DEEP-SEA MINING:

Environmental issues associated with deep-sea minerals exploitation

Mineral Resources

Interest has been growing over the last 10–15 years in exploitation of mineral resources in the deep sea. These are extensive or highly concentrated deposits typically found offshore at depths over 200 m. There are 4 main types of resource that are of current commercial potential:

Manganese nodules

These occur over large expanses of the abyssal plains at depths of 4000–6000 m. Nodules of up to 150 mm diameter form through precipitation from the surrounding seawater or sediment waters over millions of years. They are abundant in the Pacific Ocean, especially in the Clarion-Clipperton Zone, in the central-eastern Pacific and around islands in the southwest Pacific. They are rich in manganese, nickel, copper and cobalt.

Seafloor massive sulphides (SMS)

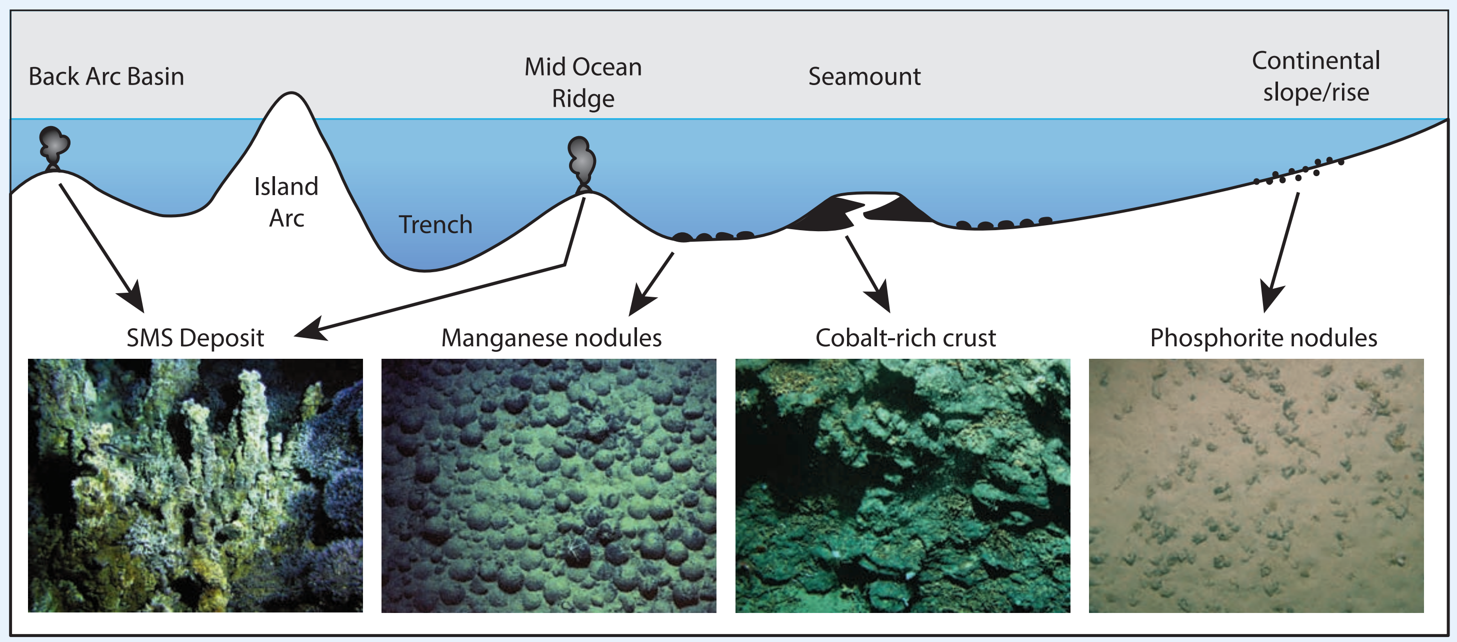
SMS deposits form when metals that are in solution in the hot sub-seafloor water precipitate out after mixing with cold oceanic waters. This typically occurs at sites of hydrothermal venting along mid-ocean ridges and certain submarine volcano systems. Deposits at depths of 1000–3000 m are of commercial interest. They comprise copper, gold, silver, zinc, and lead.

Cobalt-rich ferromanganese crust

These crusts form also from seawater precipitation over millions of years, and are thickest on the flanks of seamounts and guyots where currents keep the seafloor free of sediment. They are rich in cobalt, nickel and platinum, and can form a continuous substrate at depths of 800–2500 m. Large guyot features in the mid-north Pacific Ocean have been identified as amongst the most promising sites.

Phosphorite nodules

These nodules are found much shallower than manganese nodules, and have recently been commercially explored off New Zealand and Namibia at depths of 200–400 m. On continental margins, they form from limestone deposits, and subsequent chemical reactions forming calcium phosphate in areas with upwelling and high surface productivity. Nodules can be 1–4 cm across, and occur on the surface and in the sediment to depths of 0.5 m or more. They contain elements used to make phosphate fertiliser.



Environmental Impacts

Direct impacts, such as the physical disturbance of the seafloor with mining tools and digging up of benthic animals, are fairly clear, and can be predicted, observed and measured.
Indirect effects are secondary changes, caused by the direct physical disturbance. These are less well known, and more difficult to predict and assess. Particular issues include:

- Sediment plume dynamics. Disturbance of the seafloor will stir up sediment. There is a pressing need to understand its' composition, how variable the particle density of the plume might be, its dispersal distance away from the actual mining site, and its height in the water column. Dynamic oceanographic modelling can help, but it is often largely theoretical, and *in situ* observations, direct measurements of conditions, and experiments are needed.
- Sediment deposition associated with the plume. Sediment particles will smother and bury small animals, prevent settlement of larvae requiring hard substrate, and can clog feeding structures. Knowledge on the amount of deposited sediment that causes such impacts is required.
- Release of heavy or toxic metals or other contaminants. This can have both rapid and fatal effects or a slower accumulation through the food chain on various species and life stages.
- Recovery dynamics. Whereas hydrothermal vent communities may re-establish after a few years, recovery of other environments where the substrate is removed and the animals are typically long-lived and slow-growing, may take decades to centuries. Biological information on dispersal, potential colonisation conditions, genetic connectivity, and growth rates are needed to help understand the long-term effects of mining, and also how conservation areas should be designed.

These issues combine to emphasise the need for better understanding of the spatial and temporal scales of impact and response, and the overall effects on ecosystem structure and function.

Key management challenges

Management agencies are invariably responsible for ensuring environmental sustainability, and aim for a balance between exploitation and conservation. This will need high quality information on the scale of the mining operation relative to that of relevant biological communities. Such information will allow for structured management over an area that is large enough to safeguard the ecosystems as a whole from severe or long-term impact. Mining will always have an impact, despite mitigation to an extent by less destructive technology. Ultimately it is likely that spatial management will be required to allocate opportunities for mining and other users of the sea in ways that ensure representative local biodiversity is adequately protected. This will need integration between multiple users of the deep-sea (e.g., fisheries) and also multiple countries where mining might be close to national borders and have potential transboundary effects. Hence there needs to be a very strong element of cooperation and collaboration to promote effective management.

Regulatory framework

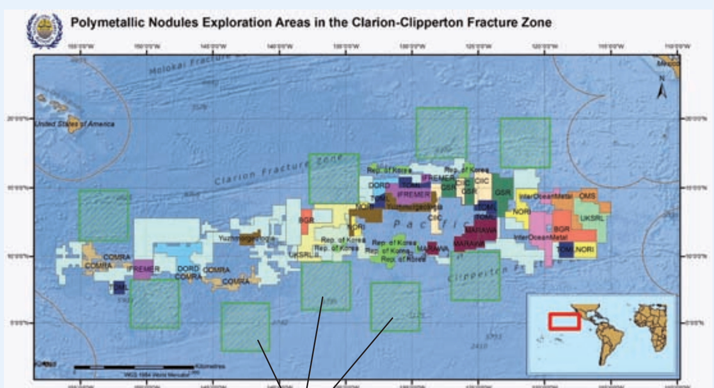
The UN Convention on the Law of the Sea (UNCLOS) provides an over-arching legal framework for deep-sea mining both within and beyond areas of national jurisdiction. The mineral resources of "the Area" beyond national jurisdiction are administered by the International Seabed Authority (ISA) which has developed rules for exploration which include method restrictions, as well as best practice data and research requirements. National laws and standards, which under UNCLOS are required to be no less effective than equivalent international ones, are also rapidly developing in countries where seabed mining is proposed- such as Papua New Guinea, New Zealand and islands in the Southwest Pacific Ocean. In addition, there are voluntary guidelines, such as a code of conduct by the International Marine Minerals Society. These specific regulations vary depending upon the resources they are covering, the physical and biological characteristics of the area and the likely methods that could be employed during mining. In general, however, they should reflect:

- The precautionary principle, whereby scientific uncertainty should not delay measures to prevent environmental degradation; and
- An ecosystem-based approach to management, whereby biological diversity and ecological processes are maintained.

These principles are coupled with the need for:

- Environmental impact assessments, whereby the best available information is presented and reviewed; and
- Best environmental practices, whereby the necessary measures are taken to protect the marine environment from harmful effects

There is a need to integrate across environmental, social, cultural and economic objectives, so the final result of any deep-sea mining is a positive and lasting contribution to life on earth.



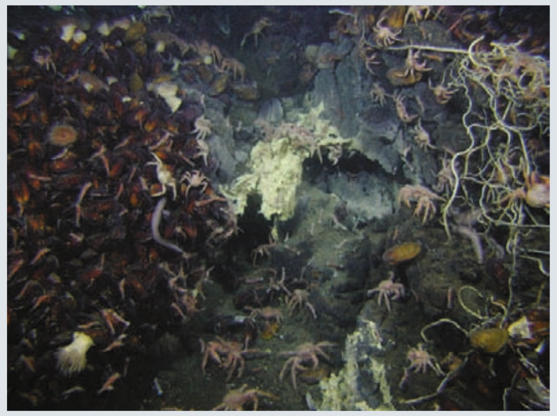
Areas of Particular Environmental Interest (closed to mining activities)

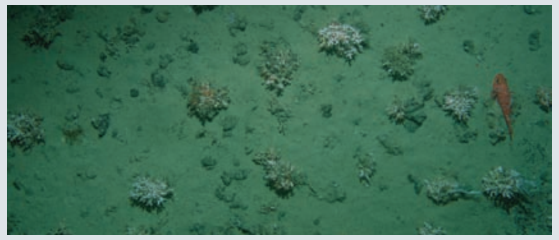
We acknowledge the use of images provided by the National Institute of Water & Atmospheric Research, International Seabed Authority, ABYSSLINE, and NOAA.

The IUCN Commission on Ecosystem Management has formed a thematic group on "Ecosystem Management and Deep-Sea Mining" to provide information and advice on aspects of scientific research and management of deep sea minerals. For further information, refer to website, www.iucn.org/about/union/commissions/cem/
or contact Dr Malcolm Clark (malcolm.clark@niwa.co.nz) or Kelvin Passfield (k.passfield@tiscookislands.org).
May 2015.

Biological communities

The benthic communities associated with each resource type are very different.





Manganese nodules:

Most of the biodiversity on the abyssal plains is composed of small animals (meio-and macrofauna) living below the surface. The soft sediment seafloor has a rich infauna, with particularly abundant nematode and polychaete worms, and small single-celled foraminiferans. The latter dominate the nodules themselves, appearing as "algal-like" mats encrusting them. Large epifauna are less common, but can include diverse sea cucumbers, octocorals, large xenophyophores, sponges, polychaete worms, seastars and urchins.

SMS fauna:

The composition of the faunal communities depend on whether the site is hydrothermally venting, or inactive after venting has stopped. Chemosynthetic species (based on symbiotic relationships with bacteria that obtain their energy for growth from oxidation of hydrogen sulphide) dominate where venting occurs, and these communities are generally characterised by low diversity, high abundance, and high endemism. These species include a range of tubeworms, mussels, barnacles, shrimps, and gastropods. They are often short-lived and fast-growing, and adapted to a potentially temporary habitat that will change as venting increases or decreases.
In contrast, the benthic fauna associated with inactive deposit areas are not chemosynthetic, but the more typical fauna of hard substrates, such as corals, sponges, urchins and featherstars. These communities are less known than those associated with active venting.

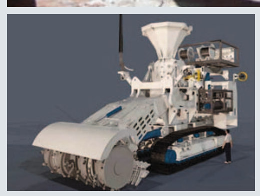
Cobalt-rich crust:

There are few studies that have examined crust fauna specifically, as opposed to communities generally found on seamounts. However, cobalt crust environments can host high densities of sessile benthic fauna such as corals and sponges, and a variety of crustacean, seastar and urchin species. The benthic fauna are likely to be found on seamounts in a broader region, although the chemical composition of the substrate may affect species composition and abundance of the communities.

Phosphorite nodules:

Faunal communities on the continental slopes and rises where nodules occur tend to be variable. Urchins, seastars, squat lobsters, and sessile encrusting bryozoans, stony corals and sponges are common. The relationship between nodules and faunal composition is uncertain, although stony coral communities have been found associated with nodules in areas of the Chatham Rise off New Zealand. Polychaetes and amphipods are abundant in the sediment.

The role that these benthic species and communities play in wider deep-sea ecosystems is poorly understood.



Mining operations

There is not yet any commercial mining activity in the deep sea, and specific operations for each resource type are not definite. The sorts of equipment and methods will differ between the mineral deposits, and also between mining companies. Phosphorite and manganese nodules are likely to be dredged off the seafloor, whereas SMS and cobalt crust extraction involve more rock-cutting technology. In general there are three key components to deep-sea mining operations, irrespective of the mineral.

Seafloor operations:

Extracting the minerals from the seafloor will involve dredging or cutting the resource. This is where large mining machines will move around on the seafloor.

Midwater transport:

Dredged or cut material is transported from the seafloor to the surface. This can be as a slurry in riser pipes, or closed bucket-type conveyor systems.

Surface processing:

The mined material will be sorted and dewatered on the surface vessel. For all types of seabed mining, the filtered wastes and seawater will be returned to the water column-somewhere between the surface and the seafloor.

Mining impacts

There is a wide range of potential environmental impacts from any mining operation. Some of the main ones include:

Surface

- Increased vessel activities and potential pollution and collisions (includes risks associated with extreme weather events)
- Changes in primary production through shading by, or nutrient levels in, discharges (if near-surface discharges occur in photic zone)
- Effects on behaviour of surface marine mammals, fish and birds through changes in water composition or clarity, and lighting/ noise from vessel activity.

Water column

- Sediment plume through water column
- Depending on discharge depth
  - potential oxygen depletion
  - nutrient and trace metal enrichment
  - change in ocean pH
- Effects on deep-diving marine mammals and fish behaviour, from the plume and noise
- Bioaccumulation of toxic metals though the food chain to higher predators
- Toxic effects in early life stages (embryos, larvae, juveniles)
- Plankton/mesopelagic fish mortality and behavioural avoidance of contaminants (e.g., high turbidity, chemically enriched plumes)

Seafloor

- Benthic organism mortality from direct physical impact of mining gear
- Smothering/burying of animals by deposited sediment
- Change in seafloor sediment characteristics post mining (e.g., removal of large particulate material suitable for sessile species and settling of larvae and colonisation)
- Clogging of suspension feeder's feeding structures
- Toxic effects with metal release (and other contaminants), and accumulation through the food chain

The nature and extent of such impacts are uncertain and need to be evaluated on a case by case basis for each mineral resource type and local conditions where mining is planned.

Key environmental research issues

Scientific-based research activities are required to inform managers and regulators as any venture progresses through prospecting and exploration, towards a full mining operation. Information is needed on baseline conditions, a monitoring programme is needed to evaluate the actual mining impacts during operation, and conservation measures need to be evaluated to ensure adequate mitigation that will maintain ecosystem structure and function. In particular, the nature of environmental impacts must be well documented and understood to enable a robust environmental impact assessment before mining begins.