.

Higher metal concentrations will reduce oxygen levels in the water column [22] and such metals may remain in the water column for approximately 100 to 1,000 years [23]. Abyssal plain sediments are said to be mercury (Hg) “accumulation hot-spots” [24]. Marine sediments are probably the largest long-term repository of mercury, and it may be that these sediments contain much greater levels of mercury than is currently known.

The bioaccumulation of mercury in cetaceans is already a cause for concern [25]. Accumulation of mercury in various tissues is linked to renal and hepatic damage, as well as reported neurotoxic, genotoxic, and immunotoxic effects.

In addition to mercury, other toxic compounds such as POPs (Persistent Organic Pollutants) have also reached the ocean depths. While data in shallower ocean waters to 2,500m shows low values, data from the Mariana Trench show high concentrations which will directly affect deep-sea ecosystems if disturbed [26].

Lastly, the removal of sediment to the surface and reintroduction of material at depth has the effect of introducing warm water at depth which may be destructive to benthic cold-water habitats, indirectly effecting cetaceans through potential changes in prey dynamics.

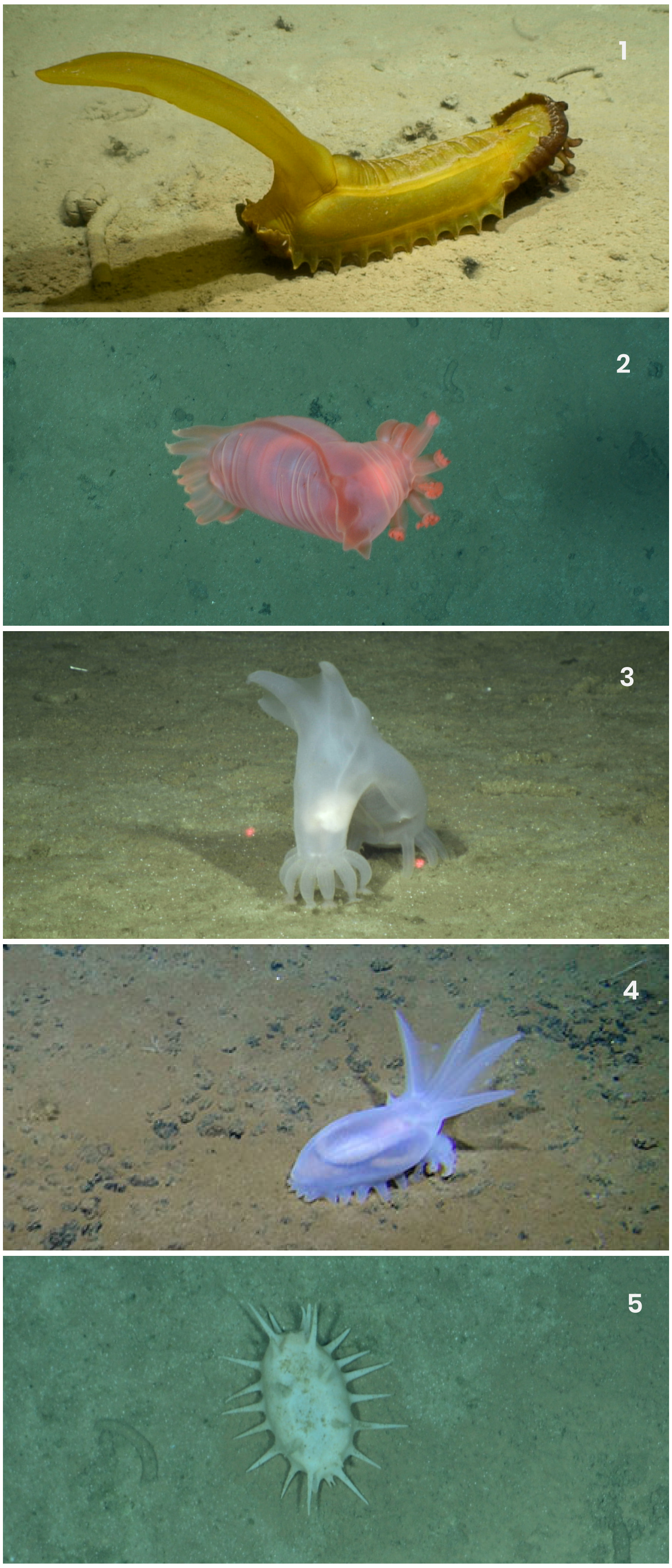
5.4 Carbon Emissions and Climate Change

The ocean contains the largest store of CO_2 on earth. In the deep ocean and abyssal depths sediments show the highest concentration of CO_2 [27], with 84.5% of marine sediment carbon existing below 1000 m water depth.

It is estimated that in the top 1 m of the deep ocean alone (>1000m) marine sediments store approximately 1,962 gigatons of carbon [27] demonstrating the importance of the environment in climate regulation and mitigation of human impact.

Since the sediment is pumped to the surface during the mining process, undetermined amounts of sequestered carbon from marine sediments are likely to be re-emitted into the atmosphere. It is worth noting that carbon concentrations in abyssal sediments are generally higher closer to the continental slope [27] and mining within EEZs is therefore more likely to release significantly higher amounts of carbon then elsewhere. It is important to know the CO_2 content of sediments to be mined, the amount of CO_2 released through the mining process, and the depth to which mining will occur in order to assess climate and ocean acidity impacts.

The release of carbon into the atmosphere will impact ocean acidity and contribute to global warming, affecting ocean ecosystems, including cetaceans.



(1)Psychropotes dyscrita - aka gummy squirrel, (2)Swimming sea cucumber over nodules 5000 m western CCZ,(3 and 5) Sea cucumber at 5000 m- DeepCCZ project, (4)Sea cucumber Amperima sp among small nodules in eastern Clarion-Clipperton Fracture Zone - D Amon and C Smith

SUMMARY 06

The deep seafloor is loaded with minerals required for a more environmentally sustainable future. But at what cost? The potential catastrophic impact of mining operations on the deep-sea environment is undeniable. These are habitats are currently largely unexplored by man and far removed from all human settlements. It is therefore difficult for many people to appreciate what impacts DSM might have on marine habitats and resources. However, any threat to deep-sea ecosystems should be considered as a threat to marine life, and ultimately humanity.

At this point, without an independent environmental regulator and sufficient knowledge of deep-sea ecosystems and how they impact on the global environment, we are not in a position to responsibly proceed with commercial DSM, both on the High Seas and within national jurisdictions. Ireland as a member of the ISA and various international treaties has a right and a duty to protect the marine environment on the high seas and within Ireland's EEZ from transboundary effects.

Pilot whales, Castlegregory Co. Kerry 2009, Simon Berrow

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Irish Whale and Dolphin Group

Our mission is to promote better understanding of cetaceans & their habitats through education & research. We carry this out by: the collection & distribution of information and collaboration with universities, government & research groups.

The IWDG relies on members and partnerships to achieve its goals.
Please visit www.iwdg.ie and join the IWDG to support our work.

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