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Strategic Environmental Goals and Objectives: Setting the basis for environmental regulation of deep seabed mining

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ABSTRACT

Deep seabed mining is a major new intersection of human enterprise and deep-ocean ecosystems. This paper reviews the concept and process for a holistic approach to planning environmental management in the deep sea based on Strategic Environmental Goals and Objectives. Strategic planning around the environment can establish a vision for the future condition of the ocean floor for which the International Seabed Authority (ISA) can draw on a wealth of precedents and experience. By engaging stakeholders and applying current knowledge of deep ecosystems, the ISA can build meaningful strategic environmental goals and objectives that give guidance to its own operation and those of its contractors. This framework builds understanding of the organization's aspirations at global, regional and contractor levels. Herein, some examples are suggested, but we focus on the process. To operationalize these goals and objectives, progress must be measurable; thus, targets are set, reports are assessed, and appropriate responses are awarded. Many management tools and actions are applicable for achieving environmental goals. To date, the ISA has considered marine spatial planning largely around the current exploration contract blocks. Other elements of environmental management, including the requirements for baseline studies, impact assessment, post-impact monitoring and the treatment of harmful effects and serious harm need to be implemented to support well-defined environmental goals and objectives. We suggest that this planning be executed for scales larger than individual blocks, through a Strategic Environmental Management Plan, to ensure sustainable use of ocean resources across the Area.

1. Introduction

The International Seabed Authority (ISA) was established through the United Nations Convention on Law of the Sea (UNCLOS) to implement Part XI: to organize and control activities related to the seabed mineral resources in the areas beyond national jurisdiction (the Area) in the context of the 'common heritage of mankind' [1]. In a concise review of the ISA, Cai (2018) describes its mandate to include development of mineral resources with equitable economic considerations, protection of the marine environment from 'harmful effects' that result from these resource-related pursuits, promotion of marine research, and relevant capacity-building for developing nations [2]. To guide the process, the ISA has developed regulations for prospecting and exploration of three resource types: polymetallic nodules, massive sulphides and cobalt crusts [3–5]. Between 2001 and 2018, the ISA approved 29 exploration contracts with public and private entities. In recent years, the ISA, through its Legal and Technical Commission (LTC), has been formulating the regulations to govern extractive mining of these mineral resources; the latest release of the Draft Exploitation Regulations was in mid-2018 [6]. The full body of regulations, guidelines and recommendations around all aspects of prospecting, exploration and exploitation is collectively known as 'The Mining Code'.

The ISA is bound to consider the effects of this endeavour in the Area on the deep-sea environment that is part of the natural wealth of the Earth. It must determine how mining can proceed without causing serious harm to that environment (and associated ecosystems). As the ISA develops the Mining Code, a major undertaking is formulation of environmental regulations that reflect principles conforming to international standards, and that recognize other uses of the seabed now and by future generations [7]. Some aspects of such principles appear in the provisions of the Exploration Regulations, including application of the precautionary approach and use of best environmental practices.

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Contractors currently have a suite of Recommendations to develop assessments for the environmental impacts of exploration activities [8]. In early 2017, the ISA released a draft discussion paper on environmental matters related to exploitation [9], and a workshop in Berlin in March 2017 ("Towards an ISA environmental management strategy for the Area" [10]) explored the many issues raised in that document including the subject of this contribution.

In both aspirational and mandated contexts, the ISA and Member States express concern for the deep ocean environment of the Area. Thus, strategic planning that addresses the desired future condition of the seabed is highly appropriate. The 'strategic' approach to any endeavour incorporates a long-term plan with clear priorities and objectives, along with a means to monitor and assess progress. In developing the Mining Code, the ISA is establishing regulations to govern the behaviour of extraction activities. However, combining rules with goal-oriented governance links the bureaucratic requirements with the larger vision of why those rules exist [11]. There are widespread calls for the ISA to establish overarching environmental goals and objectives to support all aspects of environmental management under which environmental impacts and harmful effects from seabed mining can be assessed. Several examples of those calls exist. i) An evaluation of the ideal process for environmental impact assessment (EIA) identifies the role of goals and objectives to set the context for regional strategic environmental assessments (SEA) and EIAs [12]. ii) A 2016 ISA workshop advocated such goals and objectives to support an ecosystem-based approach guiding baseline data collection, monitoring programs and decision-making [13]. iii) The Pacific Community presented a regional environmental management framework that highlights the importance of balanced objectives to achieve sustainable outcomes [14]. iv) Several stakeholder comments [15] regarding the first Draft Regulations on Exploitation [16] called for the development of environmental goals and objectives to provide context and criteria under which contractor performance, including assessment of effects of mining, can be measured. v) A recent response to the 'Discussion Paper on Environmental Matters' issued by the ISA in 2017 [9] had an analysis of aspects of environmental rulemaking that includes the formulation of goals and objectives [17].

The Berlin workshop culminated in 44 points for further work that reflect both the magnitude of the task and the depth of thinking; a governance approach that begins with overarching policy and objectives was recommended [10]. Prior workshops have focused on environmental management aspects by the ISA (such as the 2018 meetings to discuss Regional Environmental Management Plan (REMP) development for cobalt-rich crusts and polymetallic sulphides). Regional environmental planning for the Clarion-Clipperton Zone (polymetallic nodules) determined placement of conservation areas (i.e. "area of particular environmental interest" or APEI) using a process guided by environmental criteria and objectives [18]. The scientific community engaged in a similar initiative for the Mid-Atlantic Ridge (SEMPIA), proposing a specific spatial management plan based on an overarching conservation goal and five conservation objectives [19].

UNCLOS provides the ISA with the direction to "prepare assessments of the environmental implications of activities in the Area" and to "make recommendations to the Council on the protection of the marine environment…" (Article 165, 2(b, c) [1]). Such work will be greatly facilitated by clear environmental goals. This approach is acknowledged in the recently adopted Strategic Plan of the Authority in which one of the ten guiding principles is "[t]o promote harmonized approaches to the protection of the marine environment and its resources" (Item 4f in Part I [20]); other than this oblique reference, the Plan does not mention strategic environmental goals. The Exploration Regulations for all resources oblige Contractors (through the ISA and Sponsoring States) to implement a precautionary approach, meaning they must manage environmental risk at an early stage, despite scientific uncertainty [21]. However, lack of defined overarching goals and achievable objectives make it unclear whether these responsive measures would be effective for 'protection and preservation of the marine environment' from harmful effects, as mandated by UNCLOS Article 145. Additionally, the vehicle to protect the marine environment from "harmful effects" should be developed through environmental goals and objectives [22]. At the first part of the 23rd Session of Council for ISA, directions to the LTC for revision of the 2017 Draft Regulations included the request that the LTC "reflect on relevant content for an environmental policy framework" (Section E40(c) of [23]). Thus, the stage is set for developing a broader framework led by the ISA's goals for the environment.

In our study, we review the international standards both for creating overarching environmental goals and objectives and for implementing mechanisms to achieve them. The study is placed within the context of the development of the ISA's Mining Code and its mandate for stewardship of the affected ocean environment before, during and after seabed resource exploration and exploitation. We discuss the inclusive process that must take place to develop such goals and objectives, giving a few examples that can be used to initiate the discussion. While we focus on the Area, key principles are applicable to any jurisdiction embarking on mineral extraction in the ocean. The assessment of *harmful effects*, a concept articulated by UNCLOS (Article 145) and implemented in existing ISA regulations for seabed mineral exploration, must be conducted in the context of the ISA's unifying environmental goals and objectives; here, examples indicate how to address this issue. In particular, an essential part of the process of establishing goals is to define targets with measurable indicators that support assessment of progress to a goal. We address the variety of management tools that can be considered when implementing an environmental strategy, and review progress in this area. We draw on the background in work mentioned above and from a DOSI (Deep Ocean Stewardship Initiative) workshop in 2017 that discussed goals, objectives and indicators for more holistic environmental planning in the context of the draft Discussion Paper on Environmental Matters [9]. Outcomes of that workshop were presented at the Berlin workshop "Towards an ISA Environmental Management Strategy for the Area" [10].

2. Establishing Environmental Goals and Objectives

Strategic planning is a deliberate process that examines current status, a desired future status and the stepwise process to get to that future; it shapes the decisions that an organization makes [24]. This planning helps leaders enable – and defend – outcomes based on

Text Box 1
: Definitions.

Goal: a statement of general direction or intent. Goals are high level statements of the desired outcomes to be achieved.

Objective: a specific statement of desired outcomes that represent the achievement of a goal.

Target: an interim point on the way to an outcome and eventually to a long-term management goal.

Performance Indicator: quantitative or qualitative statements or measured parameters that can be used to measure the effects of specific management actions over time.

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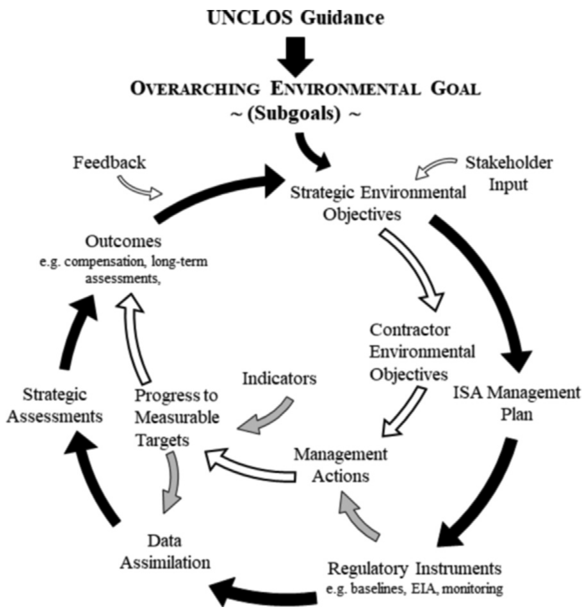

Fig. 1. Simplified representation of the cycle of setting goals and objectives that can proceed to implementation of policy and management actions, indicating the role of the International Seabed Authority in developing a strategic approach, overseeing Contractors and assessing outcomes of their progress through measurable targets. The feedback allows for adjustments of objectives over the long term.

rational choices that often include broad input. The process generally defines goals, objectives and targets as well as a mechanism to assess progress toward measurable targets using indicators: hence, Strategic Environmental Goals and Objectives. Text Box 1 presents the relevant definitions adopted by the Intergovernmental Oceanographic Commission [25]. When an organization designs a sustainable development framework, societal and economic goals contextualize goals for the environment.

The history of establishing strategic approaches to address the environment is complex; here, a few examples illustrate that there is much precedent available to the ISA. As the environmental costs of development and industrialization in the past century grew, many countries and organizations formalized environmental strategies. The World Bank reviewed emerging practices in the mid-1990s to recommend approaches that included setting priorities with clear criteria, involving stakeholders, and deciding environmental objectives [26,27]. Since then, as States have grappled with policy development around environmental strategies, most have set overarching goals and objectives with plans that are usually implemented at the state level and may be used by regional jurisdictions. One example is that of Sweden, which defined a single national strategic environmental goal and conducts regular assessments of progress towards specific objectives using defined targets and actions [28].

The principle of setting environmental goals and objectives is demonstrated in several international fora, including the Conference of the Parties to the Convention on Biological Diversity (CBD) that advocates initiating an Ecosystem Approach to sustainable development by stating that "*Collectively developing the overarching goals, objectives, targets for the exercise is important before applying the ecosystem approach* [29]." In referencing the Principles from the CBD, Henocque [30] notes that they are designed for managing humans, not environments. Similarly, as the Organization for Economic Co-operation and Development (OECD) developed guidelines to enact the Rio 21 Agenda for sustainable development, a key component was to integrate economic, social and environmental objectives at a national scale [31]. This international agenda culminated in the 2012 UN Conference on Sustainable Development that negotiated 17 Sustainable Development Goals (SDG) with 169 targets. Despite this great achievement, there remains the challenge of agreement among States on many indicators to assess performance relative to the targets and on the systems of measurement [32]. Nonetheless, there are many precedents at the levels of States and of international agreements that can assist the ISA in formulating relevant policies. In this way, it may facilitate ISA's contribution to the SDGs as set out in its Strategic Plan [20].

The articulation of an environmental goal and well-defined targets that can evaluate performance outcomes will affect whether the goal is achievable. The process requires defining priorities, thereby focusing the organization and stakeholders on how activities and operational resources are allocated. The priorities can guide formulation of goals understandable by all participants. Emergent consensus is supported by a regulatory structure to guide behaviour (e.g. during exploitation) toward the goal [11]. Whether a goal can be reached is partly dependent upon the degree of clarity in the formulation, and whether progress toward targets is measurable. An analysis of progress toward the biodiversity "Aichi Targets" finds little evidence of improvement in the selected indicators [33]; however, the progress is, indeed, measurable. Only clearly identified targets using well-defined and standardized performance indicators can provide the measuring stick used to evaluate progress (or lack thereof) towards achieving desired outcomes to meet the goal. Thus, a management approach that implements the processes designed to achieve the overarching goals will support success in executing the initial strategic environmental plan. Development of a management cycle and review process will continue to strengthen the outcomes.

3. Strategic goals, objectives and targets in the context of ISA seabed mining

Considered here are *strategic environmental goals and objectives* (SEGOs) that are long term and that should apply across the entire Area, irrespective of target resources or environmental setting. They are developed by the lead agency in a strategic planning process as identified above. There are three interconnected levels for achievement of SEGOs. One level lies with the ISA as it acts in a global context with oversight of many mining-related activities; a second lies also with the ISA at the regional level, addressed by REMPs; and the third is at the Contractor level addressing the environmental issues within and around a single operation (Fig. 1). The ability of proposed actions to meet broad environmental goals and objectives for the Area can be established in an overarching Strategic Environmental Management Policy [34]. Clear objectives explicit in the Policy would: i) inform regional- and project-level management plans; ii) be fully integrated into the Mining Code and the ISA decision-making processes; iii) ensure that environmental standards and measures are identified in a systematic manner, and allocated to the appropriate actors; iv) articulate how key principles (e.g. the precautionary approach, ecosystem approach, and best environmental practices) are operationalized in the Area; and (v) provide

Text Box 2
A Guiding Environmental Principle for the International Seabed Authority.

> To ensure effective protection for the marine environment from harmful effects, which may arise from activities in the Area (Article 145 [1])

guidance on the environmental measures required before, during and after mining.

For the ISA global level, Text Box 2 presents a key obligation set out in UNCLOS that can serve as the overarching guiding principle, under which all Member States and the ISA operate in which "activities" are those under ISA administration. The obligation of the ISA is to balance exploitation of seabed resources and protection of the marine environment, ensuring the Area and its mineral resources are used to benefit (hu)mankind as a whole (UNCLOS Articles 136 and 140 [1]).

While UNCLOS presents principles to guide the development of environmental goals and objectives, no clear objectives with measurable targets are enunciated. For example, Member States are obliged to protect the marine environment (Articles 145 and 192 [1]), in which they must "protect and preserve rare and fragile ecosystems as well as the habitat of depleted, threatened, or endangered species and other forms of marine life" (Article 194 [1]). However, the only tools offered are "measures necessary" and "best practicable means" (Article 194 [1]). Defining more specific goals, objectives, targets and measures will be necessary to ensure the ISA and Member States are following their mandate to protect the marine environment. The ISA will need a process to review progress toward its targets by evaluating quantifiable performance indicators. At the global and regional scales, this process should not be left to Contractors, as it may not guarantee that the ISA's environmental objectives are met [35], although a compilation of standardized measures from Contractors can inform progress.

At the Contractor level, the Mining Code could invoke the requirement for specific Goals, Objectives and Targets (GOTs) that align with the ISA's overarching Strategic Environmental Goals and Objectives (SEGOs) at regional and global levels. The proposed Environmental Management and Monitoring Plan [6] is an appropriate vehicle. Such tailored GOTs and measurable indicators are necessary to ensure that: i) Plans of Work provide effective protection of the marine environment, ii) effectiveness of mitigation measures can be assessed, iii) monitoring has the ability to detect environmental impact, and whether impacts are significant, and iv) that a Contractor's environmental performance is satisfactory [35]. By engaging "appropriately qualified experts" in setting and reviewing the environmental GOTs, it may be possible to address the particulars of the Contractor's activities, and also to seek commonalities across Contractors to facilitate roll-up of some measures that support assessment toward regional targets (Fig. 1).

4. Developing Strategic Environmental Goals and Objectives

Overarching environmental goals and objectives should be generalizable across mineral resource types and environmental settings, should apply to multiple spatial and temporal scales relevant to targeted ecosystems, and should consider the potential needs and expanded knowledge base of future generations. Developing overarching goals and objectives may require crossing jurisdictions or sectors and, considering cumulative impacts, could require the ISA to work with other entities that manage or influence the deep ocean. Additional regional and resource-specific goals and objectives are likely needed based on whether measurable targets can be set to evaluate progress to meet the objectives. For these targets to be operationalized, information may be required that spans multiple contract blocks, as well as reserved, protected or unmanaged areas.

The sequence of establishing SEGOs can be illustrated within the context of the ISA's efforts to articulate its environmental regulations for deep-sea mining. Given the UNCLOS Article 145 [1] overarching guiding principle (Text Box 2), a useful example for strategic goals can be found in the CBD objective: "conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources". Other examples are the five strategic goals outlined in the CBD Strategic Plan for Biodiversity 2011–2020. Guided by such initiatives, an overarching strategic goal for ISA could be:

> "to sustain marine (benthic and pelagic) ecosystem integrity including the physical, chemical, geological and biological environment".

Clear definitions are required to translate this goal to explicit objectives; for example, 'ecosystem integrity' should reflect the need to preserve ecosystem structure, function (processes), connectivity, resilience and ability to provide ecosystem services [35].

Examples of specific objectives that, if met, would make significant progress towards achieving this environmental goal include:

i. Protect ecosystems from contamination by pollutants generated during any phase of the mining process;
ii. Maintain the ability of populations to replace themselves, including ensuring population connectivity and the preservation of suitable habitat;
iii. Prevent the degradation of ecosystem functions (e.g. the long-term natural productivity of habitats, elemental cycling, trophic relationships);
iv. Prevent significant loss of genetic diversity, species richness, habitat or community types, and structural complexity on a long-term basis;
v. Sustain ecosystem services (e.g. carbon sequestration) recognizing that many are yet to be discovered; and
vi. Maintain resilience to prevent regime shift, and to support recovery from cumulative impacts, including mining, that can affect source populations and communities, connectivity corridors, life-history patterns and species distributions.

These types of objectives can be developed by experts based on a combination of fundamental ecological principles, specific biological and ecological knowledge of the particular targeted system (e.g. hydrothermal vents, polymetallic nodule fields, seamounts), and other systems with relevant processes (e.g. cold seeps and deep coral reefs), as well as from examples of advanced types of environmental management (e.g. gear restrictions at fisheries closures, Vulnerable Marine Ecosystems (VMEs), Marine Protected Areas (MPAs).

The next step in developing SEGOs is to link each objective to a target that can be measured using performance indicators. This aspect is the most challenging, but imperative, step in the process, without which success in meeting the goal cannot be assessed. The challenge may be associated directly with understanding the objective, reducing complexity in the objective, identifying a meaningful target, and/or in the selection of realistic performance indicators. An important question relates to the number of appropriate objectives that are needed to meet the environmental goal(s). The example presented here includes six objectives that mostly reflect the five components of ecological integrity (itemized above), the maintenance of which is the proposed environmental goal: objective (ii) relates to maintaining connectivity, (iii) to ecosystem function, (iv) to resilience and structure, and (v) to ecosystem services. An added objective, the first, addresses the overall issue of the direct impact of the pollutant from the activity. The complexity of objective (vi) may require the development of sub-objectives (e.g. addressing resilience to regime shifts and resilience to cumulative impacts) which may (or may not) have similar targets (e.g. "stable" domains of community structure) and indicators (gradual change in conditions) [36]. Ultimately, the objectives must be sufficiently comprehensive to adequately reflect the goal, which itself may be quite complex.

The translation of objectives to specific targets and indicators can be achieved either through scientific evidence, or by consensus based on expert opinion that is guided by the precautionary principle if data are unavailable. Collecting more baseline information may be necessary when neither of these approaches is feasible. For example, objective (i) requires relatively straightforward information on levels of contaminants generated during mining and knowledge of acceptable levels, such as LC_{50} (Lethal Concentration to 50% of the population) for different biological processes [37]. In some instances, the only way to set a target will be through the collection of extensive baseline data for the particular system. The ability to recover from disturbance and the identification of tipping points [as required for objective (vi)] can only be achieved by measuring the natural intra- and inter-annual variability of the system [22]. The challenge arises when the target needs to be set to certain numerical values. What is the number of species that must go extinct to constitute a significant loss of species richness [objective (iv)]? How much productivity loss will cause a degradation of ecosystem function [objective (ii)]? How much area, or how many individuals can be removed before connectivity amongst populations is lost [objective (ii)]? Precedent on setting targets exists widely (at the national, regional and international levels), where bodies of scientific experts make recommendations to managing authorities. Examples include percentage of area to be placed in MPAs, definitions of VMEs as followed by the Regional Fisheries Management Organizations (RFMOs) [38], and criteria for Ecologically and Biologically Significant Area (EBSAs) as defined by the CBD [39]. The ISA can also use international scientific experts to address this very critical issue and generate targets, once their overarching environmental goals are defined. Targets should be set at the level appropriate to the objective; some will be specific to ISA actions directly, while others (e.g. at regional level) would be standardized across Contractors. Targets will almost certainly need to be adjusted over the long term as more data become available, environmental conditions change, or technology advances. Although targets should not be modified haphazardly, adaptive management could allow feedback between monitoring and decision making (see section on 'Applying Management Actions').

Perhaps the most straightforward aspect of the process is the selection of appropriate indicators. For example, indicators for ecosystem function [objective (iii)] include primary productivity, oxygen consumption and nutrient cycling, while those for ecosystem structure [objective (iv)] include species composition, richness, evenness, rarity, density and biomass. Specific methodologies to measure many of these indicators are well-established, as are best practices for appropriate sampling designs. Much research has focused on such issues in the last decade (e.g. Project DEVOTES, http://www.devotes-project.eu/) as a result of international directives (e.g. Marine Strategy Framework Directive by the European Commission [40]). Similar indicators for identifying adverse change and serious harm were also proposed by participants of the Berlin workshop [10].

The examples of goals, objectives, targets and indicators provided here are not meant to be prescriptive or exhaustive (see Appendix A for additional examples of Goals, as proposed during the DOSI workshop). The purpose is to illustrate that: (1) the ISA and its Member States would set the overall strategic goals for the Area, as well as more specific regional environmental goals; and (2) the development of specific objectives, targets for these objectives and indicators to measure the targets should be done in collaboration with scientific experts, using precedents from State, regional or intergovernmental environmental management authorities where available and relevant. Several management actions are available to the ISA, however, none of them can be successful without clear and quantifiable targets against which progress towards meeting the objectives and realizing the goals can be assessed.

5. Applying management actions

Selecting the appropriate management actions to meet targets and achieve the mandated environmental goals is difficult in the deep-sea realm, with its complex ecosystems and limited data availability. Fortunately, many options are available to both the ISA itself and, through the ISA, to the Contractors and Sponsoring States. Guidance of which actions to choose should emerge from the processes that set the SEGOs [41]. In Table 1, current and possible actions are listed in two sections: those executed directly by the ISA, and those for which Contractor plus Sponsoring States would be responsible. The list includes actions that are enacted by other UN agencies and/or States to address marine environmental objectives. Some actions around seabed mining are currently in place (e.g. an environmental management plan (EMP) for the Clarion-Clipperton Zone (CCZ) [42]), or are in development (e.g. guidance for Contractor EIAs), with objectives outlined to fit the context. However, a larger integrated approach remains to be developed through a process that can and should be informed by prior work initiated at the regional scale (e.g. the LTC-conducted EIAs).

5.1. Ecosystem-based management (EBM)

One of the guiding principles in many regulatory schemes is ecosystem-based management (EBM), an approach that recognizes and integrates all interactions within an ecosystem, and includes humans, rather than focusing on single species [43]. Environmental strategies and/or goals may be implemented by applying the EBM approach. For example, the European Union established a framework to achieve good environmental status in the marine environment by developing and implementing strategies to protect and preserve the environment, and to prevent and reduce inputs into the environment [40]. To implement these strategies, the Directive recommended the application of EBM approaches.

Although many international (and national) bodies have proposed application of EBM, the challenge lies in implementation, as illustrated by the small number of examples, some more successful than others (e.g., OSPAR Northeast Atlantic Environmental Strategy [44]; FAO Ecosystem Approach to Fisheries [45]; National Marine Sanctuaries, NOAA, Ecosystem-based Fisheries Management USA [46]; Nature Diversity Act and Water Management Regulations, Norway [47]; Antarctic Fisheries, Commission for the Conservation of Antarctic Marine Living Resources [48]).

For EBM to be effective, clear overarching goals, objectives and targets towards which progress can be measured are needed. The EBM approach may be particularly well-suited to the deep-sea realm and the needs of the ISA where the focus is habitats that are occupied by entire ecosystems: polymetallic nodules (abyssal plains), massive sulphide deposits (active and inactive vents) and cobalt crusts (seamounts). Existing activities with environmental management strategies provide precedents (e.g. oil and gas drilling, fishing on the high seas, terrestrial mining). Current best practices include SEAs, EIAs, and EMPs [49], while established management tools include marine spatial planning, identification of vulnerable marine ecosystems [38], and adaptive management [50]; most of these management actions apply the EBM approach.

5.2. Marine Spatial Planning

Marine Spatial Planning (MSP) is a well-established and widely used approach that allocates and distributes human activities spatially and temporally in an ocean space to meet ecological and socioeconomic objectives [51]. Many aspects are directly relevant to deep seabed mining. To be effective and successful, MSP also requires well-defined objectives that stem from clear regulations. MSP is considered the international standard and many coastal countries adopted the tools developed over the past decade [52]. It is a practical approach for high-seas management, particularly when several agencies with overlapping mandates can cooperate [53]. For example, several RFMOs, also guided by the principles of UNCLOS, regulate fisheries both in the water column and on the seafloor through designation of fishing grounds and closed areas, some in areas of interest for deep-sea mining. The CBD, through a series of regional workshops, has facilitated the development of EBSAs that support healthy marine ecosystems throughout the world's ocean based on explicit criteria (uniqueness or rarity; special importance for life history stages of species; importance for threatened, endangered or declining species and/or habitats; vulnerability;

Table 1
Management options for achieving Strategic Environmental Goals and Objectives.

Management Action	Role and Application
A. The Authority	
Conduct Strategic Environmental Assessment (SEA)for the entire *Area*	Evaluate existing (large-scale) pressures on and sensitivities of marine ecosystems in the *Area* to develop strategic environmental goals, objectives and targets for the protection of the marine environment from seabed mining. Consider MPAs, EBSAs and VMEs, existing activities and cumulative effects including additive pressure from mining.
Conduct EIAs of activities in the Area	Provides basis for drafting the Mining Code as set out in LOSC 165 (2f) [21] and sets standards for Contractor EIAs.
Implement Strategic Environ-mental Management Plan (SEMP) for the Area	Overarching strategic goals, operationalized objectives and targets are agreed in a stakeholder inclusive process for the protection of the marine environment in the context of seabed mining in the Area. The SEMP invokes steps to develop indicators that confirm targets are reached. Processes and methods are identified to keep track of development of environmental indicators (e.g., review, adaptive measures, standard monitoring program, etc).
Identify Vulnerable Marine Ecosystems (VMEs) and Threatened or Endangered Species	Applies standard approaches to achieving SEGOs across the Area that allow specific protection for VMEs and regional vulnerability assessments; may employ vulnerability indices.
Conduct Regional Strategic Environmental Assessment	Evaluate existing pressures on and sensitivities of marine ecosystems for each region targeted for mining. Determine all existing pressures on and sensitivities of the regional marine ecosystems (fine scale), set aside MPAs, EBSAs and VMEs, identify user conflicts, determine additive pressure from mining and likely effects, precautionary assessments, identify region-specific targets and indicators needed to meet SEGOs.
Design Regional Marine Spatial Plans as part of Regional Environmental Management Plans (REMPs)	Cross resource application to capture cumulative stressors. Includes APEIs, EBSAs, VMEs, MPAs, and Reference Zones as appropriate.
Provide oversight of environmental impacts monitoring of *Area* mining activities based on indicators of serious harm	Seeks threshold encroachment and triggers for Serious Harm to the marine environment as defined in SEGOs and REMPs.
Oversight and Enforcement	Executes the power of the Authority to assess progress toward targets, including the measures necessary to ensure compliance to SEGOs
Apply Compensation Regime	Identifies the Common Heritage environmental losses that require compensatory actions. Acceptable losses must still permit achievement of SEGOs.
Long-term Assessments	Given slow metabolic rates and recovery times of some organisms in the deep sea, Contractor post-closure monitoring should transition to the ISA. Scientific input must determine what level of deterioration is serious harm and evaluate whether mining practices ultimately achieve environmental SEGOs. Long-term assessments are essential to determine the permanent consequences of mining.
Environmental Performance Evaluation	Periodic review of the indicators and progress in achieving SEGOs; includes re-assessment of Objectives.
B. Contractor & Sponsoring State	
Implement and approve Environmental Management Plan (EMP)	Works toward targets to reach environmental objectives and targets that align with ISA's Area Plan SEGOs with standardized components.
Environmental Impact Assessment	With reference to baseline data, determines likely harmful effects (those that fail to achieve SEGOs) and mitigation actions in context of SEGOs, REMP, and Contractor EMP.
Monitoring program	Documents and reports impacts and harmful effects during activity; assesses post-closure response and demonstrates that effects are within limits set to achieve SEGOs and regional objectives.
Invoke Mitigation Hierarchy	Within EIA, defines the plan to meet regulator requirements to avoid, minimize, remediate and offset impacts that counter goals and objectives.[a]

[a] Note only the first two phases are relevant to biodiversity loss incurred by seabed mining [67].

fragility, sensitivity, or slow recovery; biological productivity; biological diversity; and naturalness). Although EBSAs have no protection status, they are identified as warranting consideration for enhanced conservation and management measures. Seamounts and hydrothermal vents are explicitly identified as benthic features meeting the criteria for EBSAs (based on uniqueness or rarity, biological productivity, biological diversity), and many deep-sea species exhibit the traits of vulnerability as outlined by the CBD [54]. CBD (at COP 10) has urged regional and intergovernmental bodies to adopt measures cooperatively for conservation in identified EBSAs. With respect to deep-sea mining, spatial planning will need to be applied separately for each resource type and region, because of the corresponding variation in the ecosystem structure and function as well as connectivity to neighbouring and overlying habitats. In most cases to date, spatial planning encounters resource-based uses already in place, requiring trade-offs for environmental protection; this lack of synchronization between spatial planning and licensing was encountered in the development of the UK's strategy [55]. Given that many contracts are signed already for seabed exploration, the ISA is now facing the same problem in planning environmental measures around contract blocks, e.g., [19,56]. The recent approval of Poland's application for a polymetallic sulphides exploration contract in a region that falls within an EBSA in the North Atlantic illustrates the need for cross-agency cooperation.

5.3. Vulnerable Marine Ecosystems (VMEs)

One management intervention that is applied at regional and intergovernmental levels is highly relevant to the ISA: the conservation of VMEs (see also Gianni this issue). Criteria for determining VMEs outlined in the FAO's "International Guidelines for the Management of Deep-Sea Fisheries in the High Seas" [57] are very similar to the characteristics of species vulnerability listed by the CBD [54]. Specifically, the FAO (Food and Agriculture Organization) criteria include uniqueness or rarity, functional significance of the habitat, fragility (to anthropogenic disturbance), life-history traits of component species that may impede recovery, and structural complexity. While the FAO assesses vulnerability with respect to fishing activities, the criteria that identify VMEs are related to the ecological characteristics of the ecosystem; thus, vulnerability can be extended to include other human activities, such as deep-seabed mining. Hydrothermal vents are included in the list of VME habitat types, and numerous taxa that occur in the abyssal plain, near cobalt crusts or on inactive vents (e.g. deep-water corals, sponges, xenophyophores) appear on lists of VME indicator species, e.g. Annex I.E. of [58].

The management of deep-sea fisheries by FAO strives to achieve long-term conservation and sustainable use of natural resources and to prevent significant adverse impacts on VMEs [26]. While these impacts are described in the FAO guidelines as those compromising ecosystem

Text Box 3
Spatial Planning goals compiled during science-based workshops.

CCZ-EMP Process 2007–2011

Eight strategic aims (goals) to ensure environmentally responsible seabed mining and management of the CCZ as a whole, enabling effective protection and maintenance of regional biodiversity, ecosystem structure and function, using internationally accepted conservation management tools, and protecting and conserving the natural resources of the Area and reduce impact on the biota.

Supported by a series of more specific goals plus operational and management objectives. [42]

Dinard Workshop in 2010

Proposed Goal: "*protecting the natural diversity, ecosystem structure, function and resilience of chemosynthetic ecosystems, while enabling their rational use*".

Supported by six objectives that guide establishment of Reserves based on connectivity, replication and representativeness. [63]

SEMPIA Process 2015 to Present

Proposed Goal: Contribute to "*the protection of the natural diversity, ecosystem structure, function, connectivity, and resilience of deep-sea communities in the context of seabed mining in the [MAR] region*". Supported by a science-based ecological approach using five conservation objectives to guide APEI selection based on CBE MPA network criteria. [19]

integrity, their operationalization is extremely difficult in the largely undescribed deep-sea benthic habitats where deep-sea mining will occur. RFMOs are required to consider VMEs in their regulatory processes, and often request expert advice on their identification and distribution (e.g. the ICES/NAFO joint working group on deep-water ecology [59]). Expert advice can be beneficial during the initial steps of the process: detection of the presence of a potential VME, identification of a threshold (e.g. abundance or spatial extent) at which the regulatory process should be activated, decision on whether the observed VME exceeds the threshold, and recommendation on whether the activity (fishing or mining) is likely to cause significant adverse impact on the VME. The regulatory body (ISA in the case of deep-sea mining, as RFMOs for fisheries) can establish an activity closure around the VME.

5.4. Adaptive management (AM)

Adaptive management is an iterative process of decision-making that can be summarized as learning-by-doing: management actions are modified as needed with information accumulating or conditions changing in the managed system (currently adopted by many States, e.g. [50]). Adaptive management allows for feedback between monitoring and decision-making, mitigates risk, and can integrate environmental change (natural or as a result of the activities being managed) in management plans. Adaptive management can be a particularly useful tool for the ISA because the impacts of deep seabed mining are highly uncertain, and baseline data on targeted ecosystems are currently largely lacking. In fact, AM is considered best suited, and is most often applied, to integrate uncertainty into management and, although the duration of many existing AM programs has been short (3–10 years), some have lasted for as long as 25 years, a duration more relevant to the lifetime of ISA contracts [60,61]. Technical challenges associated with AM include directional changes in conditions (e.g. climate change), adopting the appropriate spatial scale for management that matches the scale of the variation in the ecological system, and ensuring that monitoring programs accurately represent scales of ecological change [61].

Adaptive management appears under Annex VII (Environmental Management and Monitoring Plan) in the Draft Regulations on Exploitation for Mineral Resources [6]; the way in which it will be achieved remains to be clarified. In practice, AM may be difficult to implement because it would require that mining practices, environmental standards, monitoring programs and impact assessments change over time, in mid-stream for some contracts and before others are launched [62]. We recommend that the ISA develop AM approaches that apply equally and fairly to all contractors regardless of the stage of the contract [62]. It has also been suggested that one challenge that the ISA will face is the juxtaposition of the traditional linear business model of mining with the non-linear nature of adaptive management [50]. However, given the novelty of deep seabed mining, including innovative solutions can be identified at the will of the ISA, Member States and Contractors. In any case, and as with any management tool mentioned thus far, clear objectives are required to make adaptive management successful [50].

5.5. Management actions applied in deep seabed mining

Environmental Management Plans (EMPs) for seabed mining at the regional scale have focused on area-based conservation measures (i.e. design of networks of "no mining" areas [APEIs]). Polymetallic nodules in the Pacific CCZ were the first to be addressed by scientists and the ISA [42]. A recommended framework produced during a 2007 workshop included a systematic approach to spatial management of deep-sea ecosystems, and outlined eight design elements for a network of marine protected areas, that was applied to the CCZ [56]. The ISA, in turn, adopted a network of APEIs in 2012, partly based on criteria outlined in the CBD. The EMP included statements for guiding principles, vision, goals and strategic aims for the region overall, as well as specific conservation objectives for the APEIs (Text Box 3). However, as no targets or indicators were defined, it is not possible to assess progress towards meeting those objectives. Other management tools, such as VMEs and adaptive management are mentioned in the EMP,

but with no clear plans for implementation. Unfortunately, existing exploration licenses limited the location of some APEIs, initially sited based on ecological criteria [19]. This compromise in the original design highlights the need for an EMP at the time exploration claims are initially approved.

For seafloor massive sulphides at hydrothermal vents (and other chemosynthetic ecosystems), the Dinard workshop in 2010 used outcomes of the CCZ workshop, developing guidelines for the establishment of networks of Chemosynthetic Ecosystem Reserves (Text Box 3). The framework of the CBD scientific guidelines for selecting areas to establish representative MPA networks and the CBD EBSA criteria were adopted [39]. The Dinard guidelines address the conservation goal of "protecting natural diversity and the structure, function, and resilience of chemosynthetic ecosystems while enabling their rational use" through six explicit objectives [63,64]. The recommended management strategies can be enabled by the tools described above, such as ecosystem-based management, marine spatial planning, and adaptive management. The application of measures to implement the proposed guidelines would ensure that resources from vents and seeps may be used by present and future generations, while avoiding irreversible environmental damage (serious harm) and long-term decline in biodiversity [22].

The Dinard deliberations were not site specific; their first application occurred in the Atlantic region, where the SEMPIA process (Strategic Environmental Management Plan for deep seabed mineral exploration and exploitation in the Atlantic basin) built on existing recommendations from both the Dinard guidelines and the CCZ-EMP report [42]. SEMPIA followed a structured and systematic approach to the design of networks of marine reserves, regularly utilized in shallow water systems, and applied this approach to mining of seafloor massive sulphide deposits. Dunn et al. [19] outline an overall conservation goal (Text Box 3), clear criteria for networks of APEIs, with specific objectives and targets for meeting these objectives. Most were based on the criteria laid out by CBD, but climate change considerations appear as a new element [19], not seen in the Dinard or CCZ deliberations.

Dunn et al. [19] acknowledge that networks of APEIs are not the only required element of environmental management to support the sustainable use of resources. Additional management tools can include the closure of all active vents to exploitation activities and protection of VMEs (e.g. active hydrothermal vents and seeps, cold-water coral gardens/reefs, sponge or crinoid fields). Other management actions include application of the mitigation hierarchy [65,66], regulations for claim-specific baseline and monitoring activities, and development of the compensation regime (insurance liability, environmental compensation and offsets) (Table 1; [67]). As mentioned above, cooperation with regional, intergovernmental and State management bodies can facilitate the implementation of some of these management interventions. Lastly, other considerations can include temporal closures to protect sensitive life-history stages (e.g. spawning or recruitment), as well as managing the staging, frequency and spatial configuration of mining operations.

6. Conclusions

There are many benefits to adopting a structured top-down approach with an overarching vision for the ISA as illustrated in Fig. 1. At the global scale, over-arching SEGOs with clear targets, and related policy will ensure an even-handed approach for all Contactors, especially those targeting the same resource type in different oceans. They will help operationalize the concepts of significant adverse impacts and serious harm, which may trigger further management actions. Standardized outcomes will help identify those who exceed the standards and those who need additional incentives. Formulating the ‘rules’ for environmental management without overarching goals leaves the Contractor seeing only the bureaucratic requirements in terms of hurdles. Aspirational goals contribute to a larger motivation to join a community effort to progress toward a larger vision. In practice, transcending the Contractor scale is certainly necessary in the regional context as ecosystem boundaries and possible mining effects are larger than contract blocks. The framework and toolbox for management actions are the basis for a cohesive exercise, rather than being region or resource specific. Most important, is to capture the progress toward defined outcomes over many years – progress toward targets that are measurable. Objectives do not need to be immutable; adjustments occur in response to feedback.

While we do offer some examples of possible SEGOs, we believe it is the International Seabed Authority, in close cooperation with the scientific community and other stakeholders, that must develop and implement strategic environmental goals and objectives across mineral resource types and environmental settings. This process will require targets that are measurable through a series of realistic indicators and associated ecological thresholds that would allow the ISA to operationalize serious harm.

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Competing interests statement

All authors declare: no conflicts of interest

Appendix A. : Examples of some environmental goals conceived at the DOSI “EREGS” workshop

Goal 1: Preserve the Common Heritage of (Hu)mankind for future generations including biological, geological and cultural resources and services
Goal 2: Ensure that the development of deep-sea mining is done in the context of sustainable development as reflected in NGA Sustainable Development Goal 14 and other relevant instruments.
Goal 3: Protect and preserve the marine environment (UNCLOS Art. 192 –Gen. Obl)
Goal 4: Sustain marine (benthic and pelagic) ecosystem integrity on regional scales including the physical, chemical, geological and biological environment. (see text for expanded discussion)
Goal 5: Generate and share the best scientific information available for decision-making and improve techniques for dealing with risk and uncertainty.

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