SCIENCE BRIEF

Responses of a deep pelagic jellyfish to mining-induced sediment plumes

A summary of latest research from the iAtlantic project

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Image: The helmet jellyfish *Periphylla periphylla*, collected in the Pacific Ocean. Image © V.I.Stenvers

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Key messages

- Deep-sea mining would not only affect animal communities on the seafloor but also those in the overlying water column, known as midwater or deep pelagic ocean, through the generation of sediment plumes.
- A new study published in *Nature Communications* shows high sensitivity of a midwater jellyfish to sediment plumes, which induced an acute stress response including increased metabolism and excess mucus production.
- If this response is representative for the great diversity of gelatinous animals in the deep ocean, pelagic ecosystem impacts from deep-sea mining are expected to be significant.

How does deep-sea mining of the seafloor impact the overlying water column?

While the exact layout of a deep-sea mining operation will depend on the type of mineral deposit mined, all will require collector vehicles at the seabed. These collectors will not only take up the ore-bearing minerals but also some of the underlying sediment, as well as resuspending sediment near the seabed. Once on the ship, the excess sediment will be separated from the minerals, and will either be discharged off the side of the mining vessel or pumped back into the water column. Currently, no regulations exist on what water depth this sediment should be discharged at. Sediment plumes generated by this discharge may affect the entire water column and extend for tens to hundreds of kilometers (~60 miles) before settling on the seafloor, depending on the sediment discharge release depth and duration of the mining operation[1]. The anticipated effects of sediment plumes on animals in the water column include respiratory stress, buoyancy issues or reduced feeding as a consequence of sediment accumulation on body surfaces. In addition, the suspended sediment may be a source of toxic heavy metals or reduce visual communication through the absorption and scattering of light. Since suspended sediment in the deep open ocean (also known as midwater) is usually very low, even near the seabed, midwater animals are thought to have a low tolerance to it[2]. Midwater animals form important prey for commercially important fishes and marine mammals, a number of which are endangered, in addition to being key players in the cycling of carbon and sequestering this carbon in the deep sea – an important influence on global climate.

Why is it difficult to assess the effects of deep-sea mining on animals living in the water column?

The deep, open ocean is a vast three-dimensional space that is home to a huge range of species. Many of these are poorly understood or entirely unknown, making it challenging to predict how mining activities will affect them. Additionally, midwater animals are often patchily distributed and require a specific range of environmental conditions to survive. Many midwater animals have delicate tissues that are easily damaged during scientific sampling activities; as a result, it is often highly challenging to obtain a sufficient number of healthy specimens for scientific observation. Experiments with midwater animals in their natural environment are hampered by the dynamic nature of the pelagic habitat (e.g. currents, waves), limited accessibility of the deep ocean, and the logistical and financial constraints associated with deep-sea instrumentation. These complexities underscore the need for precaution with regard to deep-sea mining and robust environmental impact assessments.

The helmet jellyfish (*Periphylla periphylla*) as a model system

Although technological advances can help overcome the challenges in studying midwater ecosystems, assessing the impacts of deep-sea mining on diverse midwater communities will take time. In the meantime, studying model animals that represent a variety of species can provide meaningful insights into the likely impacts on pelagic fauna.

We studied the helmet jellyfish, Periphylla periphylla, which occurs throughout the global ocean and has a broad water depth distribution (0 - 4000 m). Helmet jellyfish (belonging to the phylum Cnidaria) are related to the wide variety of jellyfish in the midwater, so their physiology may be representative for other midwater jellyfishes.

How will sediment plumes from deep-sea mining affect midwater fauna?

To test the effects of mining-induced sediment plumes on midwater animals, we investigated the response of the helmet jellyfish *Periphylla periphylla* to a range of suspended sediment concentrations. Any potential form of stress was measured holistically, combining physiology, gene expression and changes in the bacterial community living in symbiosis with the jellyfish.

[1] Muñoz-Royo et al. (2021) DOI: 10.1038/s43247-021-00213-8
[2] Drazen et al. (2020) DOI: 10.1073/pnas.2011914117

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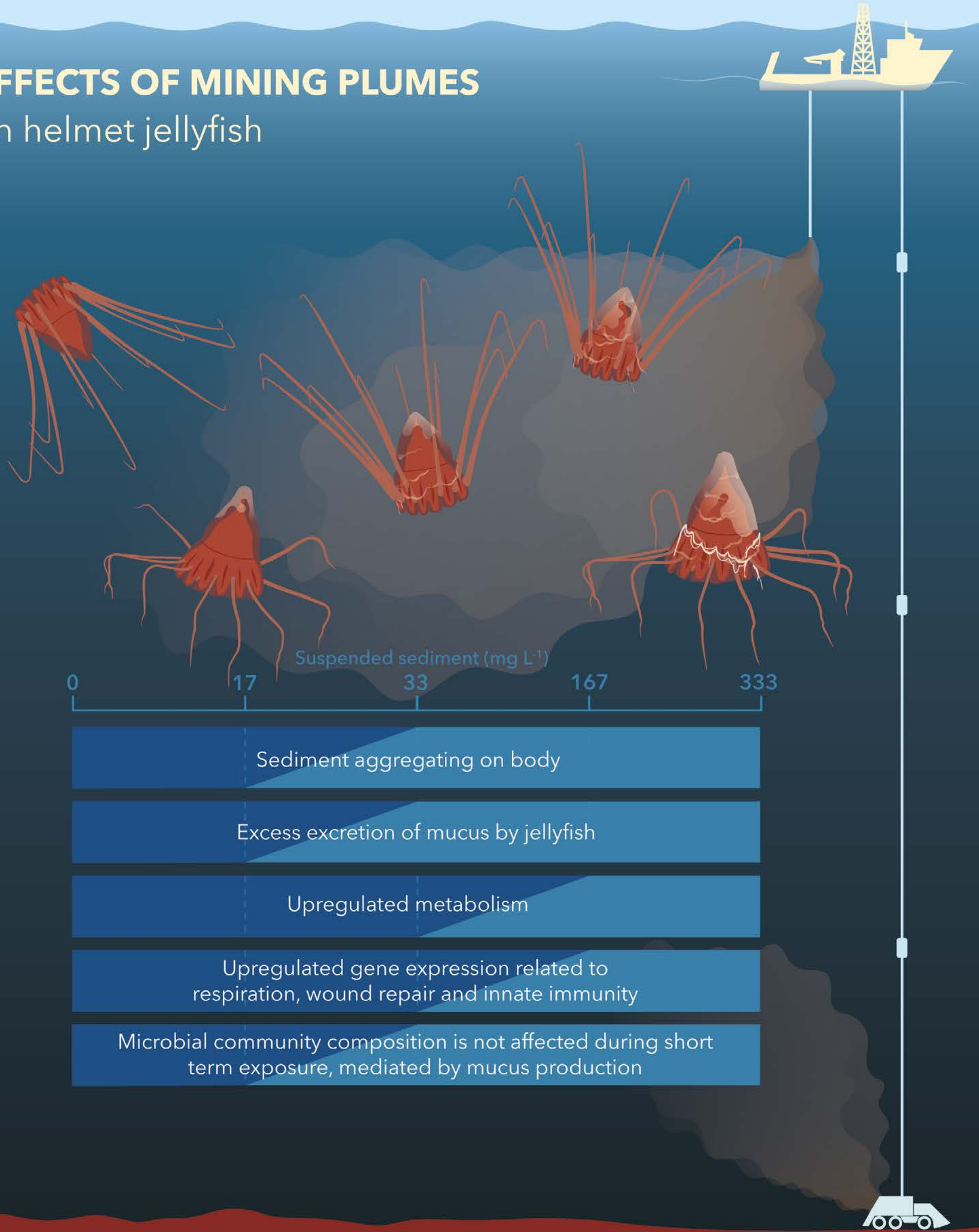
EFFECTS OF MINING PLUMES
on helmet jellyfish



Graphic adapted from Drazen et al. (2020)

CAUSES FOR CONCERN

- Energetically costly stress response (mucus, metabolism, innate immunity)
- Excess mucus produced at all sediment concentrations (which may consume up to 40% of daily energy intake)
- Jellyfish can become energetically depleted, resulting in reduced health or possibly death

The most visual effect of suspended sediment was the aggregation of sediment particles on the jellyfish. Higher sediment concentrations resulted in more sediment aggregation. In response, the jellyfish produced excess mucus to rid themselves of the adhering sediment – this was observed at all sediment concentrations. This mucus contains toxins and anti-bacterial proteins and protects the jellyfish against non-symbiotic bacteria in the sediment. This is an energetically costly response, since mucus production can demand up to 40% of a jellyfish's daily energy intake. Mucus production was accompanied by an overall increase in metabolic rates, including metabolic pathways related to innate immunity*, respiration and wound repair. These metabolic responses signal stress and were absent in the experimental controls, comprising helmet jellyfish that were not exposed to sediment. This response is concerning since it is unlikely that the higher energy demands of the stressed jellyfish can be compensated by increased food intake, given that food in the deep ocean is scarce and midwater ecosystems are generally dependent on food sinking from the sunlit surface layers of the open ocean.

To place these results in a broader framework of stress responses in helmet jellyfish, the study also measured response to temperature change, as metabolic rates in all cold-blooded animals increase with temperature. While a 4°C increase in seawater temperature induced an innate immune response and increased metabolic rates, exposure to the highest sediment concentrations induced higher metabolic activity through the acute and energetically costly production of excess mucus. These results show that the impact of sediment plumes on these animals surpasses that of the most extreme ocean warming scenario.

Recommendations for next steps

Since helmet jellyfish have adopted a slow metabolic pace and live in an environment with scarce food resources, elevated metabolism in response to environmental stressors such as sediment plumes will impact their energetics and nutritional demand for food. Consequently, seafloor disturbance – an expected by-product of deep-sea mining – could have detrimental effects on deep pelagic communities as well as seafloor ecosystems. The response of helmet jellyfish not only informs us about likely responses of related jellyfish, but may also provide clues to the response of other midwater gelatinous animals. A large portion of midwater organisms are gelatinous animals, characterised by soft, jelly-like tissue and high water content (~95%). This gelatinous body composition is not only found in cnidarian jellyfish but is present across the tree of life, including worms, molluscs, comb jellies, tunicates, radiolarians and urochordates.

These results highlight a need for a more comprehensive assessment of deep-sea mining impacts on the midwater realm, covering a wider range of organisms and body types, in order to more accurately assess the potential effects of sediment plumes on midwater species and ecosystems.

** Innate immune systems are found in most invertebrates, including jellyfish, and form a first line of defense to detect and target foreign molecules or damaged tissues. In contrast, the more complex form of immunity is known as 'adaptive immunity', where the immune system may 'learn' from infections through the generation of antibodies targeting pathogens. Adaptive immunity is only seen in vertebrates.*

EXPLAINER: **Choosing concentrations of suspended sediment to test their effects on organisms**

Deep-sea sediments comprise fine particles (0.5 to 400 µm in diameter) that have accumulated on the seafloor over millions of years. If these sediments are disturbed and suspended in seawater, fine particles can stay in the water column for extended periods of time and spread across hundreds of kilometres depending on ocean currents. To test the effects of sediment plumes, sediment concentrations in experiments therefore not only have to mimic different concentrations in space, but also over time. This study) included both these parameters by testing a range of sediment concentrations that slowly diluted with time (50% after 4-6 hours).

Experimental tanks showing different concentrations of suspended sediment. Experiments were run in the dark and red light was used to periodically track the helmet jellyfish's health, as bright light disturbs them.

The full study is available as an open access publication:

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