Policy Summary of Technical Brief: Mitigation Hierarchy in Deep-Sea Mining

What is the mitigation hierarchy?

The **mitigation hierarchy** is a structured environmental management tool used to mitigate negative impacts of projects or activities. The theoretical framework consists of four sequential steps:

1. **Avoid** impacts before they occur.
2. **Minimise** the severity of unavoidable impacts.
3. **Restore**/**Rehabilitate** the ecosystem to help it recover after impact.
4. **Offset** by enhancing nature elsewhere to account for any residual impacts.

Mitigation measures in earlier steps generally require lower implementation effort and are more effective, and always have priority over later steps.

The mitigation hierarchy provides **a mechanism for making decisions that balance conservation needs with development priorities** and is widely utilised in marine industries. Aspects of it have been included in the Mining Code of the International Seabed Authority. This policy summary highlights key elements of the **accompanying technical brief** (p. 3), which explores considerations for applying the mitigation hierarchy to deep-sea mining, to inform future policy decisions.

How does the mitigation hierarchy work?

Additional **context is required** to enable the mitigation hierarchy to be applied. Such context includes decisions on what you are monitoring (e.g. biodiversity), what frame of reference you are comparing against (e.g. pre-impact baseline), and what environmental goal you are aiming for (e.g. no net loss).

The mitigation hierarchy is then **applied throughout a project's planning and environmental impact assessment process**. They identify impacts and measures to mitigate (i.e. avoid, minimize, restore/rehabilitate and offset) those impacts, exploring various scenarios. The proposed set of mitigation measures in the environment impact statement should prioritise measures in the early steps of the hierarchy, and rationale should be provided where measures from later steps are proposed to inform the consenting process.

There are further **complexities regarding offsetting** measures, which are on a scale of decreasing ecological equivalence to the ecological loss at the impacted site. Residual impacts at the project site can be offset **in-kind** where a similar habitat is enhanced elsewhere, or **out-of-kind** where a dissimilar habitat is enhanced elsewhere, or through **Additional Conservation Actions** that are interventions intended to be positive for nature but which do not provide measurable gains.

Lessons from various case studies

- **Global governance frameworks**: Principles of the mitigation hierarchy are embedded in various environmental agreements, including in UNCLOS, CBD and BBNJ, and utilised by governance frameworks such as IFC and IUCN[1].
- **High seas fisheries**: Although not explicitly recognised, elements of all four steps of the mitigation hierarchy are used in the management of high seas fisheries. States are obliged to avoid or mitigate Significant Adverse Impacts on certain deep-sea taxa that are recognised by the FAO[2] as highly vulnerable and important. Restoration and offsetting impacts of fisheries are generally not considered beyond coastal regions.
- **UK marine industries**: The mitigation hierarchy is embedded within UK legislation and widely applied. Adverse impacts on the integrity of MPAs that cannot be avoided or minimized can only be consented to if (1) there are no alternative solutions, (2) there are imperative reasons for overriding public interest, and (3) appropriate and robust restoration/rehabilitation and offsetting measures are in place. Restoration/rehabilitation and offsetting are used cautiously across UK marine industries due to technical challenges in marine environments.

Considerations for Deep-Sea Mining

Deep-sea mining presents unique challenges due to the remote, poorly understood, and potentially vulnerable nature of deep-sea ecosystems. General considerations for applying the mitigation hierarchy to deep-sea mining are discussed below, but it must be kept in mind that specific implementation of measures may also be resource specific or specific to the associated environmental conditions.

- Measures to **avoid and minimise are technically feasible**, but largely untested for the deep-sea. Measures include spatial planning (e.g. set-aside areas), timing restrictions, and low-impact technologies. Effectiveness depends on robust ecological understanding, which is often lacking for deep-sea habitats. Tools to improve effectiveness include studying shallow-water species, impact monitoring, and adaptive management.
- Techniques to **restore/rehabilitate are being explored, but effectiveness remains unproven** for deep-sea habitats. Additional research could make such techniques feasible but may require decades due to the slow growth of many deep-sea species. Adaptive management could be considered to address uncertainty, but as positive outcomes are not guaranteed this requires further discussion.
- **In-kind offsets are not currently feasible** due to the lack of proven restoration techniques, difficulties in quantifying impacts, proving additionality, and finding suitable sites, but could theoretically become feasible in the future. **Out-of-kind offsets, including additional conservation actions, are technically possible** but raise ethical and governance concerns and thus require further discussion.

The findings of the accompanying technical brief may be used by policymakers to weigh ecological risks, technical feasibility and ethical considerations in shaping the exploitation regulations and consenting process for deep-sea mining activities.

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[1] United Nations Convention on the Law of the Sea (UNCLOS); The Convention on Biological Diversity (CBD); Agreement on Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ); International Finance Corporation (IFC); International Union for Conservation of Nature (IUCN).

[2] Food and Agriculture Organization (FAO)

Technical brief: Mitigation Hierarchy in Deep-Sea Mining

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Introduction

The mitigation hierarchy is a commonly used framework in environmental management to identify measures to reduce the environmental impacts of a proposed plan or project, and thus provides a mechanism for making decisions that balance conservation needs with development priorities (Ekstrom *et al.* 2015; CIEEM, 2018). It is recognised as a useful tool to help mitigate for the impacts of marine industries and aspects of it have been included within the 'draft regulations on the exploitation of mineral resources in the Area'[1] of the International Seabed Authority (ISA) (ISBA/30/C/CRP.1) (hereon referred to as the draft exploitation regulations), with more details provided within the draft Standard and Guidelines for the environmental impact assessment (EIA) process (ISBA/27/C/4) (hereon referred to as the draft EIA Standard and Guidelines). However, further consideration is needed on how the mitigation hierarchy could best be applied for mineral exploitation in the international seabed area in practice.

Mitigation hierarchy summary

Terminology for the mitigation hierarchy can vary, however in this brief we use the terms **(1) avoid, (2) minimise, (3) restore/rehabilitate, and (4) offset** (Figure 1), following the definitions[2] in the draft EIA Standard and Guidelines (Section V B) and as suggested by the African Group submission under the President's text for the 28th Session – Part II, July 2023.

The mitigation hierarchy, conceptualized in Figure 1 (Ekstrom *et al.*, 2015; Bull *et al.*, 2016; Niner *et al.*, 2018), should be considered from the planning stages of a project and throughout all stages of an EIA process to ensure that the different options for mitigation are considered and included into project design and implementation. To effectively implement the mitigation hierarchy, specification of context is required (Figure 1a). As part of an EIA, a frame of reference[3] must be set which quantifies the ecological variable at a certain point in space and time, for example, the pre-impact biodiversity baseline level. The EIA must then identify adverse changes in the ecological variable (**environmental effect**) due to the impact of project activities. Finally, an environmental management objective must be set, which can be either (1) accepting a certain extent of loss, (2) **no net loss** (NNL[4]), or (2) **net gain** in the ecological variable in comparison to the frame of reference.

[1] The 'Area' means the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction.

[2] Final terminology will depend on discussions in Council and adoption of a finalized set of draft exploitation regulations.

[3] The term "frame of reference" has been taken from Bull *et al.* (2016) and can be considered an umbrella term for any reference state, including, but not limited to, baselines, scenarios and counterfactuals (e.g. scenarios of what could have occurred under different circumstances).

[4] Sometimes also called 'net zero'.

The mitigation hierarchy is then applied as a **tiered process**, where mitigation measures are proposed[5] under the four tiers in order of priority (avoid, minimise, restore/rehabilitate, offset) (Figure 1b), as per the draft EIA Standard and Guidelines (section V B). Each consequent level generally requires more implementation effort and generally carries greater risks (e.g., technical, social, environmental, political, economic), and thus proposed measures should first focus on avoidance, then minimisation for impacts that cannot be avoided, then restoration/rehabilitation for impacts that cannot be minimised, and only offsetting as last resort for impacts that cannot be restored/rehabilitated (Ekstrom *et al.*, 2015). Whether or not proposed mitigation measures under the different tiers are implemented depends on existing policy and legislation (see 'Case studies'). Implementation of the mitigation hierarchy can involve adaptive management, which is an iterative process where monitoring of performance of implemented measures informs forward plans (Ekstrom *et al.*, 2015).

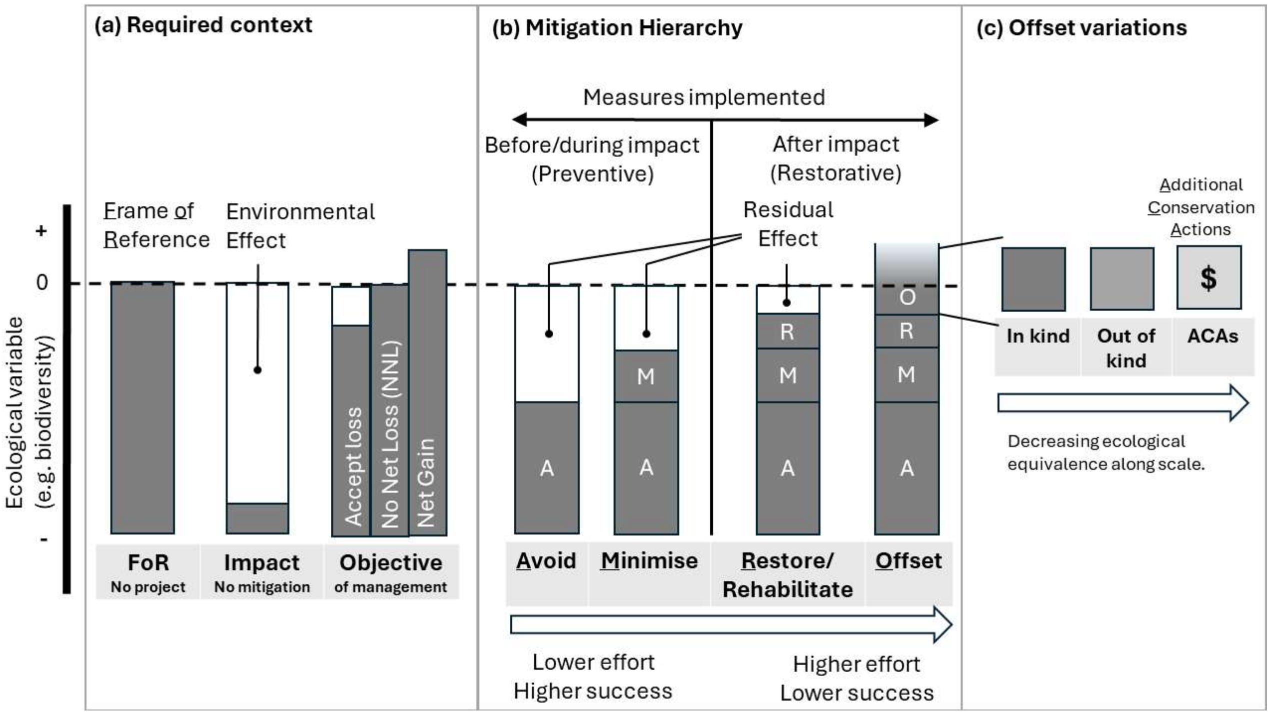

Figure 1. Diagrams highlighting important aspects of the mitigation hierarchy concept. (a) Required context for application of the mitigation hierarchy include 1) determining the ecological variable to monitor (e.g. biodiversity), 2) what frame of reference to compare to (e.g. pre-impact baseline), and 3) what the environmental objective of the management measures is (accepted loss, No Net Loss, or Net Gain compared to the frame of reference). (b) Mitigation Hierarchy concept, which includes four levels: (1) Avoid, (2) Minimise, (3) Restore/Rehabilitate, (4) Offset, which should be followed sequentially as each consequent level generally requires more implementation effort and carries greater environmental risks in the process of addressing impacts, and thus proposed measures should first focus on avoidance, then minimisation for impacts that cannot be avoided, then restoration/rehabilitation for impacts that cannot be minimised, and only offsetting as last resort for impacts that cannot be restored/rehabilitated. Whether or not the proposed mitigation measures under the different tiers are implemented depends on existing policy and legislation (see 'Case studies'). Levels are depicted in this diagram for a scenario working towards No Net Loss or Net Gain through site-specific mitigation and offsetting, but the scenario can vary depending on policy decisions. (c) Offset variations (in kind, out of kind, and Additional Conservation Actions) are depicted existing along a scale of ecological equivalence. This figure is adjusted from Niner *et al*. (2018) Figure 1, Bull *et al*. (2016) Figure 1, and Ekstrom *et al*. (2015) Figure 2 and 3.

[5] It must be noted that, in practice, mitigation measures from all four classes are often researched in parallel during the EIA process to determine their feasibility and effectiveness. However, when presenting the final mitigation package in the Environmental Impact Statement it must be demonstrated the proposed measures follow the tiered mitigation hierarchy.

Following Bull *et al.* (2016)[6], the first level of the hierarchy, **avoid**, refers to measures that, once designed into the project prior to activities beginning, do not necessarily require additional effort to remove impacts. Often these are measures considered in the project design envelope. The second level of the hierarchy, **minimise**, refers to implementation measures that require ongoing effort during activities to decrease impacts and make the adverse effects as small as possible. Avoidance and minimisation measures are both of preventative nature, i.e. they are implemented before and as impacts occur[7]. **Rehabilitate** refers to the process of assisting an ecosystem to recover certain characteristics of its pre-disturbance conditions, such as the presence of certain species, functions or services, whereas **restore** additionally refers to the process of assisting an ecosystem to recover to its overall pre-disturbance conditions, i.e. to return to its pre-existing ecosystem integrity including species composition and community structure, as also outlined in the draft EIA Standard and Guidelines (section V B)[8]. Any adverse effects remaining after implementation of all possible mitigation measures are considered the **residual effects**. Following the next steps of the hierarchy, if there is an environmental goal of NNL or net gain, the residual effects must be **offset.** Measures to restore/rehabilitate and offset are reparative in nature, i.e. they are implemented after impact. Offset measures exist on a scale of ecological equivalence and directness of effects with increasing risk and difficulty quantifying effectiveness along that scale (Figure 1c). An **in-kind offset** means implementing measures elsewhere which result in a gain of the ecological variable which is quantifiably equivalent to the loss at the impacted site. In-kind offsets can be achieved either through (1) restoration of degraded similar habitat elsewhere, or (2) averting losses of similar habitat elsewhere (Ekstrom *et al.*, 2015). **Out-of-kind offsets** can also be achieved through restoration of and averting losses in habitats elsewhere, but which are not ecologically equivalent to the impacted site. A specific implementation of this is ‘trading up’ (Bull *et al*. 2016, Ekstrom *et al.*, 2015) where a habitat is restored that is considered of higher ecological value than the habitat impacted by project activities. **Additional Conservation Actions (ACAs)**[9] are interventions intended to be positive for biodiversity and ecosystem services but do not provide measurable gains that can be set against residual impacts. ACAs may or may not target the biodiversity and ecosystem service features impacted by a project, and can have the aim of improving a certain habitat, directly or indirectly (the latter makes the outcomes very difficult to quantify). ACAs can also include investing in research and education to promote conservation of a certain habitat (Ekstrom *et al.*, 2015).

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[6] Please note a variety of definitions exist to distinguish avoid and minimise, and sometimes the terms are somewhat conflated. Here we decided to follow the definition as presented by Bull *et a*l. (2016). Other definitions can be found in Ekstrom *et al*. (2015) and Dempsey, Hein and Muenter (2023).

[7] Technically, minimisation measures can also be implemented as impacts occur via adaptive management to prevent further impacts (Dempsey, Hein and Muenter, 2023). For example, the ramping up of hammer energy or using bubble curtains during the piling of offshore wind turbine foundations to further minimise noise if continuous monitoring shows certain noise levels.

[8] The definition of the terms rehabilitate and restore vary in literature, which highlights the importance of defining these terms in policy. For example, Bull *et al.* (2016) refer to 'Remediation' for this level of the mitigation hierarchy, and they separate rehabilitate and restore as described here (certain functions vs. back to full integrity). In contrast, Ekstrom *et al*. (2015) refer to 'Restoration' for this level of the mitigation hierarchy, which includes 'remediation', 'reclamation' and rehabilitation' as specific types.

[9] Sometimes also called indirect (out of kind) offsets.

Case studies

Global governance frameworks

Thus far, there appears no explicit referral to the term 'mitigation hierarchy' in multilateral environmental agreements. Rather, the mitigation hierarchy as a concept emerged in the last couple of decades as a tool for implementing and understanding how to facilitate action for requirements in relation to environmental impact assessments and under certain legal principles, such as the prevention principle, precautionary principle, and polluter pays principle in different international environmental law or agreement texts. For example, the United Nations Convention on the Law of the Sea (UNCLOS) has various articles specifically included "*to **prevent, reduce and control** pollution of the marine environment"* (e.g. Article 194 and articles under Section 5), but does not reference the mitigation hierarchy per se, nor the related levels. The Convention on Biological Diversity (CBD) also does not specifically mention the mitigation hierarchy, but it does refer to some of the individual levels within several Articles. For example, "*Each Contracting Party shall, as far as possible and as appropriate: (b) Adopt measures relating to the use of biological resources to **avoid or minimise** adverse impacts on biological diversity* (Article 10), and "*Each Contracting Party, as far as possible and as appropriate, shall: (a) Introduce appropriate procedures requiring environmental impact assessment of its proposed projects that are likely to have significant adverse effects on biological diversity with a view to **avoiding or minimising** such effects [...]*" (Article 14), and "*Each Contracting Party shall, as far as possible and as appropriate: (f) **Rehabilitate and restore** degraded ecosystems and promote the recovery of threatened species, inter alia, through the development and implementation of plans or other management strategies*;" (Article 8). Finally, the recent BBNJ[10] agreement stipulates environmental impact assessments must be conducted in order "*to **prevent, mitigate and manage** significant adverse impacts for the purpose of protecting and preserving the marine environment*" (Article 27).

The mitigation hierarchy has been proposed to be applied at a global level to aid the achievement of global environmental goals (Arlidge *et al.* 2018). The common framework of the mitigation hierarchy could provide clarity and critical thinking but may face challenges pertaining to international coordination and standardization. For example, it is of interest to note that the Kunming-Montreal Global Biodiversity Framework (KM-GBF[11]) under CBD has the goal that "*The integrity, connectivity and resilience of all ecosystems are maintained, enhanced, or restored, substantially increasing the area of natural ecosystems by 2050*" (Goal A), where Targets, such as Targets 1 to 3, address the conservation hierarchy[12]. Conservation can be achieved by avoiding further pressures by ensuring and enabling "*that by 2030 at least 30 per cent of [...] marine and coastal areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed*" (Target 3), by minimising "*the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity [...]*" (Target 1) and to restore degraded ecosystems by ensuring "*that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and marine and coastal ecosystems are under effective restoration, in order to enhance biodiversity and ecosystem functions and services, ecological integrity and connectivity*." (Target 2).

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[10] Agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. (2023)

[11] Decision 15/4 adopted by the Conference of the Parties to the Convention on Biological Diversity. Kunming-Montreal Global Biodiversity Framework. (2022)

[12] Where the mitigation hierarchy allows reactive management of impacts, the related conservation hierarchy additionally allows proactive conservation by structuring biodiversity goals under the same levels (avoid, minimise, restore, offset). More information on the Conservation Hierarchy: https://www.cbd.int/doc/strategic-plan/Post2020/postsbi/biodiversify1.pdf

The mitigation hierarchy has been incorporated into other global governance frameworks, such as in Performance Standard 6 on Biodiversity of the International Finance Corporation (IFC, 2012). IFC is the largest global development institution focused on investing in the private sector, and has published eight performance standards to guide projects on how to consider environmental and social impacts if they receive finance from IFC. Also, the International Union for Conservation of Nature (IUCN) has published a Policy on Biodiversity Offsets (2016) which states "*it is IUCN's position that biodiversity offsets can contribute to positive conservation outcomes. However, biodiversity offsets are only appropriate for projects which have rigorously applied the mitigation hierarchy (avoid, minimise, restore/rehabilitate and offset [...]) and when a full set of alternatives to the project have been considered.*" Some further key points are that the IUCN states that offsets "*must only occur after all previous steps in the mitigation hierarchy have been considered and no alternatives are available*" and that they should "*be employed to address the residual impact in order to achieve at least No Net Loss and preferably a Net Gain*". Additionally, offsets "*must never be used to circumvent responsibilities [...] or to justify projects that would otherwise not happen*" and, importantly, it is stated offsets are not appropriate when "*residual impacts on biodiversity cannot be offset*" or when effects "*could theoretically be offset, but with a high risk of failure*". Under such circumstances, the IUCN is of the opinion a project in its current design should not proceed.

<u>High seas fisheries</u>
Although the mitigation hierarchy framework is not specifically utilized to manage fishing impacts, all four steps of the mitigation hierarchy are discussed (Arlidge *et al.*, 2018 and references therein). Within Areas Beyond National Jurisdiction there are twelve competent authorities called Regional Fisheries Management Organisations (RFMOs) that aim to manage fishing activity, four of which focus upon highly migratory species (e.g. The International Commission for the Conservation of Atlantic Tunas, ICCAT), and eight which are responsible for other fisheries, largely demersal (e.g. the Northwest Atlantic Fisheries Organisation, NAFO). In practice, approaches to mitigate a given impact, such as seabird bycatch or benthic habitat degradation, are either proposed by specific Contracting Parties or the Organisation's own scientific working group. These proposals can range from highly specific (e.g. geographic delimitations of proposed closed areas), through to more generalised requests for scientific advice (e.g. possible mitigations to achieve a certain outcome, such as bycatch reduction of juvenile fish). In either case, proposals must undergo scrutiny by the relevant scientific groups who prepare recommendations to the Commission.

Avoidance of fishing impacts upon seafloor habitats, especially vulnerable marine ecosystems (VME) can be achieved e.g. through reducing overall fishing effort, establishing closed areas, or the exclusion of particular gears which account for the majority of impacts (e.g. benthic closed areas for seven VME types in the NAFO Convention Area). Deep-sea fisheries, in particular demersal trawling, negatively impact slow-growing species such as corals and sponges. These taxa are specifically acknowledged in the Food and Agriculture Organization (FAO) guidelines for Deep-Sea Fisheries (FAO, 2009) which recognise their high vulnerability and varied importance for ecosystem services. States are obliged to avoid or mitigate 'Significant Adverse Impacts' (SAI) upon such habitats, however SAI are likely very context-specific and to date the term has evaded a robust quantitative description in almost all cases (Bell, Guijarro-Garcia and Kenny, 2019), and the standard of SAI assessments varies widely (Kaikkonen *et al.*, 2024).

Minimisation of fishing impacts upon target or non-target species, or habitats, can be achieved through a range of measures, usually technical, such as developing gears that are more selective in favour of target species (e.g. changing bait, hook type, or mesh size) and thus reducing unwanted bycatch. Minimisation may also take the form of promotion of best practice in the safe handling or release of live bycatch (to increase post-release survival rates) and altering overall fishing pressure in line with environmental variability (for instance the 'Total Catch Index' in NAFO, 2022). Minimisation can refer both to reducing bycatch rates of non-retained species (e.g. seabirds or turtles) or species of conservation concern (e.g. some pelagic sharks), as well as certain age classes of target species (i.e. juvenile fish).

Restoration in fisheries has been implemented primarily through restocking of target species, most notably salmonid hatcheries, or some limited investigations into methods for encouraging restoration of mussel and scallop beds or seagrass meadows (Lemasson *et al.*, 2020) and of oyster reefs (FPS Public Health, 2022) in nearshore ecosystems. Restoration of impacts on benthic deep-sea habitats is generally not considered due to the complexity of implementation and the likely long timescales of benefits being realised. Offsetting of fishing impacts is generally not considered beyond coastal regions and thus does not play a role in high seas fisheries management. Although removal of atmospheric carbon is one of the key ecosystem services provided by cold-water coral reefs, and indeed fishes themselves through production of marine snow, this service is not yet formally acknowledged, and no related offsetting measures have been proposed thus far.

Currently avoidance, minimisation, restoration, and offsetting measures are reviewed and adopted on a sectoral and regional basis (i.e. pertaining to specific fisheries, within the geographic remit of the organisation in question), but without significant integration between ocean basins (Bell, Guijarro-Garcia and Kenny, 2019). Each Regional Fisheries Management Organisation (RFMO) is advised by its respective Scientific Committee, but there are often specific barriers to implementation. SAI are described relating to the sensitivity to disturbance, capacity to recover, and the extent of direct impacts to certain identified species and habitats (Section 17 in FAO, 2009, following UNGAs 59/25 & 61/105). However, translating this text into scientifically meaningful quantities has proved extremely difficult and even in the most data-rich regions (the Northwest Atlantic and Southern Ocean) a formalised process of assessing whether fishing impacts constitute SAI has yet to be agreed. In the context of high seas fisheries, the burden of proof required to adopt a new proposal on a particular conservation measure is often much higher than it is to reject. Although some States have espoused implementation of risk-based methods, following the Precautionary Principle introduced in the 1992 Rio Declaration[13], this is usually met with reluctance or dismissal on the basis that risk-based measures are too difficult to validate and cannot conclusively demonstrate costs or benefits of a proposed measure.

<u>Application in UK marine industries</u>

As an example of domestic implementation, in the UK the use of the mitigation hierarchy is considered best practice for coastal and offshore industries (such as marine aggregates, offshore renewables, oil and gas, and coastal power stations), and is incorporated in UK legislation and related frameworks (including *The Conservation of Habitats and Species Regulations* 2017; *The Conservation of Offshore Marine Habitats and Species Regulations* 2017; *Energy Act* 2023; *Levelling-up and Regeneration Act* 2023) to make it a statutory part of the environmental assessment process.

[13] UN Rio Declaration on Environment and Development 1992

Two major sets of regulations exist in parallel that implement the mitigation hierarchy depending on the protection status of the impacted site(s). The EIA process[14] is applied to all UK waters and requires identification of measures to avoid, minimise, or restore/rehabilitate significant adverse effects before assessing the significance of residual impacts. If the project has the potential to impact a protected site[15], i.e. a Marine Protected Area (MPA), the Habitats Regulations Assessment (HRA) process is additionally applied, where, in principle, a project cannot gain consent if adverse effects cannot be fully mitigated by avoidance and minimisation alone[16]. In other words, restoration/rehabilitation measures may not be considered for mitigation because it implies damage will be inflicted on habitats with recognized conservation value. However, the HRA includes a formal continued consenting process (Article 6(4), EC Habitats Directive[17]) through which consent may still be granted through additional steps of demonstrating (1) there are no alternative solutions, (2) there are Imperative Reasons of Overriding Public Interest (IROPI), and (3) appropriate and robust restoration/rehabilitation and offsetting measures[18] are put in place to ‘reverse’ the residual impacts and potentially even reach a net positive impact. Furthermore, since 2024, a Biodiversity Net Gain of 10% is mandatory for new terrestrial development proposals in England (including the intertidal zone)[19], and the feasibility of marine net gain frameworks are currently being explored[20].

Impact avoidance by UK offshore industries is usually achieved by spatial and temporal measures and technical adjustments in the project design e.g. to avoid Marine Protected Areas (MPAs) or features within them, avoid protected features beyond the MPA network, or avoid breeding times for sensitive species. Minimisation of effects is usually achieved by employing less impactful technologies and through spatial and temporal management plans. The challenge of implementing restoration and/or rehabilitation and offsetting techniques in the marine environment due to its dynamic character, large-scale connectivity, and limited accessibility for observations has been recognized in the UK (CIEEM, 2018). For example, in the UK marine aggregate dredging industry there has historically been a focus on preventative measures through spatial and temporal designs (such as avoiding species breeding seasons and the requirement of leaving a layer of similar sediment composition of at least 0.5 m depth at the dredged site), without much consideration of restoration and/or rehabilitation as it is difficult to determine what should and can be restored after permanent habitat removal. A valuation exercise of a restoration plan for a dredged area showed that the restoration cost at the studied site could not be justified by the restoration value of restored ecosystem services, but also partly due to lack of baseline data and lack of an ecological objective in the licence conditions (Cooper *et al.*, 2013). The authors highlight these were site-specific results,

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[14] The Marine Works (Environmental Impact Assessment) Regulations (2007).

[15] Protected by The Conservation of Habitats and Species Regulations 2017, as amended, or The Conservation of Offshore Marine Habitats and Species Regulations 2017, such as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs).

[16] A similar process exists for sites designated under the Marine and Coastal Access Act 2009 (see section 126), which is the Marine Conservation Zone assessment process in England, and the Nature Conservation MPA assessment process in Scotland.

[17] Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, 1992

[18] The EC Habitats Directive specifies the umbrella term ‘compensatory measures’, which would be the equivalent of restore/rehabilitate and offsetting in our four-tier mitigation hierarchy (K. Randall, pers. comm.).

[19] Biodiversity Net Gain (GOV.UK) available at https://www.gov.uk/government/collections/biodiversity-net-gain

[20] Summary of responses to the public consultation on the principles of marine net gain (GOV.UK) available at https://www.gov.uk/government/consultations/consultation-on-the-principles-of-marine-net-gain/outcome/summary-of-responses

and other restoration techniques that have showed some promise of effectiveness at small scales may be used at other dredged areas.

Although The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations (2020) specify the full mitigation hierarchy in Schedule 6, the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) is of the view to generally not consent to projects requiring offsetting of significant residual effects, as it is best practice for preventative measures to leave no or negligible residual effects (OPRED, pers. comm.). If consent is granted for a project utilizing offsets, the offsets must be demonstrated at the start and carefully monitored to validate their effectiveness.

The Offshore Wind industry has historically sought to fulfil the requirements of the Habitats Regulations[21] by addressing unavoidable adverse environmental effects with 'compensatory measures', which would be equivalent to the restoration/rehabilitation and offsetting measures in the four-tier hierarchy described here. Currently, the interpretation is that such measures proposed for offshore wind farms should benefit the specific habitat or species that is being impacted, which would be equivalent to 'in kind' measures as per this brief. However, the UK government is delivering reforms[22] to introduce more flexibility by broadening the types of measures available to offshore wind developers (which could include out-of-kind measures as per this brief), to support accelerated development of offshore wind whilst protecting the marine environment[23]. The UK Offshore Wind Environmental Improvement Package is designed to help accelerate the deployment of offshore wind by de-risking and accelerating offshore wind planning decisions, whilst protecting the marine environment. The UK Government has created a library of approved strategic measures and has launched a Marine Recovery Fund (MRF) in December 2025. The industry-funded MRF will deliver the strategic measures and developers can choose to pay into this fund to secure the measures necessary for the project. Adaptive management is used in the management of offshore wind in the UK and often included in licensing conditions, where monitoring of impacts is used to review the effectiveness of implemented measures and inform potential changes in management.

Considerations for deep-sea mining

There are specific considerations to make when applying the mitigation hierarchy to deep-sea mining, due to generally poor accessibility of deep-sea habitats, large uncertainty and knowledge gaps, and potential vulnerability issues due to the slow growth and recolonization rates of most deep-sea species. Many of these considerations will be the same for other activities in the deep sea. Some deep-sea scientists have argued that restoration/rehabilitation are not currently achievable as the effectiveness of proposed measures has not been established yet or is currently under investigation, but may become feasible in the future (Cuvelier *et al.*, 2018; Da Ros *et al.*, 2019; Gollner *et al.*, 2022). Others have concluded that in-kind offsetting is also not currently achievable because impacts to offset are difficult to quantify, the effectiveness of restoration techniques is currently unproven, no degraded similar habitats exist elsewhere to restore, and additionality and jurisdiction may be problematic (Niner *et al.*, 2018). Out-of-kind offsetting is

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[21] The Habitats Regulations include the Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017, which transpose the EC Habitats Directive to UK law.

[22] Correct as of January 2026.

[23] Energy Security Bill Policy Statement on Offshore Wind Environmental Improvement Package Measures available at https://assets.publishing.service.gov.uk/media/65b13f381702b1000dcb1209/energy-security-bill-offshore-wind-environmental-improvement-measures.pdf

theoretically technically feasible but assumes that impacts to offset can be quantified and that life forms and habitats are exchangeable. To date, environmental costs of deep-sea mining have not been fully quantified, and remains challenging related to knowledge gaps on ecosystem function and services. Additional Conservation Actions are feasible but do not provide measurable gains that can be set against residual impacts, and ACAs may or may not target the biodiversity and/or ecosystem service features impacted by a project. There is broader agreement that the first two preventative steps of the mitigation hierarchy could be implemented for deep-sea mining to reduce impacts to some extent (Jones *et al.*, 2019) (Figure 2). As such, some observers to ISA Council have requested that the restore/rehabilitate and offset tiers of the hierarchy are removed from the requirements of the draft exploitation regulations and draft EIA Standard and Guidelines for all mineral types, while some member States have requested further clarification of how and under what circumstances these latter tiers could be implemented. General considerations for applying the mitigation hierarchy to deep-sea mining are discussed below, but it must be kept in mind that specific implementation of measures may also be resource specific or specific to the associated environmental conditions. For example, dynamics and geomorphology at hydrothermal vent ecosystems are different from seamount-crust ecosystems, which are different from nodule ecosystems. These differences could thus affect the type and effectiveness of mitigation measures.

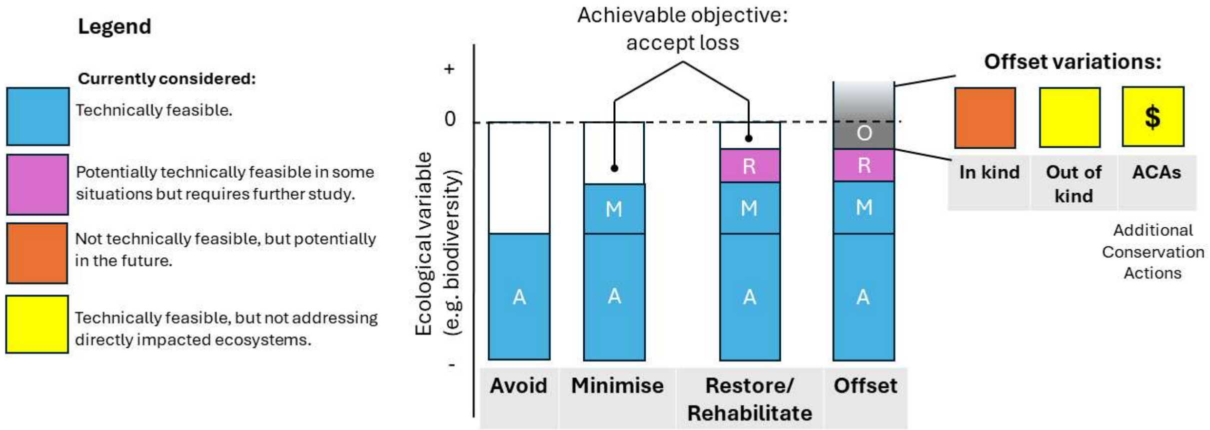

Figure 2. The mitigation hierarchy levels and offset variations are colour coded to reflect what is generally considered to be their current technical feasibility for deep-sea mining. Preventive (avoid, minimise) techniques are currently considered technically feasible to effectively reduce the impacts of deep-sea mining (blue). Currently, restoration/rehabilitation measures have not yet been shown to be technically feasible to effectively mitigate impacts on communities related to any of the targeted deposits, but may become effective in the future through additional research (pink). In-kind offsetting is currently not considered technically feasible (orange) as diversity and functions to offset are difficult to quantify, no degraded similar habitats exist elsewhere to restore, and averting losses at similar habitat elsewhere would have issues with proving additionality and possibly jurisdiction. Out-of-kind offsetting is currently technically feasible, but they assume life forms and habitats are exchangeable, and effects may be hard to quantify and monitor (yellow). Therefore, taking into account current technical feasibilities, an achievable objective for mitigating impacts of deep-sea mining is to accept a certain extent of loss of directly impacted ecosystems.

Avoid and Minimise

Identified impacts from deep-sea mining can be avoided and minimised through spatial and temporal project design. These could include establishing set-aside areas, optimizing mining patterns with respect to environmental protection targets, timing restrictions to avoid impact to migration and breeding seasons of species, and consideration of less impactful discharge procedures (Cuvelier *et al.*, 2018). Similarly to the environmental assessment of marine aggregates, some of the impacts from resource extraction cannot be avoided as the exploited resource functioning as habitat will be permanently removed. Therefore, representative set-aside areas (such as Areas of Particular Environmental Interest [APEIs] as defined under the Regional Environmental Management Plans) of suitable scale and connectivity are considered a mitigation measure of utmost importance (Cuvelier *et al.*, 2018), and additional suitable conservation areas may need to be defined. Such spatial and temporal project design requires scientific knowledge on local and regional environmental conditions, biodiversity, habitat distributions, species ranges, species life history, and connectivity (Cuvelier *et al.*, 2018; Niner *et al.*, 2018). Although such information is available for some well-studied sites and species, general scientific understanding of ecosystem variability over longer temporal and spatial scales and for newly discovered/undiscovered species is currently still limited or lacking for the habitats where deep-sea mining is proposed (Niner *et al.*, 2018; Lusty *et al.*, 2021; Rabone *et al.*, 2023). For example, a habitat type classification study of the Clarion-Clipperton Zone (CCZ) highlighted lack of sufficient protection of certain habitat types in the original design of APEIs, resulting in the designation of four additional APEIs for better representativity in established refuge areas (McQuaid *et al.*, 2020).

Some mitigation measures proposed for deep-sea mining are similar or the same as those used for other industries, and therefore have established effectiveness (e.g. noise mitigation at the surface for marine mammals and other megafauna[24], avoidance of marine mammal collisions[25], and areas closed to activities to protect sensitive habitats). However, measures proposed for deeper waters are largely untested, and the sensitivities of the species therein are virtually unknown. Some estimates of species sensitivities may be able to be made by studying analogous families, genera, or species with similar functions residing in shallower waters (e.g. van der Grient and Drazen, 2022) utilizing concepts such as phylogenetic constraint. Such estimates would require validation for deep-sea species as adaptations to deep-sea characteristics (such as food-limitation, high pressure, low temperatures, darkness) may have resulted in specific life history and physiology traits that affect sensitivities to impacts (Cattin *et al.*, 2004; Bryant and McClain, 2022). Pre- and post-impact monitoring studies are essential to evaluate to what extent proposed mitigation measures (such as collectors designed with low sediment discharge, light, noise and vibration buoyancy adjustments) are effective in avoiding or minimising impacts (Cuvelier *et al.*, 2018; Niner *et al.*, 2018). Adaptive management could be used as a tool to address uncertainty of measure effectiveness through ‘learning by doing‘, where clear hypotheses are formulated about measure effectiveness, the uncertain measure is implemented in the field, carefully designed monitoring is used to test those hypotheses, and finally monitoring results are used in a structured decision-making process to adjust management plans if required. Adaptive management has been implemented for chemosynthetic seep communities in the Gulf of Mexico (Boland, 2010), but may be more challenging for other deep-sea habitats due to their vulnerability to impacts and generally slow recovery rates (Jones *et al.*, 2019).

Rehabilitation/Restoration

Rehabilitation/restoration techniques have been proposed (such as the installation of artificial substrates, sediment decompaction, artificial nutrient enrichment, increasing crust rugosity, and translocation of communities), but their effectiveness has not been established to date or is currently

[24] Guidelines for the Reduction of Underwater Noise From Commercial Shipping to Address Adverse Impacts on Marine Life (IMO) available at https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/833%20Guidance%20on%20reducing%20underwater%20noise%20from%20commercial%20shipping,.pdf

[25] Guidance Document for Minimizing the Risk of Ship Strikes with Cetaceans (IMO) available at https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/674.pdf

under investigation (Cuvelier *et al.*, 2018; Da Ros *et al.*, 2019; Gollner *et al.*, 2022). Should mid-water populations be adversely affected by sediment plumes (Stenvers *et al.*, 2023) or should mobilisation of toxins potentially accumulate in the food web (Hauton *et al.*, 2017), which is currently unclear, it is uncertain what restoration or rehabilitation techniques would be viable. Although assisted recovery of some ecosystem characteristics may be possible in the future (i.e. rehabilitation), assisted recovery to pre-impact conditions (i.e. restoration) is not considered realistic when habitat is permanently removed and long-term structural changes have been made to the ecosystem[26]. Rehabilitation/restoration experiments may require decades of monitoring to establish effectiveness due to the slow growth and recolonization rates in most deep-sea environments (Gollner *et al.*, 2022), and thus, generally speaking, it may not be possible to transfer experiences and measures from coastal and shallow marine systems to deep offshore systems. Therefore, currently rehabilitation/restoration measures cannot yet be effectively applied to mitigate impacts on deep-sea communities, but they may become effective in the future through additional research (Figure 2). Again, adaptive management may be considered a tool to address the uncertainty of rehabilitation/restoration measures' effectiveness (see 'Avoid and Minimise' above).

<u>Offsetting</u>
As far as we know, no offsetting techniques have been proposed or studied for direct application to deep-sea mining. Stakeholder views vary with regard to true in-kind offsetting ranging from it not being currently achievable to it being unlikely to ever be achievable for deep-sea mining (Figure 2). This is because effects on the ecological variable will be difficult to quantify, no degraded similar habitats exist elsewhere to restore, and additionality[27] and jurisdiction may be problematic under various international treaties and governance policies when averting losses at similar habitat elsewhere (Niner *et al.*, 2018; Lusty *et al.*, 2021). From a technical perspective, in-kind offsetting may become available in the future if increased knowledge about the efficacy of restoration/rehabilitation techniques could be used in previously mined areas. Out-of-kind offsetting (including ACAs) is technically possible and would allow lost and damaged ecological components to be exchanged for other ecological components (e.g., a coral reef to offset lost deep-sea habitat), either through direct or indirect measures (e.g., establishing a new habitat or funding research/education, respectively) (Bull *et al.*, 2016; Ekstrom *et al.*, 2015). However, the effects may be difficult to quantify and monitor, and out-of-kind offsetting also remains the subject of environmental and ethical debate, such as on exchangeability of life forms and movement of natural capital (Niner *et al.* 2018 and references therein). Offsetting through the movement of natural capital may result in benefits being transferred from the Area to areas within national jurisdiction, or different parts of the Area. Therefore, out-of-kind offsetting has been proposed by some not to be used or used with great caution in general, for any environment (Bull *et al.*, 2016; Niner *et al.*, 2018).

Conclusion
In summary, avoidance and minimisation measures could be effectively applied to DSM if the appropriate ecological knowledge is available, but they cannot be used in isolation to completely prevent losses in the ecosystem as extractive industries by definition permanently remove habitat. Currently, effective restoration/rehabilitation of affected deep ecosystems has not yet been demonstrated but additional research may result in effective measures for future implementation.

[26] Various studies indicate the concept of complete restoration to pre-impact conditions may not be realistic, and at the very least incredibly difficult to achieve, in any habitat, including on land (e.g. Bayraktarov *et al.*, 2016; Cross *et al.*, 2021; Piccolo *et al.*, 2024).
[27] Additionality means demonstrating the proposed offset measures makes a difference which would not have occurred without the offset measure (Bull *et al*. 2016).

Such research will likely take a long time due to the slow growth and recolonization rates of deep-sea species. Finally, in-kind offsetting of damaged deep ecosystems is not currently considered technically feasible, and whether it may become achievable in the future is linked to increased knowledge on restoration/rehabilitation techniques and access to damaged deep habitats to restore/rehabilitate. Currently, DSM can only occur when a certain extent of loss is accepted where the impacts and effects of extraction occur (Figure 2) (Niner *et al.*, 2018). Out-of-kind offsetting and ACAs that aim to improve overall ocean and planetary health may be achievable and warrant further discussion. While, by definition, such initiatives cannot directly contribute to restoring the environmental status of impacted deep ecosystems, they could contribute to global environmental goals.

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