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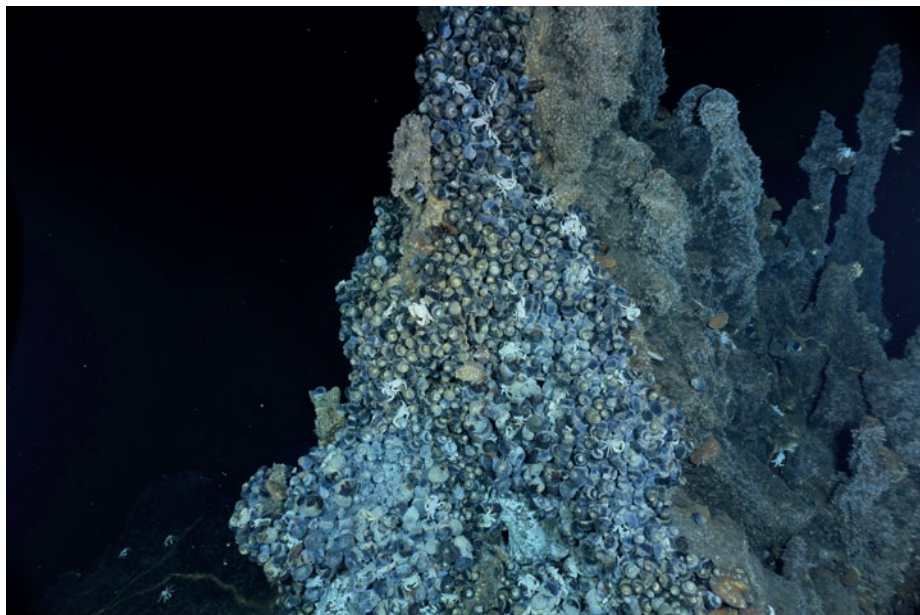
Biodiversity loss from deep-sea mining

To the Editor — The emerging deep-sea mining industry is seen by some to be an engine for economic development in the maritime sector¹. The International Seabed Authority — the body that regulates mining activities on the seabed beyond national jurisdiction — must also protect the marine environment from harmful effects that arise from mining². The International Seabed Authority is currently drafting a regulatory framework for deep-sea mining that includes measures for environmental protection. Responsible mining increasingly strives to work with no net loss of biodiversity³. Financial and regulatory frameworks commonly require extractive industries to use a four-tier mitigation hierarchy to prevent biodiversity loss: in order of priority, biodiversity loss is to be avoided, minimized, remediated and — as a last resort — offset^{4,5}. We argue here that mining with no net loss of biodiversity using this mitigation hierarchy in the deep sea is an unattainable goal.

The first tier of the mitigation hierarchy is avoidance. Potentially useful mitigation strategies in the deep sea include patchwork extraction, whereby some minerals with associated fauna are left undisturbed, or other means to limit the direct mining footprint. Even so, loss of biodiversity will be unavoidable because mining directly destroys habitat and indirectly degrades large volumes of the water column and areas of the seabed due to the generation of sediment plumes that are enriched in bioavailable metals.

Although biodiversity loss within mines is inevitable, innovative engineering design could reduce or minimize some risks to far-field biodiversity [Au: Ok?]. For example, shrouds fitted to cutting equipment might reduce the dispersion of sediment plumes and the footprint of plume impacts such as the burial of organisms. Similarly, vehicle design might limit compaction of seabed sediments. Of course, the efficacy of such efforts in mitigating biodiversity loss would need to be tested.

Remediation addresses the residual loss of biodiversity at and around a mine site after avoidance and minimization interventions. In the deep sea, native species are often slow to recruit and recolonize disturbed habitats: slow recovery on the scale of decades to



Endemic fauna at the Tahiti Moana vent field in the Lau Basin, southwest Pacific. Black snails (*Ifremeria nautilei*), Hairy snails (*Alviniconcha* spp.), and mussels (*Bathymodiolus spetemdierum*) all host chemoautotrophic, endosymbiotic bacteria and live on sulfide deposits that are a target for deep-sea mining. Photograph courtesy of the Schmidt Ocean Institute/Cherisse Du Preez, Pennsylvania State University and the Canadian Scientific Submersible Facility (ROPOS).

centuries, enormous spatial scales of mines for certain mineral resources (a single 30-year operation license to mine metal-rich nodules will involve an area about the size of Austria⁶) and the high cost of working in the deep sea mean that remediation is unrealistic⁷ [Au: Ok?]. Further, the science of deep-sea benthic remediation is a nascent field⁸. It is far from established that remediation of industrial mine sites in the deep sea is feasible for any mineral resource, and we know of no remediation actions that can be applied to the water column.

The last resort in the mitigation hierarchy is in-kind or like-for-like offsets within a biogeographical region. When offsets cannot be located where the affected biodiversity is found, and where the affected biodiversity is important for geographically restricted functions such as connectivity (as is the case for the deep sea), in-kind offsets are not an appropriate mitigation strategy⁹. Out-of-kind offsets¹⁰, such as restoring coral reefs in exchange for loss of deep-sea biodiversity, have been proposed, but this practice assumes that

loss of largely unknown deep-sea species and ecosystems is acceptable. We question this assumption on scientific grounds. The relationship between any gain in biological diversity in an out-of-kind setting and loss of biological diversity in the deep sea is so ambiguous as to be scientifically meaningless. Further, compensating biodiversity loss in international waters with biodiversity gains in national waters could constitute a transfer of wealth that runs counter to the Law of the Sea, where benefits from deep seabed mining must accrue to the international community at large, as part of the common heritage of humankind. Given the paucity of other industrial activities in the deep sea (except perhaps fisheries), it is difficult to imagine a scenario where averted risk offsets¹⁰ could apply; that is, where a mining operation could avert biodiversity losses from other activities.

The four-tier mitigation hierarchy used so often to minimize biodiversity loss in terrestrial mining and offshore oil and gas operations thus fails when applied to the deep ocean. Residual biodiversity

loss cannot be mitigated through remediation or offsets and the goal of no net biodiversity loss is not achievable for deep-seabed mining. Focus therefore must be on avoiding and minimizing harm. Most mining-induced loss of biodiversity in the deep sea is likely to last forever on human timescales, given the very slow natural rates of recovery in affected ecosystems. It is incumbent on the International Seabed Authority to communicate to the public the potentially serious implications of this loss of biodiversity and ask for a response. □

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