TOXIC IMPACTS OF DEEP-SEA MINING

Deep-sea mineral deposits comprise complex mixtures of potentially toxic elements. These toxicants may be released at sea during different stages of the mining process. Toxicants will impact organism physiology and therefore can perturb whole populations and lead to ecosystem impacts, making it essential to accurately predict toxic effects to assess the ecological impacts of deep-sea mining. Whilst there are extensive data assessing toxicity in shallow-water animals, these may not be representative of toxicity in deep-sea animals, which differ biochemically and physiologically from shallow-water animals. Evaluating whether shallow-water animals are suitable ecotoxicological proxies for deep-sea animals is crucial for accurately projecting toxic effects of deep-sea mining.

The mining cycle and potential toxin release

Deep sea mining, whether of seafloor massive sulphides (SMS), ferromanganese nodules, or cobalt-rich crusts may release toxic concentrations of metal ions into the environment at distinct phases of the mining cycle.

The mining of SMS or cobalt crusts will involve crushed ore being pumped from the seafloor to the surface as a slurry. Whilst nodules may be collected whole, nodules in the Clarion Clipperton Fracture Zone in the Pacific Ocean crumble easily on manipulation. Consequently, for both resources there is a risk that extraction will release metal ions into the water column as a plume around the mining tool. Dewatering the ore slurry at the surface may also release metals into the marine environment in the return water. Releasing return water into the surface ocean will disperse potential toxicants widely and may impact photosynthetic microalgae or animals within the water column. Return water discharged near the ocean bottom will disperse over the seafloor, carrying potential toxicants with it.

Predictions of toxicity

Strict protocols for conducting laboratory assessment of lethal toxicity specify standard temperature and pressure conditions (20 °C and 0.1 MPa). These have no ecological relevance to deep-sea mining, which will take place at low temperatures (down to 2 °C) and at high pressures (up to 60 MPa). Low temperature can reduce the apparent lethal toxicity of some metals present in deep-sea mineral deposits, but increased pressure can increase apparent toxicity (Fig. 1). However, these temperature and pressure effects are not consistent among metal ions making the interaction of temperature and pressure unpredictable.

Furthermore, mineral ores represent complex mixtures of metals that are site-specific, making it extremely difficult to predict the exact toxic potential of a mineral resource from laboratory studies on single metals, or even metal mixtures. Consequently, it will be necessary to assess the toxicity of individual mineral deposits independently before exploitation is licensed, in order to accurately predict the potential toxic impacts of that exploitation. The toxicity of return water will need to be similarly assessed.

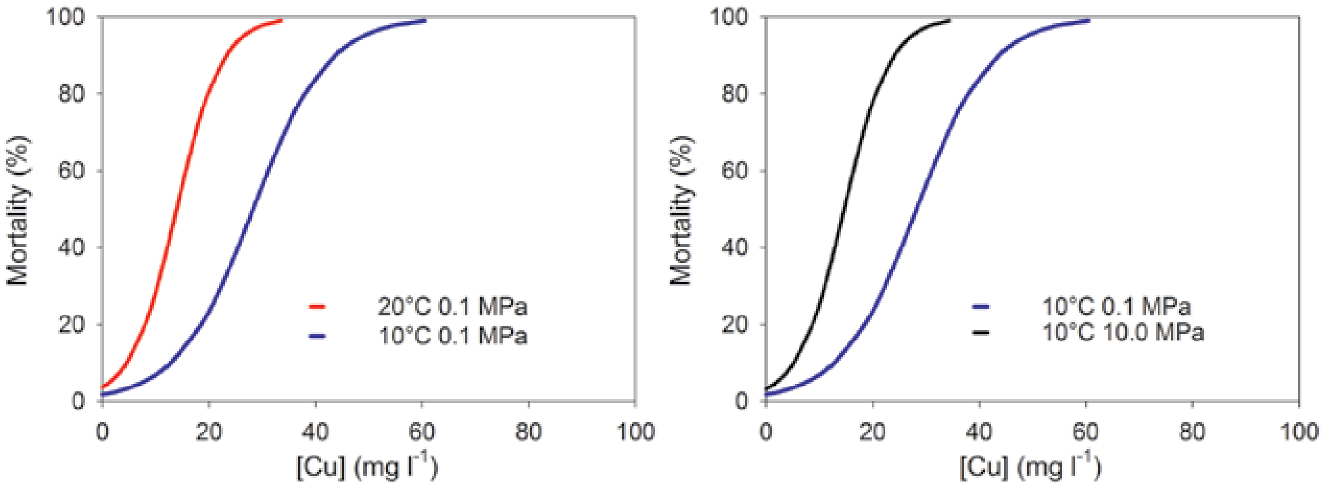


Figure 1: Acute copper (Cu) toxicity (mortality at 96 hours) is lower at temperature representative of North Atlantic sites of SMS deposits (10°C) than at the temperature toxicity assessments are typically made (20°C) (left panel). Acute toxicity is higher at hydrostatic pressures representative of SMS deposits (10.0 MPa ≈ 1000 m depth) than at the pressure toxicity assessments are typically made (0.1 MPa ≈ sea surface) (right panel). However, these effects of temperature and hydrostatic pressure are not consistent for different metal ions generated during the MIDAS project.

Sub-lethal impacts of chronic exposure

Lethal toxicity is conventionally assessed in terms of the “96-hour LC50”: a measure that identifies the concentration of toxicant that kills 50% of the exposed organisms during a 96-hour period. However, 96-hour LC50 limits only indicate acute impacts. Mining within a licence block will continue for years to decades. Organisms will be subject to chronic metal exposures that might be orders of magnitude lower than the lethal dose and at a considerable distance from the mined site. Organisms may be able to detoxify sub-lethal concentrations of metals in their tissues and so reduce or prevent cell and tissue damage (Fig. 2, panel A). For example metallothionein (MT) proteins are produced in tissues to bind free metal ions and so reduce their toxic action (Fig. 2, panel B). However, detoxification represents an energetic cost to the organism. The additional energy expended in detoxification will reduce that available for other critical biological processes such as reproduction, which may limit the performance of ecologically important organisms, potentially far field from the immediate mining site (Fig. 3).

Behavioural avoidance indicators

Some deep-sea organisms detect and respond to metal phases in the environment. Experiments conducted at 4200 m depth in the Peru Basin have revealed that an abyssal holothurian species avoids copper-contaminated sediment. Other mobile species may demonstrate chronic impacts by moving away from areas of contamination during exploitation. These migrations may also produce long-lived changes in the biological community structure at sites far field from the immediate mining site. Identifying the impact of deep-sea mining will require monitoring of such effects in addition to determining lethal toxicity.

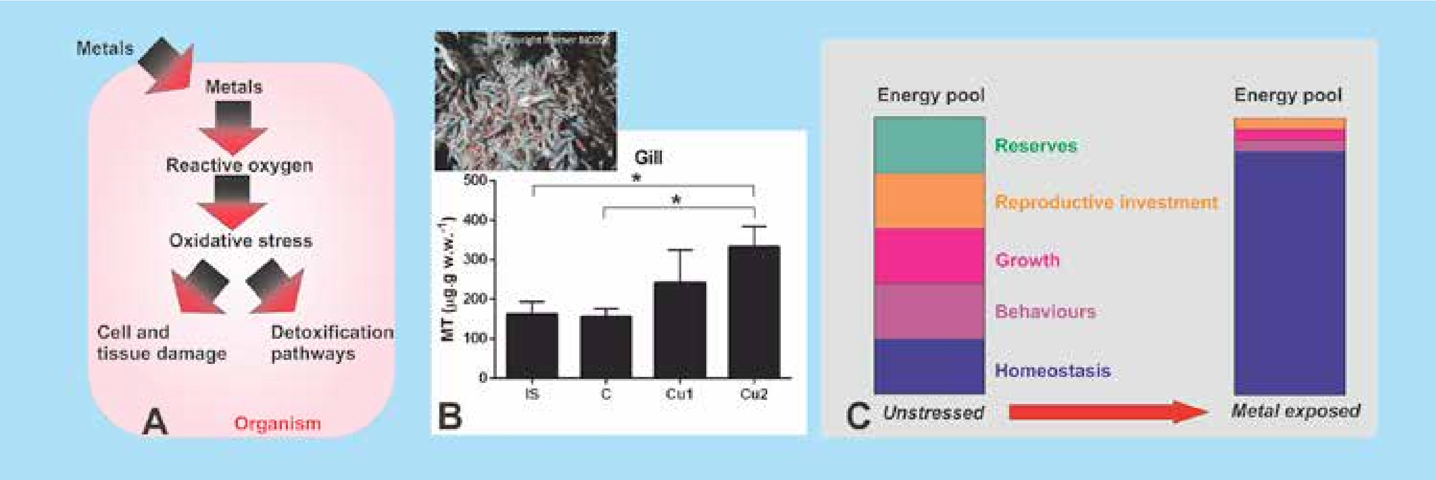
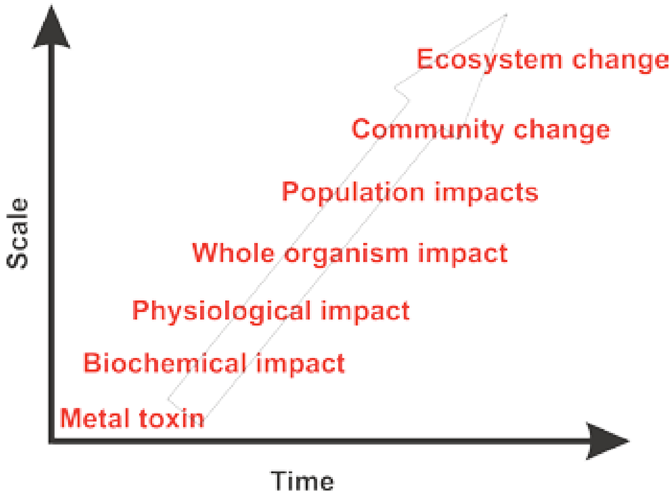


Figure 2: Metal uptake by organisms can cause oxidative stress that, if unchecked, causes damage. However, if not lethal, detoxification pathways can restrict damage (panel A). Metallothioneins (MT) can bind and detoxify metals. They are induced in the gills (panel B) of the vent shrimp Rimicaris exoculata *(image courtesy Ifremer-Victor/Bicose 2014) in response to two different copper doses (Cu1 and Cu2) (IS =protein concentration in shrimp in situ around an active vent, C = control lab exposure with no copper; Auguste et al., 2016). Detoxification requires energy and sub-lethal exposure to metals can divert energy away from other physiological processes (panel C, adapted from Sokolova et al., 2012).*



References and further reading

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Figure 3 (left): The biochemical impacts of exposure to metal toxin can, if sustained, lead to significant changes in the function of the ecosystem (based on Walker et al., 2012).

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