# Addressing the Financial Consequences of Unknown Environmental Impacts in Deep-Sea Mining

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The emerging deep-sea mining industry faces an opportunity for tremendous economic gain through the commercial harvest of a variety of high-grade minerals found at great ocean depths around the world. A certain negative consequence of mining, and thus a potential flashpoint for social conflict, lies in the damage to deep-sea ecosystems that will result from these activities. To advance the conversation on managing the economic consequences of currently unknown environmental impacts of deep-sea mining, we develop a typology of potential environmental impacts. We draw on the literature from similar industries to show how others have implemented financial tools – specifically, environmental bonds, environmental insurance, and mutual insurance – to deal with each type of impact. We argue that proper planning is needed to specify and identify the most appropriate mechanism, or combination thereof, that provides adequate financial protection against unknown environmental impacts related to deep-sea mining.

## Introduction

High-grade mineral deposits found on the ocean floor present an opportunity for tremendous economic benefit for the emerging deep-sea mining industry (SPC 2013, p. 47). The damage to deep-sea ecosystems that will result from mining on a commercial scale may spark social conflict. Indeed, the balance between economic gain and environmental loss is currently uncertain. It is quite unknown whether deep-sea mining can be both profitable and environmentally responsible, or whether such activities will generate positive net economic benefits to society when environmental consequences are considered. Differing perceptions and a lack of a clear understanding among regulators, industry actors, scientists, environmental advocates, and policymakers about the magnitude of these impacts and how to manage, mitigate, and compensate for environmental damages is one of the barriers to the industry's transition from exploration to exploitation. Of particular concern is how to deal with the economic and financial consequences of unknown environmental impacts, and the associated liability regimes that could be implemented.

As stressed by Faure (2016), such liability regimes could pursue two broad objectives: (a) from a traditional legal perspective, to compensate society for the damages borne following the environmental impacts of a mining activity; and (b) from an economic point of view, to provide incentives for mining operations to achieve collectively efficient levels of impacts. While the former focuses on ex-post compensation, the latter, building on the economic analysis of accident law (SHAVELL, 1987), addresses how exposing economic agents to liability may provide incentives for accident prevention. According to Faure (2016), the importance of liability rules as an instrument of prevention has been increasingly supported by empirical evidence. A key challenge, however, in designing such liability regimes is to address both the growing requirement for compensation of damages caused to marine ecosystems, and the degree of financial security required by industrial sectors. There must be a balance of financial liability such that compensation payments do not prohibit the development of industrial activity (HAY and THÉBAUD, 2006). To advance the conversation on managing the economic consequences of currently unknown environmental impacts of deep-sea mining, we develop a simple typology of potential environmental impacts and draw on the literature from terrestrial mining and maritime shipping industries to show how other sectors have dealt with these impacts. We apply the framework to three financial mechanisms that address both the economic and financial consequences of uncertainty in the environmental impacts of deep-sea mining – environmental bonds, mutual insurance, and private insurance –and discuss trade-offs of each.

## Three types of environmental impact: A framework for understanding unknown environmental risks

The deep-sea can seem an alien and ecologically unique place, but the environmental impacts and regulatory challenges that need to be addressed by regulators and deep-sea mining firms are likely not. Chief among these challenges is how to deal with the consequences of both known and unknown environmental damages that could be caused by deep-sea mining and carry an associated financial cost borne by either the regulator (and hence, society) or the firm or a combination of both. To clarify our discussion, we define environmental impacts of mining as the direct and indirect effects of mining operations on ecosystem function and on the associated ecosystem services (MA 2005).

The uncertainty associated with potential environmental consequences and the associated penalties that mining firms may face determine the degree to which these impacts can be regulated *ex ante*. When environmental impacts are not known in advance, society, deep-sea mining firms, and the industry as a whole may be left bearing the burden of unforeseen environmental consequences. Firms need to be prepared to deal financially with such consequences, especially if they can be held accountable *post facto*. Regulators also may need to recognize that there are limits to the financial liability of deep-sea mining firms in relation to the environmental impacts of their activities. This need is perhaps made greater given the attention to the Deepwater Horizon accident (JOYE, 2015) and a history of mining-related pollution on land. While the financial risks from environmental damage are not unique to deep-sea mining, what is unique is the high level of uncertainty surrounding the potential environmental impacts of commercial-scale deep-sea mineral extraction.

A framework can be useful to systematically draw lessons learned in similar, established industries and demonstrate the need for a variety of financial mechanisms that may help address the economic consequences of unknown environmental impacts from deep-sea mining projects. We divide environmental impacts into three types based on what is known and unknown about these impacts, and each is amenable to different environmental regulations and financial tools. The three types of environmental impact are: (1) known impacts with known consequences; (2) known impacts with only partially known or unknown consequences; and (3) unknown impacts with unknown consequences.

Type 1 environmental impacts include those that have been historically documented and have known consequences, including environmental impacts onsite as well as potential offsite impacts beyond the mining area. Type 1 impacts are those upon which environmental permitting is usually based, and the consequences could in principle be financially quantified and regulated through *ex ante* royalties, payments, or taxes. Such regulatory mechanisms may be considered *ex ante* because they anticipate impacts and collect funds or provisions up-front for the forecasted consequence, as opposed to other mechanisms which collect funds following an impact and an *ex post* understanding of the nature of its consequence. An assessment of the economic payments for environmental impacts in this first type requires scientific data and an agreement on the metrics by which impacts could be measured. Due to the limited scientific understanding of the environmental impacts to the seafloor, no environmental impacts associated with deep-sea mining currently fall in this category. Thus, *ex ante* taxes and royalties may not be appropriate regulatory mechanisms for seafloor mineral extraction at this time. If the science is accurate, financial regulation for type 1 impacts should take into account all the permitted impacts. Thus, the only reason that pre-determined limits on environmental impacts would be exceeded would be due to negligence or non-compliance with agreed-upon mitigation measures, triggering litigation actions.

Type 2 environmental impacts are more difficult to plan for, given their inherent uncertainty, and leave even the most careful and conscientious regulators and firms at risk. For deep-sea mining, type 2 impacts include those associated with light and sound pollution that are known to be a part of mining and cannot be easily controlled, but for which the extent and nature of the impact is uncertain (Global Ocean Commission, 2013). Other type 2 impacts include habitat destruction, resuspension of mineral compounds in the water column, and siltation (Global Ocean Commission, 2013). The compensation for type 2 impacts could be settled *ex ante* through a social negotiation to balance the precautionary concerns of society with realistic financial liability rules for deep-sea mining firms. For instance, a firm would be required to remit payment that is assessed *ex post* should it exceed agreed-upon levels of environmental damage. This social negotiation would be evident in an environmental permit that stipulates requirements for full remediation or compensation for unanticipated damages beyond pre-determined limits to environmental damages (IDELHAKKAR and HAMZA, 2010). Such *post facto* actions could however prove costly to firms, hence

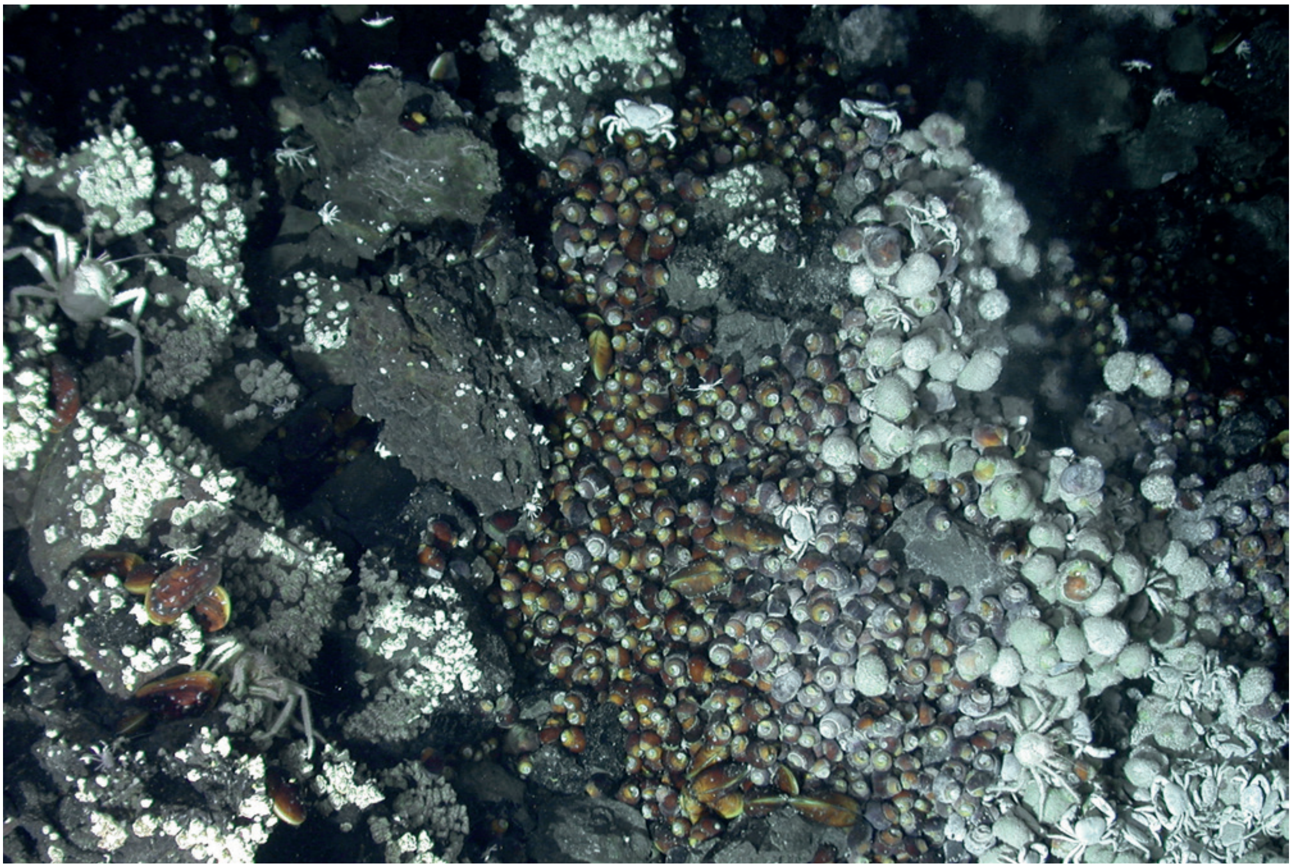

Figure 1 - An example of a habitat at risk if deep-sea mining were to take place at an active hydrothermal vent in the SW Pacific. Barnacles, snails, mussels and crabs live in dense assemblages at depths of more than 2000 m (Photo courtesy of CL Van Dover and the Woods Hole Oceanographic).

creating a strong disincentive to invest in commercial mining operations.

The uncertainties associated with type 2 impacts will be resolved with experience and thus many type 2 impacts will become type 1 impacts as time progresses. As a result, environmental regulations, limits on acceptable impacts, and economic incentives for environmental compliance will likely have to be updated rapidly and continuously in the early years of mining. Any regulatory mechanism should consequently have an adaptive component until the impacts are better understood. Adaptive measures may argue for smaller areas of trial extraction while ensuring that monitoring systems are in place to enable improved measurement of environmental impacts. Scientific knowledge concerning these impacts from mining must also be simultaneously assessed and incorporated into regulation and management.

Finally, type 3 impacts include large-scale disasters, for which there is no precedent. The environmental consequences of the Deepwater Horizon disaster (JOYE, 20150) exemplify a type 3 impact. The inherent uncertainty associated with type 3 impacts imply difficulty in assessing an impact's consequence, including its magnitude and financial cost. Because these events are rare, by definition, regulators cannot learn by doing and thus will never be able to set *ex ante* fees or charges. *Ex ante* environmental charges that may be appropriate for known environmental impacts with known consequences cannot be easily applied to type 3 impacts. As a result, firms may face the possibility of having to pay for costly remediation or compensation for unforeseen environmental damages.

If firms cannot or do not bear this burden, the regulator or society at large may be left with the burden of the economic, financial and environmental consequences associated with the impact either by suffering the loss of environmental quality or by paying for clean-up and remediation, as has been faced in the context of major oil spills (THÉBAUD et *al.*, 2006; HAY et *al.*, 2008). Much of the planning for and proposed regulation of deep-sea mining anticipates type 1 environmental impacts. If these represented the majority of environmental risks associated with mining, regulation would be a relatively straightforward process, involving multi-stakeholder negotiation and the design of adequate monitoring and enforcement systems. Instead, however, the current deep-sea mining sector is characterized by a preponderance of types 2 and 3 impacts that cannot be easily regulated and could be the source of very large economic and financial risks. Without mechanisms to deal with these risks, it is unlikely that deep-sea mining could proceed.

## Three regulatory alternatives for managing types 2 and 3 environmental impacts

Terrestrial mining and maritime shipping have undertaken a variety of approaches to deal with the potential financial and economic consequences of types 2 and 3 environmental impacts. Taken in the context of established industries, we briefly describe how three such mechanisms – environmental bonds, private insurance, and mutual insurance – may be appropriate for deep-sea mining. Such an approach could guide the conversation of how to move forward with nascent seafloor mining operations in a dynamic way that would incorporate future scientific and environmental management advancements and would not necessarily create a liability gap or place undue burden on industry, regulators, or society at large.

### Environmental bonds

Environmental bonds are based on the idea of strict liability in which the regulator would not need to prove a company liable for environmental damage, and the full or partial cost of environmental damage or remediation is delivered upfront. In some cases, there are provisions for funds to be returned to a mining entity in a pay-for-performance mechanism (sometimes known as performance bonds). Environmental bonds are prominent in the terrestrial mining industry, particularly for their use in setting aside funds to remediate environmental damage after a mine site is closed (WHITE et *al.*, 2012 ; SASSOON, 2008). The International Council on Mining and Metals (ICMM 2005) has published latest information on the difficulties of implementing this type of regulatory mechanism, particularly around estimating true financial cost of environmental remediation of closed mine sites.

Regulators may favor environmental bonds because this approach embeds processes for quickly accessing funds should an unforeseen environmental impact occur after mining has already begun. To fully cover all possible damages, environmental bonds may require an unfavorably high upfront payment on behalf of a firm. Such a bond would, however, provide an element of certainty around the coverage of potential costs for unknown environmental consequences (even if those impacts are not fully detected). To some firms, this certainty may be worth a potentially higher upfront fee that could be associated with a bond, while a high upfront fee may price other firms out of the market. Environmental bonds that emphasize flexibility in fit-for-purpose or context-driven solutions can provide time- and capital-sensitive support to accommodate for a variety of development plans and locations of deep-sea mining sites. For example, a phased or staged payment structure may help firms with fewer financial resources balance both economic and environmental responsibility needs. A flexible bond alternative also allows for incorporating the latest science as it becomes available.

For environmental bonds, if the unforeseen risk is underestimated, the regulator and thus society bear the burden of unforeseen environmental impacts that go beyond the scope of a bond. If risks are overestimated, then the firm could end up paying more than is economically warranted. Performance bonds are a type of environmental bonds that would return funds to the firm if unforeseen environmental impacts are smaller or do not occur, thus reducing this risk to the firm, and if adequately set, providing an incentive for firms to limit the environmental impacts.

### Private insurance

Private insurance is founded on a negligence-based system that relies on contracts to allocate risk (SCHÄFER and MÜLLER-LANGER, 2008, p. 23). Under these rules, insurance companies, a third party, would pay damages if their client, a deep-sea mining firm, is found responsible for environmental damage that occurs beyond permitted activities (FREEMAN and KUNREUTHER, 2003). While insurance is an *ex post* measure of remediation and negligence must be proven following an unanticipated (which may include accidental) environmental impact event, Boyer and Porrini (2008) argue that these measures, including *ex ante* premium payments and the monitoring required on the part of insurance companies, may likely stimulate upfront investment from the firm to minimize environmental impact and avoid having to pay *ex post*. In industries similar to deep-sea mining, such as terrestrial mining, environmental insurance is difficult to apply because the financial consequences of an impact are hard to quantify (SASSOON, 2008 ; KEMPTON et *al.*, 2010). Dechar JLT Mining (2014) argues that environmental liabilities are amplified in marine environments because the uncertain nature of the deep-sea mining industry and its impacts will likely attract few underwriters. Deep-sea mining firms may prefer to seek private insurance for type 2 impacts because of the minimal upfront financial burden; however, lack of historical data and economic values associated with deep-sea ecosystems may make insurers unwilling to underwrite such activities in the early stages. It may prove difficult to establish the *ex-ante* level of acceptable damages beyond which a firm's activity is deemed to be negligent, particularly in the case of type 2 environmental impacts. Moreover, it is unlikely that type 3 environmental impacts might be covered by a private insurance system, given the difficulty to assess the potential damages *ex ante*.

In the private insurance market, the risks are borne entirely by the insurer and the insured. If the firm overestimates environmental risk, then they may end up paying too much for insurance. On the other hand, if the private insurer underestimates risk, they bear the burden. The regulator and society at large do not bear a financial burden unless the private insurer fails to pay for damages, a situation which has been encountered in the case of oil spills at sea (see e.g. Hay and Thébaud, 2002 for an evaluation in the case of the Amoco Cadiz oil spill). The reason why insurers may fail to pay for damages can be related to the difficulty of establishing the actual level of damages caused by industrial activities. Such difficulty surrounds the measurement and ecological understanding of impacts on indirect use values and non-use values associated with marine ecosystem functioning (see Hay and Thébaud, 2006 for a discussion of this difficulty in the context of oil spills).

### Mutual insurance

Mutual insurance is a form of co-managed, or mutual, insurance and is different from private insurance in that entities are co-insured. In maritime shipping, one vessel or ship owner contributes to an organization that insures the entire member group against a host of uncertain liabilities and is organized by a set of rules by which each member must abide (RONNEBERG, 1991; HAY et *al.*, 2008). In the event of damage, compensation payments that result from the activity of one of the group members can then be levied according to these pre-agreed rules. Also referred to as Protection & Indemnity Clubs, mutual insurance may align the incentives of deep-sea mining firms and regulators due to the pooling of financial resources and quick availability of funds following an impact. Asymmetry of information could exist in this scenario, however, where a single firm may withhold information about its environmental risk profile to the Protection & Indemnity Club that, in turn, would contribute to weaker regulatory oversight.

Mutual insurance may not be a long-term solution, however, if the environmental consequences of commercial-scale deep-sea mining turn out to be too costly and drain the mutual insurance plan too quickly. Indeed, within the international liability regime for damage caused by oil pollution from tankers, implementation of this type of liability system has been tightly linked with negotiations on maximum potential levels of financial compensation as well as the sharing of contributions to compensation payments between different stakeholders (namely ship owners in the P&I Clubs and cargo owners under the International Oil Pollution Compensation Fund). It has also involved detailed discussions on the nature of acceptable damages for compensation under the liability system (HAY et *al.*, 2008). Without agreement on such maximum potential levels, a large type 3 disaster could lead to the insolvency of the insurance pool for the entire industry. The conflict of interest inherent to industry-run programs could exacerbate tensions between economic solvency and environmental responsibility.

In mutual insurance, the financial burden of over- or underestimating potential risks is borne by the industry at large. This should encourage the transfer within the industry of technical knowledge about environmental mitigation methods and best practices. Society and the regulator only bear a financial burden if the mutual insurance fails to pay, or where maximum compensation limits are established that were under-estimated compared to actual impacts – an outcome that could threaten the viability of the industry as a whole.

## Conclusion

While there is tremendous potential for economic gain by extracting mineral resources from deep-sea ecosystems, the lasting impacts to the environment may impose costs to many stakeholder groups. First to the firm in the case that *ex-ante* environmental payments negatively affect the profitability of a commercial-scale mining operation such that the industry does not develop. Second to regulators and society should the financial responsibility of environmental risk management not fall appropriately with the firm and incentives for environmentally responsible operations prove ineffective.

Proper planning will be required in order to specify and identify the most appropriate financial mechanism, or combination of mechanisms, that provides adequate financial protection against unknown environmental impacts from deep-sea mining. A thorough study of how similar industries have implemented a variety of tools may be especially useful to regulators, such as the International Seabed Authority, as they deliberate a variety of enforcement mechanisms for exploitation regulations. Environmental managers, policymakers, and scientists may also find that studying the effectiveness of these regulations in successful environmental outcomes could contribute to environmental management guidelines. Firms, too, can learn from past experience in similar industries and incorporate these learnings into operational and environmental management planning.

Regulations must support both a profitable industry and ensure that ocean industrial development is managed for the benefit of future generations. This is a tall order, and in recognizing the existence of uncertainty, stakeholders can have a practical and structured discussion to develop dynamic financial and regulatory instruments that learn as we go and, over the long term, reduce a potential environmental liability gap and contribute to a sustainable blue economy.

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