DEEP-OCEAN STEWARDSHIP INITIATIVE

POLICY BRIEF

July 2026

Towards an ecologically meaningful toxicity assessment of deep-sea mining

Key messages

- Deep-sea mining can introduce new pollutants and redistribute contaminants already stored in sediments, creating conditions for chronic, long-term exposure in affected ecosystems.
- Background concentrations of metals and persistent organic pollutants in some deep-sea sediments already exceed levels of toxicological concern. Deep-sea mining is likely to resuspend these contaminants into sensitive mid-water and deep-sea ecosystems.
- Bioaccumulation and biomagnification through food webs may increase long-term risk beyond the immediate footprint of mining operations.
- Adverse effects, including on behaviour, reproduction, and ecosystem function, may not be immediately evident but are likely to result from sustained sublethal exposures.
- Scientific evidence is limited: few studies capture true deep-sea conditions, validated biomarkers are lacking, and major logistical constraints hinder mechanistic ecotoxicology in the deep sea.

Policy relevance

The draft **International Seabed Authority (ISA) guidelines (ISBA/27/C/11)** encourage contractors to establish environmental baselines and demonstrate that deep-sea mining will not cause "**serious harm**" to the marine environment. Current guidelines encourage the investigation of natural levels of contaminants and **biomarkers** in key benthic, abyssopelagic and bathypelagic species, including seasonal replication to capture natural variability. However, these guidelines remain non-binding and are not yet formally incorporated into the Exploitation Regulations.

The ecological impacts of deep-sea mining are not confined to the contract area (**Figure 1**). Collector sediment plumes and mid-water discharge of mining effluent are expected to disperse dissolved metals and suspended particulates beyond the active mining footprint through both horizontal and vertical transport, while **bioaccumulation** and **biomagnification** may transfer contaminants further via mobile fauna and across food webs. These impacts have direct implications for the network of **Areas of Particular Environmental Interest (APEIs)** established to protect representative deep-sea habitats, and raise transboundary concerns relevant under the **Biodiversity Beyond National Jurisdiction (BBNJ) Agreement**.

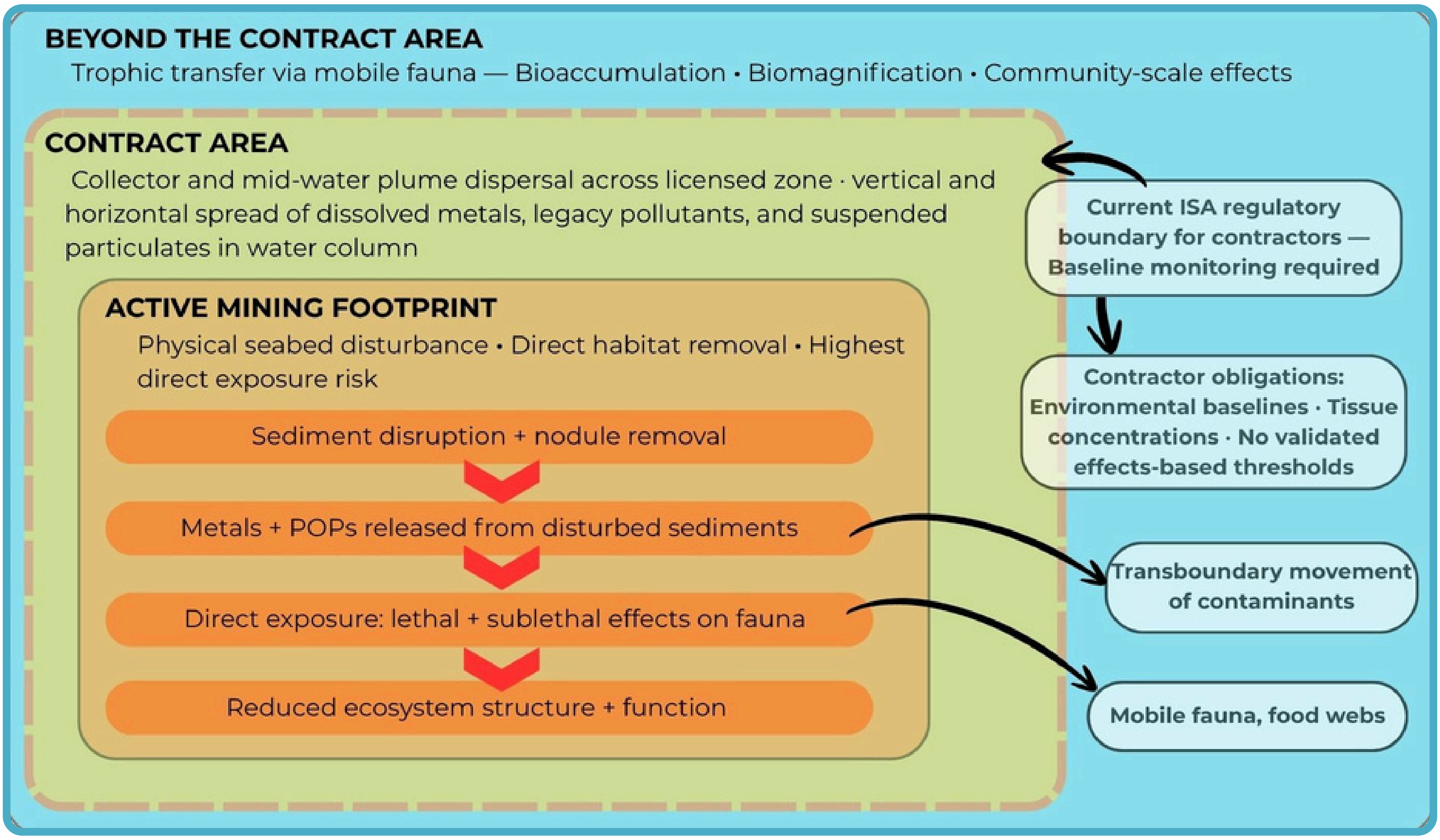

Figure 1: *How the ecological footprint of deep-sea mining extends beyond the contract area via collector and mid-water plume dispersal, bioaccumulation, and mobile fauna.*

Without requirements to monitor contaminant dispersal beyond contract boundaries, and without validated, ecologically meaningful indicators and defined thresholds, it is not possible to detect harm early or to demonstrate whether the standard of "serious harm" has been met. The ISA has established an Intersessional Expert Group to support the Legal and Technical Commission in developing thresholds and indicators on toxicity, with a first report expected in 2026. The findings of this Policy Brief are directly relevant to that process.

Background

Ecotoxicology is the study of how contaminants affect living organisms and the ecosystems they belong to. It links molecular and cellular responses to population- and ecosystem-level outcomes (**Figure 2**). This framing is directly relevant to "serious harm" under ISA guidance: impacts that may be invisible at an organism's tissue level can translate to disrupted biodiversity, reduced ecosystem function, and impaired ecosystem services, including those relevant to fisheries and carbon cycling.

Deep-sea sediments act as long-term sinks for contaminants from surface waters, including metals and **persistent organic pollutants (POPs)**. As a result, concentrations of some contaminants in deep-sea sediments and biota already exceed those recorded in aquatic environments more closely affected by human pollution. Deep-sea mining will disturb these sediments and resuspend accumulated contaminants in collector plumes and mid-water discharge plumes, increasing their **bioavailability** and ecosystem exposures throughout the water column. Even at low concentrations, contaminants are known to disrupt physiology, growth, reproduction, behaviour, and survival. Exposures are likely to be chronic and continuous, intensifying through concurrent extraction.

The ecological footprint of deep-sea mining is likely to extend beyond the active extraction site, as collector and mid-water discharge plumes may disperse dissolved metals and POPs across the wider contract area and throughout the water column, while bioaccumulation and biomagnification transfer contaminants further still via mobile fauna and food webs. The current regulatory guidance is not designed to account for this broader ecological footprint.

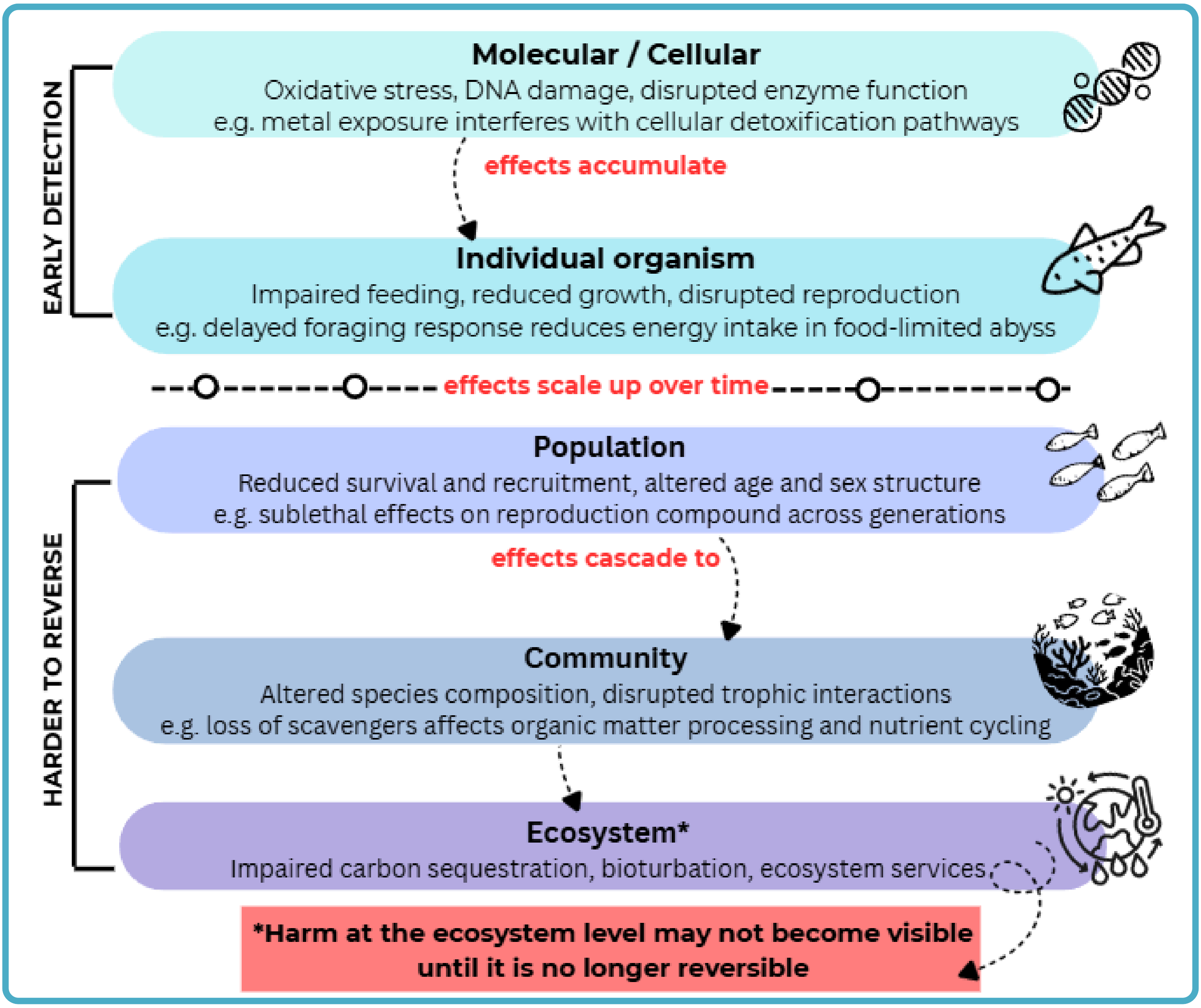

Figure 2: *How contaminant effects scale from the cellular level to ecosystem-level consequences and how the most serious harm may go undetected until it is irreversible.*

Scientific understanding

The science needed to assess whether mining-related contaminant exposures constitute "serious harm" is not yet established. Empirical evidence on the toxic effects of deep-sea mining remains very limited. Fewer than half a dozen studies have been conducted under natural conditions. Other studies relied on laboratory conditions that do not reflect the conditions of the open ocean or deep sea, yet have demonstrated the effects of mining effluent on organisms. While field trials have documented the physical dispersal of sediment plumes beyond the mining footprint, the chemical fate and effects of metals and POPs mobilised within those plumes remain uncharacterised. Traditional biomarkers used in shallow-water environmental monitoring have not been validated under abyssal conditions, where high hydrostatic pressure and cold temperatures can alter or suppress the biological stress responses these indicators are designed to detect. Toxicity thresholds derived from shallow-water species cannot be applied to deep-sea fauna without validation. Natural variability in contaminant concentrations is also poorly characterised, making it difficult to distinguish mining-related change from background fluctuation. **Without these foundations, there is no reliable basis for detecting ecotoxicological harm early, or for demonstrating that a “serious harm” threshold has been crossed**.

Recommendations

1. **Prioritise effects-based assessment –** Regulatory guidance should require biologically meaningful endpoints, including **sublethal** and functional responses (e.g. behaviour, reproduction, metabolism, growth), rather than relying solely on tissue concentrations. Effects-based indicators provide earlier and more ecologically relevant signals of toxicity.
2. **Develop and validate deep-sea and open-ocean relevant biomarkers –** Biomarkers must reflect the distinctive physiology and life-history traits of deep-sea and open-ocean organisms. Research should establish chronic response patterns, sensitivity, and tolerance ranges under realistic deep-sea and open-ocean conditions. Baseline biomarker data across species and sites are a prerequisite for detecting change and interpreting exposure effects.
3. **Establish precautionary, deep-sea-specific and open-ocean-specific toxicity thresholds –** Validated effect indicators should be used to derive defensible environmental thresholds that trigger management action. Thresholds must account for chronic exposure, cumulative stressors, and ecosystem connectivity. Given persistent uncertainty, thresholds should be precautionary and embedded within adaptive management frameworks.

Key terms

- **Bioaccumulation:** The buildup of a chemical in an organism over time from its environment or diet, often because it accumulates faster than it can be removed by the organism.
- **Bioavailability:** The availability of a chemical in the environment for uptake by an organism.
- **Biomagnification:** The increase in a chemical concentration at a higher trophic level when predators eat contaminated prey.
- **Biomarker:** A measurable biological response (molecular, cellular, physiological, or behavioural) that indicates an effect of a contaminant following exposure, used as an early-warning indicator.
- **Persistent organic pollutants (POPs):** Synthetic chemical compounds that resist environmental breakdown, accumulate in living organisms, and persist in ecosystems over long timescales.
- **Sublethal effect:** An adverse effect that does not acutely or directly result in death, but can be caused by diverting energy away from normal functions (e.g. behaviour, reproduction, metabolism, growth) towards protecting the organism from a chemical exposure.

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About DOSI

The Deep-Ocean Stewardship Initiative is a global network of experts that integrates science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdiction.

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Further reading

For further information and relevant scientific literature, see the related Information Sheet – DOSI (2026) Ecotoxicological risks of deep-sea mining: scientific context and evidence

How to cite

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