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Recommendations of the workshop on polymetallic sulphides and cobalt crusts: their environment and considerations for the establishment of environmental baselines and an associated monitoring programme for exploration

I. Introduction

1. In respect of the protection and preservation of the marine environment during prospecting and exploration for polymetallic sulphides and cobalt-rich ferromanganese crust deposits, the draft regulations on prospecting and exploration for polymetallic sulphides and cobalt-rich ferromanganese crusts in the Area (ISBA/10/C/WP.1) would require the International Seabed Authority, inter alia, to establish and keep under periodic review environmental rules, regulations and procedures to ensure effective protection for the marine environment from harmful effects which may arise from activities in the Area, and together with sponsoring States, to apply a precautionary approach to such activities based on recommendations of the Legal and Technical Commission (see ibid., regulation 33, paras. 1 and 2). The draft regulations also state that each contract for exploration for polymetallic sulphides or cobalt-rich crust deposits would require the contractor to gather environmental baseline data and to establish environmental baselines, taking into account any recommendations issued by the Legal and Technical Commission, against which to assess the likely effects of its programme of work for exploration of the marine environment and a programme to monitor and report on such effects. The draft regulations would require contractors to cooperate with the International Seabed Authority and the sponsoring State or States in the establishment and implementation of such monitoring programmes. With regard to the recommendations issued by the Legal and Technical Commission, the regulations indicate that they may list those exploration activities which may be considered to have no potential for causing harmful effects (ibid., regulation 34, para. 1).

2. The regulations would require that an application for approval of a plan of work for exploration should include a description of the programme for oceanographic and environmental baseline studies in accordance with the

regulations and any environmental rules, regulations and procedures established by the Authority that would enable an assessment to be made of the potential environmental impact of the proposed exploration activities, taking into account any recommendations issued by the Legal and Technical Commission, and a preliminary assessment of the possible impact of the proposed exploration activities on the marine environment (ibid., regulation 20).

3. After approval of the plan of work for exploration in the form of a contract and prior to the commencement of exploration activities, the contractor is required to submit to the Authority:

(a) An impact assessment of the potential effects on the marine environment of the proposed activities;

(b) A proposal for a monitoring programme to determine the potential effect on the marine environment of proposed activities;

(c) Data that could be used to establish an environmental baseline against which to assess the effect of the proposed activities (ibid., annex 4, para. 5.2).

4. As exploration activities progress, the contractor is to gather environmental baseline data and develop and establish environmental baselines against which to assess the likely effects of its exploration activities on the marine environment (ibid., para. 5.3); establish and carry out a programme to monitor and report on such effects on the marine environment, cooperating with the Authority in the implementation of such monitoring (ibid., para. 5.4); and, within 90 days of the end of each calendar year, report in writing to the Secretary-General on the implementation and results of its monitoring programme and submit data and information in accordance with the regulations, taking into account any recommendations issued by the Legal and Technical Commission (ibid., annex 4, para. 5.5, and regulation 34, para. 2).

5. Article 165, paragraph 2 (e), of the United Nations Convention on the Law of the Sea states that the Legal and Technical Commission is to make recommendations to the Council of the Authority on the protection of the environment, taking into account the views of recognized experts in that field. The workshop on polymetallic sulphides and cobalt crusts: their environment and considerations for the establishment of environmental baselines and an associated monitoring programme for exploration, held in Kingston from 6 to 10 September 2004, was held in response to that requirement.

6. It is recalled that in June 1998 the International Seabed Authority convened a workshop on the development of environmental guidelines for exploration for polymetallic nodule deposits. The outcome of the workshop was a set of draft guidelines for the assessment of possible environmental impacts from exploration for polymetallic nodule deposits in the Area. The workshop noted the need for clear and common methods of environmental characterization based on established scientific principles and taking into account oceanographic constraints. Aspects of the guidelines for polymetallic nodules (ISBA/7/LTC/1/Rev.1) are relevant to the proposed guidelines for polymetallic sulphides and cobalt crust deposits.

7. The recommendations of the workshop are based on the current scientific knowledge of the marine environment and the technology to be used. Taking into account the progress of science and technology, in particular as they relate to

knowledge of the environments where the deposits occur, deposit characterization and subsequent mining technology, the proposed guidelines may need to be modified. Unless otherwise noted, the recommendations contained in the present report relating to exploration and test mining of sulphides and crusts apply to both types of deposits. At some sites it may not be reasonably feasible to implement some of the specific recommendations. In such a situation, the contractor should provide arguments to that effect when submitting a work programme to the Legal and Technical Commission, which can then exempt the contractor from the specific requirement.

8. The nature of the environmental considerations associated with test mining of polymetallic sulphides and cobalt-rich crust deposits depends on the type of mining technology used to extract the minerals and on the scale of the operation (i.e., number of tons extracted per annum per region). Mechanical removal without initial processing at the seabed was deemed the most likely technology to be used and is the method of mineral extraction assumed in the present report. It is likely that future mining operations will employ techniques not considered here. The International Seabed Authority should revisit the environmental guideline considerations as technologies are developed and the proposed mining technology is identified to ensure that the assumptions and considerations described herein continue to be relevant.

II. Scope

A. Purpose

9. The recommendations contained in the present report describe the procedures to be followed in the acquisition of baseline data and the monitoring to be performed during and after any activities in the exploration area with a potential to cause serious harm to the environment. Their specific purposes are:

(a) To define the biological, chemical, geological and physical components to be measured and the procedures to be followed by contractors to ensure effective protection for the marine environment from harmful effects which may arise from the contractors’ activities in the Area;

(b) To facilitate reporting by contractors;

(c) To provide guidance to potential contractors in preparing a plan of work for exploration for polymetallic sulphides and cobalt crusts in conformity with the provisions of the Convention, the 1994 Agreement relating to the Implementation of Part XI of the Convention and the regulations.

B. Definitions

10. Except as otherwise specified in the present document, the terms and phrases defined in the draft regulations shall have the same meaning in these recommendations for guidance. A glossary of technical terms is contained in the annex to the present report.

C. Environmental studies

11. Every plan of work for exploration for polymetallic sulphides and cobalt crusts should take into consideration the following phases of environmental studies:

(a) Environmental baseline studies;

(b) Monitoring prior, during and after test mining.

III. Environmental baseline studies relevant to both resources

12. It is important to obtain sufficient information from potential test-mining sites to document the natural conditions that exist prior to test mining, to gain insight into natural processes such as the dispersion and settling of particles and benthic faunal succession and to gather other data which may make it possible to acquire the capability necessary for accurate environmental impact prediction. The impact of naturally occurring periodic processes on the marine environment may be significant but are not well quantified. It is thus also important to acquire as long a history as possible of the natural responses of surface and benthic communities to those processes.

13. Under the provisions of the draft regulations on prospecting and exploration for polymetallic sulphides and cobalt-rich ferromanganese crusts in the Area (hereinafter referred to as the draft mining code), contractors are required, in cooperation with the International Seabed Authority and the sponsoring State or States, to establish environmental baselines against which to assess the likely effects of the programme of work on the marine environment and a programme to monitor and report on such effects. To maintain the credibility of the environmental impact assessment, it is critical that qualified independent scientists be contracted to establish the environmental baseline and to monitor and report on potential impacts.

14. Contractors should also be required to permit the International Seabed Authority to send its inspectors on board vessels and installations used by the contractor to carry out exploration activities in the Area to, inter alia, monitor the effects of such activities on the marine environment.

A. Baseline data requirements

15. To set up the environmental baseline in the exploration area, the contractor, using the best available technology, should collect data for the purpose of establishing baseline conditions of physical, chemical, biological and other parameters that characterize the systems likely to be affected by exploration and test-mining activities. Baseline data document natural conditions in existence prior to test mining and are essential for monitoring changes resulting from test-mining impacts for prediction of the effects of commercial mining activities.

16. The workshop suggested that the Legal and Technical Commission, in developing guidelines for baseline data requirements:

(a) Advocate strategic selection of index parameters, with robust statistical design wherever possible, rather than haphazard inventories with inadequate, inappropriate sampling;

(b) Advocate using to best advantage baseline data-collection methods that are used during mineral exploration (e.g., imaging, mapping);

(c) Recognize that quantitative sampling of hard substratum environments (polymetallic sulphides, cobalt crusts, basalt) in the deep sea is a challenge that academic scientists do not routinely achieve. Small animals, or animals hidden in crevices, among coral, for example, would require several types of sampling equipment;

(d) Recognize that exposed mineral surfaces may be irregular, potentially steep-sloped and difficult to image quantitatively without the use of a remotely operated vehicle or a new technology yet to be developed;

(e) Recognize that samples are required for taxonomic identification, DNA sequencing and voucher collections and that a repository (or multiple repositories, as appropriate) should be designated for voucher collections;

(f) Recognize the value of digital photographic and genomic libraries of faunal vouchers and microbial assemblages; a financially, logistically and scientifically rational programme for the acquisition of these types of databases is a requisite part of the baseline requirements;

(g) Understand that taxonomy by numbers (e.g., species 1, species 2, etc.), if consistent rules are used and vouchers are maintained, is a good basis for baseline studies, but that classical and molecular taxonomy must be supported, either directly by the contractor or as part of cooperative research programmes;

(h) Anticipate that molecular methods will advance rapidly during the next decade, making biotic surveys at all levels, especially at the level of micro-organisms, much more rapid and economically feasible than they are today. Molecular sequences should be deposited in Genbank or equivalent internationally recognized sequence databases. The International Seabed Authority should monitor progress in these molecular technologies and revise baseline requirements as appropriate.

B. Regional environmental baseline data

17. While test mining may physically affect only a local area, the sensitivity of the ecosystem to the disturbance is a function of the degree to which the components of the system are unique or common. For this reason, the contractor must obtain some degree of regional-scale baseline data. The scope of this effort will likely be particular to the setting (e.g., seamount, polymetallic sulphide deposit, etc.).

18. Because the populations of fauna of sulphide deposits and cobalt crusts are subsets of meta-populations that interact through dispersal and colonization, it is important to know the degree of isolation of populations occupying the mineral deposits that are to be removed and whether a given population serves as a critical brood stock for other populations.

19. Regardless of the mining techniques to be employed, it is expected that some amount of particulate and/or dissolved mining by-products will be released into the water column in the vicinity of the mined deposits, the transport conduits and the processing sites. With the currently proposed exploration and test-mining techniques, the primary anticipated test-mining by-products are particles created by

the mechanical break-up of the mined minerals. While it is expected that mining operators will minimize the loss of economically valuable minerals, it does not seem realistic to assume zero loss. Since the particle size range is not known, it is assumed that the by-products of test mining will include very small particles, which can remain in suspension for months. The possibility for the introduction of toxic substances cannot be excluded either. While bound metals are not biologically available, dissolution of metals, and consequently metal toxicity, may take place under particular environmental conditions (e.g., low pH in guts of marine invertebrates, oxygen minimum zones in the water column). Other possible examples include accidental or intended release of chemicals used during exploration and test mining. A primary goal of the physical baseline data collection consists of assessing the dispersal potential both for particles and for dissolved substances. Knowledge of the dispersal potential is also required for monitoring and mitigating the effects of accidental spills related to the test-mining operations. We recommend that the dispersal potential near future mining sites be assessed even if the design target of the mining technology includes avoidance of the release of any test-mining by-products into the environment.

C. Regional-scale physical and chemical oceanographic baseline data

20. Physical and chemical baseline data should be collected over the entire exploration area, including the perimeter. The recommended sampling resolution is loosely based on World Ocean Circulation Experiment and CLIVAR standards,[1] with station spacing not exceeding 50 km. In regions of large lateral gradients (e.g., in boundary currents and near major topographic structures), the horizontal sampling spacing should be decreased in order to allow resolution of the gradients. In the vertical, there should be at least five samples each in the top and bottom 200 m of the water column. In the interior, the vertical sample spacing should be no more than 100 m. Here too, the resolution should be increased in high-gradient regions (e.g., to locate and quantify any oxygen minimum). For parameters without significant horizontal gradients the determination of baseline ranges (e.g., means and standard deviations) is considered adequate. For parameters with significant spatial structure (gradients, extrema) the sampling resolution must allow the structure to be characterized. Because of the strong influence of topography on the spatial scales of oceanic features, it is expected that this will require a survey plan with station spacing depending on topographic scales, for example, with finer resolution on steep slopes.

21. Water-column sampling must include all standard parameters (i.e., temperature, salinity, oxygen, chlorophyll in the euphotic zone, particle load), as well as the chemical parameters listed in table 3 of the International Seabed Authority report entitled "Standardization of Environmental Data and Information: Development of Guidelines"[2] (phosphate, nitrate, nitrite, silicate, carbonate alkalinity, oxygen, zinc, cadmium, lead, copper, mercury, total organic carbon). In addition, relevant physical and geochemical parameters (including pore-water chemistry) of the sediment should be determined, again with the same International Seabed Authority guidelines serving as a reference for the list of chemical parameters to be reported (ibid., table 2: phosphate, nitrate, silicate, nitrite, carbonate alkalinity, Eh, pH, iron, manganese, zinc, cadmium, lead copper, mercury). Once details of the proposed test-mining techniques are known, the

parameter lists should be extended to include any potentially hazardous substances that may be released into the water column during test mining. All measurements must be accurate to accepted scientific standards (e.g., CLIVAR). In order to allow for later analysis of additional parameters, water samples suitable for analysis of dissolved and particulate matter should be collected and archived in a repository accessible for scientific study.

22. A general scheme for physical and chemical oceanographic baselines includes:

(a) Collection of water-column hydrographic and light-transmission data of sufficient resolution to characterize the dominant patterns, taking into account the topographic characteristics of the exploration site;

(b) Collection of data appropriate for assessing the horizontal and vertical advective and eddy-diffusive dispersal potential for dissolved and particulate matter on the environmentally relevant time and space scales;

(c) Set-up and validation of a numerical circulation model that covers the temporal and spatial scales important for dispersal and carry out experiments, for example, to investigate the potential impact of accidental spills;

(d) Collection of water-column chemical data of sufficient resolution to characterize the dominant patterns, taking into account the topographic characteristics of the exploration site;

(e) Collection and archiving of water-column samples for possible later analysis of additional parameters.

23. For each test-mining by-product, the time scale over which it causes significant environmental impact must be modelled. Such time scales may depend on dilution, in which case the determination of vertical and horizontal mixing rates near the target site must be included in the dispersal assessment. Dispersal potential must be assessed over time scales that range from the tidal frequencies to the largest of these “environmental-impact” time scales. Both advective and eddy-diffusive contributions to the dispersal potential must be assessed. An assessment of the dispersal potential in the deep ocean generally requires long-term monitoring efforts. Even the determination of mean-flow directions and speeds at depth can require several years’ worth of current-meter data. Assessing eddy-diffusive dispersal is even harder and generally requires the application of Lagrangian techniques, such as neutrally buoyant floats or dye-release experiments. For these reasons, it is recommended that an assessment of the regional dispersal potential at several levels in the water column begin early during exploration. It may be possible to assess dispersal near the surface and near 1,000 m from available data — surface drifters and Argo floats, respectively — and at the time of test mining additional data sets may have become available.

24. Before test mining is to begin, the dispersal potential must be assessed at all levels where environmentally significant test-mining by-products are to be released into the water column and where accidental spills are considered most likely. The required vertical resolution will depend on the regional dynamical regime (vertical shear of the horizontal currents), but it is anticipated that at least three levels would need to be sampled (near-surface, mid-depth, near-bottom). The flow near the seabed in particular must be temporally and spatially well resolved, for example, by using bottom-mounted acoustic Doppler current profiler measurements with

sufficient sampling to resolve the dominant tidal flows. In regions of topographic relief near the test-mining site, both the horizontal and vertical resolutions must be increased to allow the dominant dynamical structures that are usually associated with deep-sea topography (boundary currents, trapped eddies, overflows, etc.) to be resolved. Near active hydrothermal vent fields, it is often possible to gain useful first-order dispersal information at the level of neutrally buoyant plumes from hydrographic, chemical and optical observations. Interpreting plume-dispersal observations in terms of dispersal potential for mining by-products is complicated by a variety of factors, including the generally poor knowledge of the temporal and spatial characteristics of hydrothermal sources, the fact that hydrothermal plumes disperse at their equilibrium level, which depends both on the source and environmental background characteristics, and by the fact that the particle composition (and, thus, the settling velocity) of hydrothermal plumes cannot be controlled. Nevertheless, it is expected that hydrothermal-plume dispersal observations will be useful, in particular for designing controlled follow-up dispersal studies.

25. In order to complete an assessment of the dispersal potential, a three-dimensional hydrodynamic numerical model that covers the temporal and spatial scales important for dispersal must be constructed and applied in a series of experiments. The contractor should use a model that is accepted by the ocean modelling community as well suited for dispersal studies near the seabed; simple box models or z-coordinate models with coarse vertical resolution at depth are not expected to be adequate. The details of this model will be dependent on the topographic and oceanographic settings of the target site. Resolution should be in accordance with the scales described above (i.e., gradients should be resolved by several points), and the model needs to be validated by comparison with the observational data. After validation, the numerical model should be used to investigate "what if" scenarios, for example to estimate the potential impact of accidental spills or for certain extreme cases, such as atmospheric storms.

D. Regional-scale geological baseline data

26. The workshop recommended the following in connection with the collection of regional-scale geological baseline data:

(a) Regional maps should be produced of the size and distribution of sulphide deposits, cobalt crusts and other critical habitats (seeps, diffuse low-temperature vents, whale skeletons, etc.);

(b) High-resolution (at least 200 m horizontal, 10 m vertical), high-quality (accuracy of 1 per cent of water depth or better) bathymetric data should be collected over the area where the dispersal of test-mining by-products is expected to significantly affect the environment, that is, over the entire region covered by the numerical circulation model;

(c) As part of the high-resolution baseline survey, a suite of representative pre-mining cores of the deposit, as well as a suite of representative pre-mining cores of seafloor sediment (including the top few centimetres, which can be lost when standard corers are used) around the target area should be collected and stored in a suitable repository available for appropriate scientific study respecting the commercial implications to the contractor. A reasonable sampling strategy would consist of sediment cores taken at 1-km intervals starting at the margin of the deposit and extending at least 10 km along the four cardinal points;

(d) Water-column vertical particle flux time series at the target test-mining site near the surface, at mid-depth and near the seabed, must be determined. The temporal resolution of the particle-flux measurements must be one month or better and nephelometry time series should be recorded on the sediment traps;

(e) Knowledge of in situ settling velocities for test-mining discharge particles, both in mid-water and near the seafloor, will help to verify and improve the capacity of mathematical models for accurately predicting the dispersion of the mid-water and benthic plumes. This information is relevant to the concerns expressed regarding the mid-water plume and to the primary concern of impacts from the benthic plume on the benthic biota;

(f) For sulphide deposits, the status of hydrothermal activity must be classified as either dormant sites, which are still under the potential influence of a heat source although there is currently no venting of hydrothermal fluids, and extinct sites, which have been carried away from their heat sources, or the heat sources of which have been extinguished. From an ecological point of view, these two scenarios can be considered largely equivalent. What is important biologically, however, is whether there is active hydrothermal venting at the site (case 1), whether the planned test-mining operations will restart hydrothermal venting at an otherwise inactive site (case 2), or whether a site is hydrothermally inactive even when disturbed by test mining (case 3). It is therefore important that the baseline assessment include a determination of whether the target site is case 1, 2 or 3.

E. Regional-scale geochemical baseline data

27. The recommendations of the workshop in connection with regional-scale geochemical baseline data are as follows:

(a) Where applicable, sediment chemical data of sufficient resolution to characterize the dominant patterns should be collected;

(b) Representative pre-test-mining cores and sediment samples should be collected and archived (if deemed advisable by the Legal and Technical Commission);

(c) Water-column vertical particle-flux baseline data of sufficient resolution to assess potential environmental impacts should be collected.

F. Regional-scale biological baseline data

28. In the case of regional-scale biological baseline data, the workshop recommended the following:

(a) If there is potential for surface discharge, the plankton community in the upper 200 m of the water column should be characterized. Measurements should be made of phytoplankton composition, biomass and production, zooplankton composition and biomass and bacterial plankton biomass and productivity. Temporal variation of the plankton community in the upper surface waters on seasonal and inter-annual scales should be studied. Remote sensing can be used to augment field programmes. Calibration and validation of remote-sensing results are essential;

(b) Observations on marine mammals and, insofar as possible, other near-surface megafauna (e.g., turtles, fish schools) are required. Sightings of marine mammals and other pelagic megafauna should be recorded during the baseline study. It is recommended that marine mammal and megafaunal species and their behaviour be recorded on transects between stations. Temporal variability should be assessed;

(c) Information from samples, photographs, videotapes or other means will assist in determining the impact on the benthos. Such information will help to resolve questions about the significance of the impact and may assist in developing any appropriate mitigation strategies for commercial recovery operations. Information on the faunal succession that follows the test mining will help to determine the potential for the recovery of the benthic population from the effects of such mining. Data should include samples in the immediate test area before and after test mining, at selected distances away from the mined area to determine the effect of the benthic plume, and at selected times after test mining. Such impact experiments can be conducted collaboratively;

(d) A combination of monitoring and shipboard and laboratory experimentation may be necessary to resolve completely, prior to test mining, the issues of impacts on phytoplankton and zooplankton if there is surface discharge and the effects of trace metals;

(e) Information on other effects of the plume on the mid-water biota can be gathered by making observations of unusual events, such as fish kills from air embolism in the area of the test-mining discharge zone, and unusually large concentrations of fish, marine mammals, turtles and birds;

(f) The vertical distribution of light directly affects primary productivity in the euphotic zone. If there is surface discharge, vertical light-intensity profiles will show the effect of discharged particles on light attenuation and spectral bands (photosynthetically active radiation: 400-700 nm, and blue light: 475 nm) over time, depth and distance from the mining ship. Those values can be used to detect any accumulation of the suspended particles at the pycnocline;

(g) Data on the dispersion of mining-solid discharges will refine existing dispersion models to make accurate predictions of plume behaviour and to assist in extrapolating from test mining to commercial-scale mining.

G. Local baseline biological data

29. The fundamental requirement for a baseline study that can be used to assess whether serious harm has occurred to a marine environment as a result of test mining of polymetallic sulphides or cobalt crusts is a species-abundance matrix for those areas likely to be affected by the test mining. This is the basic information that biologists acquire to make an assessment of any community they encounter. Incremental sampling efforts should be used by the contractor to develop species-effort curves for representative hard substratum microhabitats likely to be affected by test-mining activities, from which robust measures of species richness may be determined. Specific recommendations for sampling protocols on hard substrata are

provided below. Appropriate methods for acquisition of quantitative species-abundance matrices for soft-sediment and pelagic environments likely to be impacted by exploration and test mining of polymetallic sulphides and cobalt crusts are described in detail in the draft guidelines for manganese nodules and are not repeated here. The contractor is responsible for obtaining this baseline data where they are relevant to understanding the potential impact of test mining.

30. Hard substrata, especially where the organisms are small, are recognized as challenging environments to sample quantitatively. Slurp sampling, grab samples of any larger organisms in the area and video documentation or photographic transects may be the only means suitable for developing a species-abundance matrix. Remotely operated vehicles (ROVs) will be a better tool for documentation and sampling near or on vertical and hard substratum habitats than camera sleds. Autonomous underwater vehicles (AUVs) or hybrid ROV-AUVs may ultimately prove to be ideal survey/sampling platforms.

31. The general practices are described below:

(a) Baseline data from impact and preservation reference zones allow one to understand natural variability in time and space associated with natural geological, hydrodynamic and biological processes prior to test mining. Impact reference zones and preservation reference zones should be carefully selected and should be known (based on biotic surveys) to share the biotic characteristics of the habitats likely to be affected by test mining. The selection of these zones should be reviewed by the International Seabed Authority and an advisory board of scientists prior to approval of test mining. Impact zones and preservation zones are likely to be extremely useful in evaluating environmental impact (direct, indirect, cumulative and interactive);

(b) The biotic survey of polymetallic sulphide deposits or cobalt crusts prior to test mining should be of deposits that are biotically representative of the kind of deposit to be recovered or otherwise directly or indirectly affected during the test-mining programme;

(c) Methods for collecting baseline biological data prior to test mining must be adapted for each specific set of conditions;

(d) Geographic Information System mapping tools are recommended as a means to place habitat and sample characteristics in spatial contexts;

(e) Standard practices for the proper preservation of organisms should be followed, including discrete sampling of sub-habitats into separate sample containers (preferably insulated) with closed lids to prevent washing on recovery, recovery of samples within 12 hours of collection to obtain quality material, immediate processing and preservation of samples on deck or maintenance in cold rooms for durations of no more than 6 hours before preservation (less where molecular assays are planned);

(f) Multiple preservation methods should be required, including preservation in formalin for taxonomic studies, freezing or preservation in 100 per cent ethanol for molecular studies and drying of whole animals and/or selected tissues for stable isotope analyses;

(g) Colour photographic documentation of organisms should be obtained whenever possible (organisms in situ and/or fresh material on deck to document natural coloration). These photos should become part of an archival collection;

(h) All samples and sample products (photos, preserved material, gene sequences) should be linked to relevant collection information (e.g., date, time, method of sampling, latitude, longitude, depth, etc.);

(i) Identification and enumeration of samples at sea and in the laboratory should be complemented by molecular and isotopic analyses as appropriate. Species-abundance and species-biomass matrices should be standard products wherever practical;

(j) Exchange of identification codes, keys, drawings, sequences with major laboratories or collections that carry out taxonomic studies of vent fauna to facilitate identification is recommended;

(k) Specimens must be archived for comparison with taxonomic identifications from other sites and to verify the details of changes over time. If species composition does change, the change may be subtle, and reference to the original animals (where there might only have been a putative identification) is essential;

(l) Temporal variation must be evaluated for at least one potential test-mining site and the preservation reference site for the test-mining activity (ideally, once every year for three years; minimally, twice — once at the beginning and once at the end of a single year). This temporal study should be reviewed by the International Seabed Authority prior to the start of test mining. The temporal evaluation must include a video/photo survey of sub-habitat distribution and, for sulphide deposits, associated temperatures and sampling of any new sub-habitats that appear. In addition to baseline data on species abundance, biomass, community structure, etc., strategies (including cooperative research) for determining growth rates, recruitment rates and the trophic status of dominant taxa should be developed and executed as part of the time-series studies. Where multiple test-mining sites are identified, the contractor must assess the degree to which temporal studies at one site are applicable to another site; this assessment should also be reviewed by the International Seabed Authority and an advisory board of scientists;

(m) Spatial variation in the biological community must be evaluated prior to test mining by sampling at least three mineral deposits, if present, in the area, each separated by a distance greater than the projected deposition of 90 per cent of the particles suspended by the mining operation;

(n) Standardization of methodology and reporting of the results is extremely important. Standardization should include instruments and equipment, quality assurance in general, sample collection, treatment and preservation techniques, determination methods and quality control on board vessels, analytical methods and quality control in laboratories and data processing and reporting. Method standardization will allow for the comparison of results across provinces and lead to the selection of critical parameters for monitoring efforts;

(o) Collection and analytical techniques must follow best practices such as those developed by the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization and available at world data centres and responsible national oceanographic data centres, or those established or recommended by the International Seabed Authority;

(p) To maintain the credibility of the environmental impact assessment, qualified independent scientists should be contracted to establish the environmental baseline and to monitor and report on potential impacts.

IV. Specific environmental baseline requirements for sulphide deposits

32. Analyses of organic carbon, nitrogen and sulphur stable isotope compositions of selected organisms are useful preliminary screens for unusual trophic ecologies (i.e., reliance on chemoautotrophic or methanotrophic production rather than photosynthetic production). The workshop recommends that isotopic analyses (organic carbon, organic nitrogen and organic sulphur isotope analyses) be conducted on a statistically representative number of individuals for the one or more species that make up the bulk of the biomass within different sub-habitats.

33. The minimum requirements to be submitted to the International Seabed Authority prior to approval of test mining of polymetallic sulphide deposits are as follows:

(a) Identify and qualitatively assess the distribution of all major sub-habitats of the proposed test-mining site (e.g., mussel beds, tubeworm clumps, bacterial mats and peripheral fauna); note that in the case of inactive sulphides or hard substrata away from sulphides, there may not necessarily be easily recognized sub-habitats (in which case a random sampling strategy can be developed);

(b) For active sulphides, survey temperature-fauna relationships (e.g., 5-10 discrete, video-documented temperature measures within each sub-habitat);

(c) Undertake bulk collection (slurp, grab or other quantitative or semi-quantitative sampling methods as appropriate to the sub-habitat) of invertebrates by sub-habitat into discrete sample boxes, seven samples per sub-habitat, where possible, plus selective acquisition of individuals of representative fauna. This will enable the determination of biomass, abundance or coverage dominants in a given sub-habitat. Discrete sampling methods should be designed to allow the contractor to estimate species richness using species-effort curves, where effort is the cumulative number of individuals or other suitable metric. Collections should be photo-documented (and indexed to video imaging) in situ to provide an archive of context/setting information for each sample;

(d) Each of the seven samples per sub-habitat should be separated into macro- and meiofauna using stacked 45 µm and 250 µm sieves. Five of those sets of samples collected on sieves should be preserved for 24 hours in 10 per cent buffered seawater formalin then in 70 per cent ethanol for subsequent sorting, identification, enumeration and development of species-abundance matrices. Two of the sets of samples should be preserved in ethanol using methods appropriate for molecular sequencing and molecular archives. As an alternative method of preservation for molecular analyses, material sorted to individuals may be frozen;

(e) Other sampling efforts should be used to characterize the less-abundant but potentially key megafaunal invertebrates in the system (including fish, crabs and other motile organisms). Representative samples of those organisms should be preserved for taxonomic, molecular and isotopic analyses.

V. Specific environmental baseline requirements for cobalt crusts

34. Cobalt-enriched crusts are found on various hard substrata, including mid-ocean ridges and seamounts, but they have been explored predominantly on seamounts. We focus here on mining in the seamount environment, but the general recommendations could be applied to ridge systems. As a large proportion of the seamount community may have a highly localized distribution, biological sampling should be carried out, insofar as possible, on a representative subset of all features of potential mining interest within each claim area in order to build a picture of the distribution of the community within that area. Benthic faunas typically vary in relation to local topography (e.g., summit, slope or base of a seamount), sediment cover, depth, seamount height and size, slope angle, oxygen content in the water, currents, regional productivity and potentially other factors. Habitat types should be assessed initially on the basis of photographic/video transects and by submersible or ROV, if possible. Imaging surveys carried out by the contractors to map sites of potential test-mining interest can serve several purposes, so long as there is adequate biological resolution (see below). Further biological sampling must be stratified by habitat type, which will be defined by seamount topography (e.g., summit, slope and base), hydrography, current regime, predominant megafauna (e.g., coral mounds), oxygen content of the water if the oxygen minimum layer intersects the seamount and potentially by depth as well, with replicate biological samples obtained using appropriate sampling tools in each stratum. A minimum of five replicate epibenthic sled samples per stratum is recommended for the collection of specimens and to assess species richness.

35. The minimum requirements to be submitted to the International Seabed Authority prior to approval of test mining of cobalt crusts are as follows:

(a) Undertake photographic transects to determine habitat type, community structure and associations of megafauna with specific types of substrata. Abundance, percentage cover and diversity of megafauna should be based initially on at least four photographic transects (1-cm resolution) to cover the four quadrants. The transects should extend from the flat seafloor 100 m or more from the base of the seamount, along the slope of the seamount and across its summit. More limited sampling may be required on larger seamount features. Further photographic transects should be carried out in crust areas of potential test-mining interest;

(b) To resolve megafaunal and macrofaunal species, biological sampling is required, using appropriate samplers within each habitat and community type. Hard substratum habitats should be sampled with a dredge or epibenthic sled with an inner cod-end mesh of 25 mm (e.g., the CSIRO seamount epibenthic sampler);[3]

(c) Meiofaunal and microbial community structure and biomass associated with the cobalt-enriched crust should be examined from rock dredge and rock drill samples or obtained from ROV or submersible sampling, where possible. At least 10 samples should be taken from cobalt crusts, from which species that live on the rock or in crevices and pits in the crust should be identified;

(d) Demersal fishes and other nekton living over the seafloor should be assessed by trawling, insofar as possible. At depths beyond trawl capabilities and on very rugged bottoms, this community should be assessed on the basis of towed photographic/video transects, with deployed cameras set up to record at different time periods or with submersible or ROV observations and photographs. Seamounts can be important ecosystems with a variety of habitats for a number of fish species that form aggregations there for spawning or feeding. Test mining operations could affect fish behaviour;

(e) Trace metals should be assessed in muscle and target organs of dominant benthic and benthopelagic fish and invertebrate species. This should be done at least four times before test-mining operations begin (to measure natural variability) and thereafter at least annually to monitor possible changes due to test-mining activity;

(f) The pelagic community structure of deep zooplankton and fish around the depth of the plume and in the benthic boundary layer need to be assessed prior to test mining. It is recommended that the fish community be assessed in the upper 1,500 m on the basis of depth-stratified sampling in at least three depth strata. Replicate sampling should be carried out on a diel basis and temporal variability examined.

VI. Monitoring prior, during, and after test mining: environmental impact assessment

36. The purpose of environmental monitoring during test mining is to determine whether effects are consistent with those predicted in the existing environmental assessments and to ensure the detection of any unanticipated serious harm.

37. Monitoring results should be the primary basis for test-mining impact assessments. Prior to, during and after test mining, the regional and local baseline parameters should be collected. To obtain statistically defensible data, the period of monitoring should be determined in accordance with sound scientific principles. Impact assessment must be based on a properly designed before-after control-impact study with sufficient replication to detect impacts on the order of a 50 per cent change in community structure in surrounding areas. Environmental monitoring during test mining must therefore be carried out at test-mining impact and comparable reference sites, to be selected on the basis of an initial assessment of their faunal composition. The guidelines suggested here will help to identify and predict the relevant effects of the test mining and to ensure that environmental considerations are explicitly addressed and incorporated into the decision-making process.

38. The main environmental impacts are expected to be at the seafloor, with minor impact expected at the tailings-discharge depth and in the water column at depth. The impact assessment must include a study of impacts on both the benthic and pelagic environments. The test-mining operation will remove minerals and associated fauna and the test-mining vehicle will compress and damage the benthic fauna in areas adjacent to where it operates. The break-up and extraction of minerals may create a near-bottom plume, which may partly be transported to the ocean surface depending on the technology used for lifting the material.

39. Disposal in the surface waters may interfere with primary productivity by increasing the nutrient levels and decreasing the light penetration into the ocean,

enter the food chain and disturb vertical and other migrations and lead to the reduction of manganese oxide and the solution of metal components in the oxygen-minimum zone. For these reasons, tailing discharge should be well below the oxygen-minimum zone. Because the oxygen-minimum zone varies regionally and to some extent seasonally, environmental studies must determine the depth range of the oxygen-minimum layer at each test-mining area. Baseline data in the upper water column should concentrate on the oceanographic properties around the discharge depth.

40. Available information on community structure and function of the sites where deep-sea test mining will take place is limited, therefore voucher collection repositories, a gene sequence database repository and a photo library of species and specimens will help to evaluate and to anticipate, avoid, minimize or offset the adverse effects of the activities considered in test mining and mining of deep seafloor sites. The goal of the impact assessment — to protect the productivity and capacity of natural systems and the ecological processes that maintain the functions of these natural systems — requires traceability.

41. Contractors should be required to permit the International Seabed Authority to send its inspectors on board vessels and installations used by the contractor to carry out activities in the exploration area to, inter alia, monitor the effects of such activities on the marine environment.

42. Monitoring of test mining will focus on acquiring a predictive capability for the impacts to be expected from the commercial or strategic system.

A. Activities not expected to cause serious environmental harm

43. Based on available information, a variety of technologies currently used in exploration are not considered to have the potential to provoke serious harm to the marine environment and thus do not require an environmental impact assessment. These include:

(a) Positioning systems, including bottom transponders and surface and subsurface buoys filed in notices to mariners;

(b) Meteorological observations and measurements, including instrument deployment;

(c) Satellite monitoring (e.g., advanced very-high resolution radiometer) for plumes in surface waters;

(d) Oceanographic observations, including hydrographic observations and measurements with instrument deployment;

(e) Gravity and magnetic observations;

(f) Towed plume-sensor measurements (chemical analysis, nephelometers, fluorometers, etc.);

(g) Bottom or sub-bottom acoustic profiling (without use of explosives), electromagnetic profiling, profiling of resistivity, self potential or induced polarization;

(h) Mineral sampling of a limited nature such as those using grab or bucket samplers;

(i) Shipboard mineral assay and analysis;

(j) Dye release or tracer studies;

(k) Sampling by box core, small diameter core, reamed reverse-circulation drilling or grab;

(l) Video/film and still photographic observation and measurements;

(m) Sampling of small quantities of water, sediment and biota;

(n) Sampling with epibenthic sled, dredge or trawl so long as the sampling area is less than approximately 5 per cent of the habitat area;

(o) In situ metabolic measurements (e.g., dissolved oxygen consumption);

(p) DNA screening of biological samples.

B. Test-mining activities with potential for causing environmental harm

44. Mining tests are to be conducted by all contractors unless they use mining equipment that has already been tested by other contractors. In a mining test, all components of the mining system will be assembled and the whole process of test mining, the lifting of minerals to the ocean surface and the discharge of tailings will be executed. It is assumed that the mining test will have a duration of up to several months and may be done with a somewhat scaled-down system. For environmental assessments, this test phase should be carefully monitored and investigated, as should tests of any test-mining component. After in-depth evaluation of the first mining test, impacts of other test-mining systems will be predictable and in later tests environmental studies may be restricted to unresolved questions, specific local environmental conditions or changes of impact due to different techniques. It seems reasonable to assume that a first mining test will extend our knowledge considerably and that all contractors will gain through the experience. Subsequent mining tests may be conducted with much less effort. For these reasons, it is expected that contractors will unite their efforts in the first and following mining test to achieve the maximum in knowledge increase with a minimum of effort on behalf of each contractor.

45. Current scientific information indicates that some environmental impacts may be caused by test mining during the exploration period, although the potential for serious environmental harm is not known. It is anticipated that the potential for serious environmental impact will be greatest at the seafloor and at the depth zone of discharge of mine tailings and effluent and below.

1. Potential benthic impacts

46. The potential benthic impacts include:

(a) Direct impacts of mineral recovery, where minerals and associated organisms will be crushed or dispersed in a plume as the mineral deposits are removed;

(b) Smothering or entombment of benthic organisms away from the site of mineral removal where the sediment plume settles. This may be especially critical for sessile organisms attached to hard substrata and for epifaunal or infaunal organisms that cannot move quickly enough to adjust their position;

(c) Alteration of the nutritive quality of surfaces used by surface deposit-feeders or chemosynthetic associations;

(d) Clogging of the feeding apparatus of suspension feeders and dilution of resources for deposit-feeders;

(e) Toxic effects associated with the deposition of fine and coarse particulate minerals in benthic habitats away from the site of sulphide removal;

(f) Loss of brood stocks for populations of species associated with polymetallic sulphides, cobalt crusts or other specialized and restricted habitats (whale falls, wood islands, etc.) within the dispersal shadow of the test-mining-generated plume.

2. Potential water-column impacts

47. The potential water-column impacts (deriving from discharge of tailings or effluent at depth) include:

(a) Mortality of and changes in composition of plankton exposed to discharge plume, effluent (including larval stages of invertebrates colonizing sulphide deposits) caused by toxicity, interference with feeding mechanisms and alteration of trophic interactions;

(b) Effects on meso- and bathypelagic fish and other nekton caused directly by sediment plume or associated metallic species or indirectly through the food web;

(c) Impacts on deep-diving mammals, such as through impacts on abundance of their prey;

(d) Depletion of oxygen by bacterial growth on suspended particles;

(e) Effects on fish behaviour and mortality caused by sediments or trace metals;

(f) Dissolution of heavy metals within the oxygen minimum zone and their potential incorporation into the food chain;

(g) Large-scale impact expected from discharged tailings over longer time spans (decadal).

3. Potential upper-water-column impacts

48. The potential upper-water-column impacts (if tailings, sediment or effluent are discharged near the surface) include:

(a) Trace metal bioaccumulation in surface organisms;

(b) Reduction in primary productivity due to shading;

(c) Effects (positive or negative) of trace metals on surface productivity;

(d) Effects on behaviour of marine mammals and seabirds due to reduced water clarity and/or reduction in the abundance of prey.

49. Each contractor should include in its programme specification of events that could cause suspension or modification of the activities owing to serious environmental harm if the effects of the events cannot be adequately mitigated.

C. Information to be provided by the contractor prior to test-mining operations

50. The contractor should provide the International Seabed Authority with a general description and a schedule of the proposed exploration programme, including the programme of work for the immediate five-year period, such as studies to be undertaken in respect of the environmental, technical, economic and other appropriate factors that must be taken into account during test mining. This general description should include:

(a) A programme for oceanographic and environmental baseline studies in accordance with the draft regulations and any environmental regulations and procedures issued by the International Seabed Authority that would enable an assessment of the potential environmental impact of the proposed exploration activities, taking into account any guidelines issued by the Authority;

(b) Proposed measures for the prevention, reduction and control of pollution and other hazards, as well as possible impact on the marine environment;

(c) A preliminary assessment of the possible impact of the proposed exploration activities on the marine environment;

(d) A delineation of the impact reference area and preservation reference area (recommended): the impact reference area should be selected on the basis of its being representative of the environmental characteristics, including the biota, of the site to be test mined. The preservation reference area should be carefully located and large enough so that it is not affected by the natural variations of local environmental conditions. Its species composition should be comparable to that of the test-mining area and it should be located upstream of test-mining operations. The preservation reference area should be outside the test-mining area and areas influenced by any test mining or processing plumes.

51. This general description should also include the following information, as appropriate to the activities to be conducted:

(a) Regional and local environmental baseline data;

(b) Size, shape, tonnage and grade of the deposit;

(c) Sulphide or cobalt crust collection technique;

(d) Depth of penetration into the seabed;

(e) Description of the running gear that contacts the seabed;

(f) Seabed processing methods, as applicable;

(g) Crushing methods, as applicable;

(h) Methods for transporting minerals to the surface;

(i) Mineral processing on the surface vessel;

(j) Volume, rate and depth of overflow discharge;

(k) Concentration of particles in the discharged water;

(l) Chemical and physical characteristics of the discharge;

(m) Location of the mining test and boundaries of the test area;

(n) Probable duration of the test;

(o) Test plans (collecting pattern, area to be perturbed, etc.);

(p) For mineral deposits, baseline maps (e.g., side-scan sonar, high-resolution bathymetry) of the deposits to be removed.

D. Observations and measurements to be made while performing a specific activity

52. The contractor should provide the International Seabed Authority with some or all of the following information, depending on the specific activity to be carried out:

(a) Width, length and pattern of the miner tracks on the seafloor;

(b) Actual depth of penetration of the miner;

(c) Lateral disturbance caused by the miner;

(d) Volume of material taken by the miner;

(e) Volume of material rejected by the miner at depth;

(f) Size and geometry of the discharged plume;

(g) Behaviour of the plume behind the miner;

(h) Area and thickness of resedimentation to the distance where resedimentation is negligible;

(i) Volume of overflow discharge from the surface vessel;

(j) Concentration of particles in the discharged water;

(k) Chemical and physical characteristics of the discharge;

(l) Behaviour of the discharged plume at surface or in mid-water;

(m) Modification of fluid discharge in hydrothermal settings (using photo documentation, temperature measurements and other metrics, as appropriate).

E. Observations and measurements to be made after the performance of a specific activity

53. The contractor should provide the International Seabed Authority with some or all of the following information, depending on the specific activity to be carried out:

(a) Resampling of local environmental baseline data at reference and test zones and evaluation of the environmental impact;

(b) Thickness of redeposited sediment on the side of the miner tracks;

(c) Behaviour of the different types of benthic fauna subjected to resedimentation;

(d) Changes of the benthic fauna in the miner tracks, including possible recolonization;

(e) Possible changes in the benthic fauna in adjacent areas apparently not perturbed by the activity;

(f) Changes in water characteristics at the level of the discharge from the surface vessel during the mining test and possible changes in the behaviour of the corresponding fauna;

(g) Changes in fluid flux and response of organisms to this change in hydrothermal settings;

(h) For mineral deposits, post-test-mining maps of the mined area, highlighting any changes in topography at one-metre scale resolution or better.

VII. Cooperative research

54. Recent years have witnessed a revolution in the development of knowledge and technology in deep-sea sciences. A number of research institutes around the world are carrying out extensive research programmes on seamount and ridge systems. Those institutions have considerable biological and scientific expertise and could be willing to join with the mining contractors in conducting some of the required environmental research. They could provide sampling equipment and expertise and would likely be eager to join the mining contractor's vessel and to assist in sampling remote areas.

55. General guidelines for cooperative research:

(a) Cooperative research can involve interactions with multiple oceanographic disciplines and multiple institutions;

(b) Cooperative research can facilitate the establishment of baselines of natural variability on the basis of geological, biological and other environmental records acquired in selected areas;

(c) During the test-mining phase, mining companies and cooperative research programmes may prove especially synergistic, bringing together the expertise, research facilities, logistical capability and common interests of the mining companies and cooperative institutions and agencies. In this way, the mining companies may make the best use of expensive research facilities, such as vessels, and the extensive expertise in geology, ecology, chemistry and physical oceanography of academic colleagues;

(d) Voucher collection repositories, a gene sequence database repository, stable isotope analysis and interpretation and a photo library of species/specimens can be part of a partnership between scientific and corporate groups. The basic scientific information acquired in partnership should result in the cost-effective acquisition of information that will assist in development planning and decision-making and the timely recognition of any significant environmental effects or issues prior to and during test mining. This information can be used to find solutions with a minimum-conflict approach;

(e) Taxonomic expertise is extremely limited, even for major groups within the fauna (e.g. fish, molluscs, decapod crustaceans, corals, sponges and echinoderms). It will be important that at least these key groups — and as many others as possible — be assessed at each site. This can be accomplished most efficiently through the development of cooperative taxonomic centres or groups of experts who will be responsible for the taxonomic identification of each major group;

(f) To answer certain questions on the environmental impacts of mining, specific experiments, observations and measurements must be conducted. All contractors need not execute the same studies. Repeating certain experiments or impact studies would not necessarily add to scientific knowledge or to impact assessments, while needlessly consuming financial, human and technological resources. Contractors are advised to explore opportunities to unite their efforts in international cooperative oceanographic studies to the extent feasible;

(g) The potential risk of extinction for a significant fraction of a community of fauna within a potential test-mine site will depend largely on the distribution of the fauna: how localized or widespread the species are distributed. Assessment will require syntheses of the biogeography of the fauna. This assessment should be facilitated by collaboration among mining contractors and with the broader research community;

(h) The biology of dominant components of seamount fauna is poorly known but is of considerable importance in the assessment of the potential impact of test mining and population and ecosystem recovery rates after the cessation of test-mining activities. Critical parameters include rates of growth, longevity, age of reproductive maturity, modes of reproduction and dispersal and recruitment dynamics. Population genetic studies should be carried out to provide further insight into exchange processes between and among target sites. Such studies can be carried out collaboratively and/or the results shared among mining contractors;

(i) Modelling studies should be undertaken collaboratively, closely linked to the field studies, to assess extinction risks under various management strategies, including various options for the design of protected areas. Overall conservation strategies need to take into account non-test-mining impacts on the communities (e.g., in the case of seamounts, bottom trawling and coral harvesting);

(j) The International Seabed Authority should serve in an advisory capacity to mining contractors in terms of the identification of cooperative research opportunities, but contractors are free to seek their own links to academic and other professional expertise;

(k) The Authority and mining contractors should work together with cooperative research programmes to maximize the assessment of environmental impact while minimizing the cost of these assessments to the industry.

VIII. Data collection, reporting and archival protocol

A. Data collection and analysis

56. The types of data to be collected, the frequency of collection and the analytical techniques used, in accordance with the present recommendations, should follow the best available methodology and the use of an international quality system and certified operation and laboratories. Synthesis of such data can work to the advantage of all contractors. As an example, synthesized data on bathymetry, currents, winds, salinity, temperature and dissolved oxygen fields can form critical inputs for the modelling of regional- or basin-scale oceanographic processes. Models can be validated and fine-tuned by such sea-truth data and can then partially supplement costly data-collection exercises. Some claim areas may lie adjacent to or in the vicinity of other claims, providing further justification for data accessibility and the joining of efforts in modelling so that the impact of activities in neighbouring areas can be evaluated without repeating all aspects of environmental assessment.

B. Data archival and retrieval scheme

57. The contractor should provide the International Seabed Authority with all relevant data, data standards and inventories. Environmental data of non-commercial significance (including hydrographical, chemical and biological data) should be freely available for scientific analysis, and an inventory of the data holdings from each contractor should be accessible on the Internet. Metadata that detail the analytical techniques, error analyses, descriptions of failures, techniques and technologies to avoid, comments on sufficiency of data and other relevant descriptors should also be included in addition to the actual data.

C. Reporting

58. Assessed and interpreted results of the monitoring should be reported to the International Seabed Authority together with the data, according to the draft mining code.

D. Transmission of data

59. All data relating to the protection and preservation of the marine environment, other than equipment design data, collected pursuant to the present recommendations should be transmitted to the Authority to be freely available for scientific analysis and research within two years, subject to confidentiality requirements. The contractor should transmit to the Authority any other non-confidential data in its possession that could be relevant for the purpose of the protection and preservation of the marine environment.

IX. Recommendations to close gaps in knowledge

60. Representatives of independent environmental consulting firms, scientists, engineers and contractors should be brought together to discuss in further detail approaches to environmental baselines in sulphide and crust environments. Microbiologists as well as benthic ecologists should be participants in such a workshop.

Notes

[1] International Research Programme on Climate Variability and Predictability (http://www.clivar.org/).

[2] International Seabed Authority, *Standardization of Environmental Data and Information: Development of Guidelines* (ISA/02/02) (Kingston, 2002). Available from http://www.isa.org.jm/en/seabedarea/StandWShop/StandRep_splash.htm.

[3] Lewis, M. "SCIRO-SEBS (Seamount, Epibenthic Sampler), a new epibenthic sled for sampling seamounts and other rough terrain", *Deep-Sea Research Part I: Oceanographic Research Papers*, vol. 46, No. 6 (June 1999).

Annex

Glossary

Active sulphides — polymetallic sulphides through which warm water is flowing. Active sulphides (also called hydrothermal vents) deliver reduced compounds (e.g., sulphide) to the seafloor-seawater interface where they can be oxidized or otherwise autotrophically metabolized by free-living or symbiotic micro-organisms.

Chemosynthesis — process by which micro-organisms metabolically transform inorganic carbon to organic carbon (cells) using energy derived from the oxidation of reduced compounds. Chemosynthesis is the basis for the food web associated with deep-sea hydrothermal vents. Chemoautotrophy is a more descriptive and precise term for the general phenomenon of chemosynthesis; the two words are often used interchangeably.

Cobalt-enriched crusts — ferromanganese crusts with enriched cobalt content typically formed by precipitation and found on hard substrates in the deep sea on features with significant topographic relief, such as seamounts and ridges.

Cumulative impacts — impacts resulting from incremental changes caused by other past, present or foreseeable actions.

Direct impacts — impacts that are a direct result of an action, such as loss of habitat and populations, owing to removal of sulphides or other materials.

Endemism — the degree to which a species is restricted to a particular geographic region; endemism usually occurs in areas that are isolated in some way. Biologists also use the term "endemic" to refer to an organism that might be geographically widespread but that is restricted to a specific habitat, e.g., hydrothermal vents.

Fauna — the term fauna includes invertebrates and vertebrates.

Hard substrata — outcrops in the form of carbonate concretions, solid material, crustal rocks or deposits of precipitated materials, metals and minerals discharged from the subsurface by hydrothermal systems.

Impact zone — zone where impacts (direct, indirect, cumulative and/or interactive) result from the activity.

Impact reference zones — areas used to assess the effect of activities in the Area on the marine environment; these impact reference zones must be representative of the environmental characteristics (physical, chemical, biological) of the area to be mined.

Inactive (or dormant) sulphides — polymetallic sulphides through which warm water is no longer flowing into the overlying seawater (i.e., they are "cold"). Disturbance of these sulphides may result in renewal of hydrothermal fluxes into the water column, turning inactive sulphides into active sulphides (hence the concept of "dormant" sulphides).

Indirect impacts — impacts on the environment that are not a direct result of the activity, often produced away from or as a result of a complex pathway (physical, chemical, biological). Often referred to as secondary (or even tertiary) impacts.

Micro-organisms — includes bacteria, archaea and microscopic eukarya.

Plankton — includes larval stages of benthic and pelagic organisms, phytoplankton (in surface waters), zooplankton, jellies and other drifting or weakly swimming organisms.

Polymetallic sulphides — hydrothermally formed deposits of sulphide minerals which contain concentrations of metals including, inter alia, copper, lead, zinc, gold and silver (ISBA/10/C/WP.1, para. 3 (f)). These deposits include sulphides associated with active as well as inactive hydrothermal vent settings. They may occur as buried deposits or they may be exposed on the seafloor. They may occur on seamounts, mid-ocean ridges or back-arc ridges.

Preservation reference zones — areas representative of the test-mining site but in which no test mining shall occur; used to assess changes in the biological status of the environment caused by test-mining activities.

Seamounts — isolated topographic features, usually of volcanic origin, of significant height above the seafloor.

Subhabitat — a visually recognizable component of a larger habitat; for example, tubeworm and mussel beds may be subhabitats of a specific active polymetallic sulphide field; an operational term that facilitates an understanding of the habitat as a whole.

Symbioses (chemosynthetic) — associations between bacteria (symbionts) and invertebrates or vertebrates (hosts), in which the symbionts are chemosynthetic and provide nourishment to the host. The bacteria may be either endosymbiotic (living within the host tissues; e.g., tubeworms, clams, mussels) or episymbiotic (living on the outside of the host; e.g., bresiliid shrimp, alvinellid polychaetes).