International Seabed Authority ISBA/10/LTC/4

Legal and Technical Commission

Distr.: General
15 May 2004

Original: English

Tenth session
Kingston, Jamaica
24 May-4 June 2004

RECOMMENDATIONS OF THE WORKSHOP TO STANDARDIZE THE ENVIRONMENTAL DATA AND INFORMATION REQUIRED BY ON PROSPECTING AND EXPLORATION FOR POLYMETALLIC NODULES IN THE AREA (ISBA/6/A/18), AND RECOMMENDATIONS FOR THE GUIDANCE OF CONTRACTORS FOR THE ASSESSMENT OF THE POSSIBLE ENVIRONMENTAL IMPACT ARISING FROM THE EXPLORATION OF POLYMETALLIC NODULES IN THE AREA (ISBA/7/LTC/1)

I. INTRODUCTION

1. The International Seabed Authority convened the Workshop to standardize the environmental data and information required by the Regulations on Prospecting and Exploration for polymetallic nodules in the Area (ISBA/6/A/18) and Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from the exploration of polymetallic nodules in the Area (ISBA/7/LTC/1) from the 25 to 29 June 2001. Thirty-nine engineers, scientists and other experts from 17 countries and the United Nations took part in the workshop, including representatives of six of the seven exploration contractors with the Authority for polymetallic nodules in the Area. They heard and discussed 21 presentations on various topics related to standardizing the environmental data and information that must be gathered by contractors authorized by the Authority to explore for polymetallic nodules in seabed areas beyond national jurisdiction. The proceedings of workshop have been made available on the Authority's web page (electronic version in pdf format) and are also available (in printed copy) in the library of the Secretariat.

2. The workshop was convened in accordance with paragraph 5(g) of Section 1 of the annex to the Implementation Agreement, and paragraph 2(e) and 2(h) of article 165 of the Convention, in particular it was convened to assist the Legal and Technical Commission issue guidelines on the use of standardized environmental data and information as required by the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area (ISBA/6/A/18) and the Recommendations for guidance of the contactors for the assessment of the possible environmental impacts arising from exploration for polymetallic nodules in the Area (ISBA/7/LTC/1/Rev.1).

3. The purpose of the Workshop was to provide a basis for facilitating the work of contractors in establishing environmental baselines, for subsequent monitoring of the effects of their activities on the marine environment, and to allow for comparisons in different nodule-bearing provinces. Specifically, it was

a. To propose standards for the measurement of the biological, chemical, geological and physical components of the marine environment essential for establishing environmental baselines and for environmental impact assessment;

b. To recommend general sampling designs for the acquisition of environmental data and information;

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c. To recommend appropriate standardization strategies for ongoing efforts in taxonomy, sample processing and field collection of data; and

d. To recommend strategies that will facilitate the conversion of relevant data and information that have been acquired by the contractors and concerned international scientific institutions into the standards proposed, thereby enabling the creation of a central database for subsequent use in managing impacts from deep seabed mining of polymetallic nodules when it occurs.

4. This report contains the recommendations of the workshop with regard to these matters. The Workshop began with presentations on the legal framework for deep seabed polymetallic nodule exploration and the Authority's regulations and recommendations to ensure the effective protection of the marine environment from harmful effects that may arise from activities in the Area. These presentations provided the basis for further presentations and discussions during the Workshop. The highlights of these presentations are presented in Part II of this report. The Workshop also heard and discussed 19 other presentations by academic and government experts on various topics. These included presentations on, *inter alia*, work already carried out in the international seabed area by contractors and other researching organizations to assess environmental conditions with details on the parameters measured and the standards used, sampling designs for baseline studies, database development and standardization strategies. Several of the papers and presentations suggested standards that contractors might adopt to improve the comparability of data. The Workshop devoted much of its time to matters that must be resolved to ensure that contractors will know what data and information they are expected to submit on environmental conditions in the areas allocated to them for polymetallic nodule exploration. During its discussions, the workshop participants also raised a number of issues that went beyond the specifics of standardizing data gathering and measurement. Recommendations made on matters included cooperative biological research, the creation of a central database on environmental information collected by others, including contractors, taxonomic coordination utilizing recognized experts to assist in the correct identification of animal fauna living on the seabed in nodule provinces, exchange of seagoing scientists and cooperative cruises with contractors, workshops to enable scientists and technicians from different countries who are involved in environmental monitoring to share, compare and standardize procedures, and other standardization activity. These recommendations are contained in Part III of the report.

5. Following three days of presentations and discussions, three Working Groups were set up by the Workshop to formulate recommendations concerning baseline and impact studies. These were a Chemical/Geological Working Group, a Benthic Biological/Environment Working Group and a Water-Column Working Group. Each of the groups was requested to:

a. Identify key parameters to be measured and to be listed in an ISA database;

b. Identify currently accepted standards and protocols for measuring these key parameters;

c. Identify community-wide issues that would benefit from a common approach;

d. Outline a cooperative research programme or programmes to address the key community-wide issues; and

e. Indicate ways in which the ISA can facilitate cooperative work, maintenance of high data standards and responses to major environmental questions.

6. The recommendations of the Working Groups on the key parameters to be measured and listed in an ISA database, and currently accepted standards and protocols for measuring these parameters are set out in Part IV of the report. These are grouped under physical, chemical, biological and geological components of the marine environment essential for establishing environmental baselines and for environmental impact assessment, as well as recommendations on appropriate sampling design and strategy for the acquisition of environmental baseline data and for conducting monitoring tests during exploration.

7. The recommendations contained in Parts III and IV have been made available to the Legal and Technical Commission with a view that the Commission considers them in relation to making recommendations to the Council on

rules, regulations and procedures incorporating applicable standards for the protection and preservation of the marine environment,[1] and in relation to its recommendations to the Council to promote and encourage the conduct of marine scientific research related to the environmental impact of activities in the Area.[2]

II. THE AUTHORITY'S LEGAL FRAMEWORK TO ENSURE THE EFFECTIVE PROTECTION OF THE MARINE ENVIRONMENT FROM HARMFUL EFFECTS FROM POLYMETALLIC NODULE EXPLORATION

8. During the workshop, a presentation was made by a member of the Legal and Technical Commission on document ISBA/7/LTC/1/Rev.1, Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration of polymetallic nodules in the Area. The paper, presentation and discussions that followed, served as a basis for subsequent discussions during the workshop.[3]

9. Participants were informed that document ISBA/7/LTC/1/Rev.1 contains three elements:

a. Environmental baseline studies,

b. Environmental impact assessment during exploration, and

c. A monitoring programme during and after activities that have potential for causing harmful effects on the marine environment.

III. ENVIRONMENTAL BASELINE STUDIES

10. It was pointed out that the purpose of environmental baseline studies is to establish the initial state of the marine environment before activities by the contractor that have potential for causing harmful effects on this environment occur. In this regard it was also pointed out that relevant studies required to establish environmental baselines would be in the areas of physical and chemical oceanography, sedimentation and sediment properties, biological communities, and bioturbation.

11. Participants were informed that within the context of ISBA/7/LTC/1, physical oceanographic studies are required of contractors in order to estimate the potential influence of the plume of discharged material during mining. Chemical oceanographic studies are required of contractors in order to assess the possible influence of the modification of the composition of seawater on biological activity. Studies on sediment properties and sedimentation are required of contractors, in order to assess the natural variability of sediments in potential mining areas, and to predict the behaviour of the discharged plume. In addition, participants were informed that studies on the biological communities in potential mining areas and bioturbation were required of contractors in order to determine the natural state and variability of biological communities (megafauna, macrofauna, meiofaunal, microbial biomass, nodule fauna and demersal scavengers), and to assess the effects of mining on these seafloor communities.

IV. ENVIRONMENTAL IMPACT ASSESSMENT DURING EXPLORATION

12. It was pointed out that a number of activities that have long been used in marine scientific research and in marine industrial surveys are not considered as having a recognizable environmental impact on the marine environment, and

[1] Paragraph 5 (g) of Section 1 of the Annex to the Implementation Agreement.
[2] Paragraph 5 (h) of Section 1 of the Annex to the Implementation Agreement.
[3] Chapter 2. Overview of the Authority's Regulations and recommendations to ensure the effective protection of the marine environment from harmful effects that may arise from activities in the Area. Mr Jean-Pierre Lenoble. Standardization of Environmental data and Information: Development of Guidelines. Proceedings of the 2001 International Seabed Authority Workshop held in Kingston, Jamaica.

therefore did not need to be assessed for their impacts.[4] It was however pointed out that for deep seabed polymetallic nodule mining, the Legal and Technical Commission had identified some activities that require contractors to undertake environmental impact assessment studies. These activities are:

a. Dredging to collect nodules for on land studies for mining and/or processing (i.e., dredging for several hundred tons of nodules;

b. Use of special equipment to study the reaction of the sediments to disturbance made by collecting devices (such as dredges) or running gears; and

c. Testing of collection systems and equipment.

13. It was further pointed out that under the regulations, environmental impact assessments and associated monitoring programmes are to be submitted to the Secretary-General of the Authority at least one year before the activity takes place, or for integrated tests of the mining system, at least two years in advance.

14. Participants were informed that most of the parameters to be measured by contractors had already been listed by the Legal and Technical Commission in an explanatory commentary annexed to its environmental assessment recommendations. What was expected from the Workshop was to add precision to this list by specifying what ought to be sampled to ascertain the chemical and geological conditions, biological and habitat conditions, water-column conditions, and the appropriate standards for taking measurements.

V. COOPERATIVE BIOLOGICAL RESEARCH

15. Participants in the Workshop felt that it would be very important for the Authority to address a number of biological questions in order to improve it's ability to predict the environmental impacts of manganese nodule mining. These questions are,

a. What are the typical latitudinal and longitudinal ranges of benthic species, and what are the rates and spatial scales of gene flow?

b. What is the dose-response function for the benthic community, given a single deposition event?

c. How frequently must modest deposition events (less than 1 millimetre) occur for their effects to become chronic?

d. What are the time scales of community recovery following various intensities of disturbance (e.g., removal of the top 2 centimetres of sediment, heavy burial, light burial) and how do these recovery times vary with the spatial scale of disturbance?

e. What are the natural patterns and scales of benthic community variability in space and time?

16. Participants recommended that the Authority should facilitate additional research programmes, using new resources, to address these questions. It was suggested that facilitation may take the form of bringing scientists and funding-agency representatives together for discussions, providing support for the writing of proposals, and convening a

[4] These include: gravity and magnetometric observations and measurements; bottom and sub-bottom acoustic or electromagnetic profiling or imaging without the use of explosives; water and biotic sampling and mineral sampling of a limited nature such as those obtained using core, grab or basket samplers to determine seabed geological or geotechnical properties; meteorological observations and measurements, including setting up of instruments; oceanographic, including hydrographic, observations and measurements and the setting of instruments; television and still photographic observations and measurements; shipboard mineral assaying and analysis, and positioning systems, including bottom transponders and surface and subsurface buoys.

workshop to formulate coordinated scientific research plans. Facilitation of these research activities and identification of new resources should be given high priority.

VI. DATABASES

17. It was suggested that the Authority should facilitate the integration and distribution of environmental data and information from contractors through database development. It was recommended that the Authority should give guidance to contractors on the maintenance of databases, including data standards, standard data formats, accessibility and lifetime.

18. It was recommended that the Authority should establish a common environmental database. It was recommended that the Authority should hire consultants to set up and manage this database.

19. As part of this effort, it was also recommended that the Authority should facilitate the compilation of a metadatabase linking the various contractor and non-contractor databases and to publish the metadata base on the World Wide Web.

VII. TAXONOMIC COORDINATION

20. It was pointed out that the taxonomy of micro zooplankton, deep-water zooplankton and small phytoplankton in nodule exploration areas is problematic. Participants recommended that contractors collaborate with each other and with other scientists to coordinate taxonomic descriptions.

21. It was agreed that the objective of the effort would be to ensure that species are being identified similarly (and accurately) during taxonomic analysis of samples that may have been taken by different contractors, in different locations and at different times. It was pointed out that a common (and accurate) taxonomy among field programmes is essential to determine species ranges, and to evaluate the potential for extinctions, within the potential nodule-mining areas. It was noted that producing accurate taxonomy is particularly problematic in the deep sea because many abundant taxa (e.g., polychaetes and nematodes) contain a large proportion of undescribed species; consequently, useful taxonomic keys are virtually nonexistent. It was also recognized that taxonomic research is largely carried out in museums, so that such organizations are likely to be particularly, but not exclusively, useful for taxonomic coordination.

22. Participants in the Workshop made the following recommendations:

a. Taxonomic standardisation of species identification in samples collected during the environmental monitoring of mineral exploration and exploitation areas should be coordinated through a single location so that contractors have a central facility, and a reference taxonomist, to assist them in finding the taxonomic advice and expertise that they might require. In this scheme, the central coordinator would compile a taxonomic database for the taxon in question and make available such information.

b. A recognized taxonomic expert should be appointed as reference taxonomist for each taxonomic group to facilitate taxonomic standardization within that group. This expert will be responsible for taxonomic quality control within the taxon. This will involve such actions as offering advice, checking identifications, preparing and controlling voucher collections for quality, and contributing to the training of taxonomists from the contractors as required. Coordinators for different taxa will probably be located in various institutions.

c. For taxa having many unknown species, participants recommended the use of voucher collections. It was agreed that supplying contractors with such collections would be an important contribution toward ensuring taxonomic standardization.

d. It was suggested that coordinating taxonomists would need financial resources to conduct this task. The ISA was requested to select coordinating taxonomists and to identify the required resources.

VIII. EXCHANGE OF SEAGOING SCIENTISTS AND COOPERATIVE CRUISES

23. Because it is vital for scientists from different countries to use similar techniques and protocols for collecting data, participants recommended that periodic exchanges of scientists from different countries should take place onboard cruises to sample exploration areas. It was pointed out that this would enable scientists to compare and standardise exactly how particular procedures are conducted in the field (e.g. lowering box cores). It was recommended that the ISA should support/facilitate such efforts.

24. It was also recommended that the Authority should facilitate the organization of cooperative cruises in order to allow for the exchange of samples, technologies and protocols, and for sampling in areas allocated to different contractors and over longer periods.

IX. WORKSHOPS

25. Participants recommended that workshops should be held periodically for scientists and technicians from different countries that are involved with environmental monitoring of exploration and mining operations, to enable them to share, compare and standardise procedures. Participants noted that such workshops would be essential to ensure that the data collected from different programmes are comparable. Among the topics for such workshops, participants suggested methods for sampling, storage, preservation and curation, and other analytical methods related to oceanography and the marine environment.

26. Assessment of spatial and temporal variability in the exploration areas is a key issue that will be facilitated by coordination of cruises and collaborative interpretation of the data among contractors. It is recommended that ISA sponsor workshops to this end.

X. ASSESSMENT OF KEY ENVIRONMENTAL PARAMETERS

A. CHEMICAL/GEOLOGICAL PARAMETERS

27. The Workshop adopted the recommendations of the working group on chemical/geological parameters. This working group identified key parameters and methodologies for three environments, namely sediment properties, sediment pore water and water-column chemistry. The working group informed the Workshop that these parameters were identified based on their importance for one or more of three criteria: *geotechnical*, *habitat* and *impact assessment*. *Geotechnical* criteria were defined as those that are important for predicting the nature of the sediment plume and for assessing the physical nature of the seabed. In addition, some geotechnical criteria are important for understanding the benthic habitat. *Habitat* criteria were defined as those that are directly related to the benthic habitat, such as sediment grain size, as well as those that indirectly affect the life support of the organisms, such as nutrients. *Impact assessment* is used for those criteria that present a toxicological concern, either to the organisms themselves, or to human health by bioaccumulation up the food chain. Heavy metals are examples of this category.

(i) Sediment properties

28. Sediment properties are important for understanding sediment resuspension and transport of the plume as well as providing supporting information for benthic and chemical studies. The participants agreed with the LTC Recommendations (ISBA/7/LTC/Rev.1) on the key parameters to be investigated: specific gravity, bulk density, water content (porosity), shear strength, grain size and distribution, depth of the redox boundary, organic and inorganic carbon content, chemical composition and bioturbation depth (Table 1). It was noted that for several of these parameters no one standard method of analysis exists, and there was no agreement on a preferred method. It is recommended that any one of several common, state-of-the-art methods be used.

Table 1. Key parameters for the measurements of the physical properties of sediment

Parameter	Primary purposes	Methodologies	Recommendations
Specific gravity	Geotechnical properties	Wet weight and volume	No common standard; use
			Best available method
Bulk density	Geotechnical properties	Gamma-ray attenuation;	No common standard; use
		Volume and dry weight	Best available method
Water content	Geotechnical properties	Wet weight; dry weight	Dry at 105 degrees Celsius
			For 24 hours
Porosity	Geotechnical properties,	Calculated from other	Calculated from other
	Environmental risk	Measured parameters	Measured parameters
Shear strength	Geotechnical properties –	Vane shear; best	Best available method may
	Variation with depth	Available method	Be in situ
Grain size	Geotechnical and habitat	Sediment balance;	No common standard; use
	Properties (benthic	Sedigraph; wet sieving;	Best available method. Use
	Communities)	Pipette analysis	Seawater
Oxidation-reduction Potential (ORP)	Impact assessment	Eh/ORP electrode	Eh/ORP electrode
Organic carbon	Habitat	CHN analyser	CHN analyzer
Inorganic carbon	Impact assessment	CHN analyzer; acid Dissolution-CO2	Best available method
Chemical composition	Impact assessment	X-ray fluorescence (XRF), Atomic absorption Spectroscopy (AAS), Inductively coupled Plasma (ICP) Spectroscopy	Best available method
Bioturbation depth	Benthic mixing depth	Pb-210	Pb-210

Source: Standardization of Environmental data and Information – Development of Guidelines. Proceedings of the International Seabed Authority's Workshop held in Kingston, Jamaica 25-29 June 2001. ISA/02/02

29. It was recommended that, in wet sieving for grain-size analysis, seawater should be used and no chemical detergents should be added. It was pointed out that while this would result in larger grain sizes, it would more closely approximate the nature of the suspended sediment plume.

30. It was suggested that since sedimentation rates in claim areas are generally considered very low, they are not an important parameter and should be excluded from the list of key parameters.

31. It was recommended that the parameters cited in table 1 should be measured at the following core-depth intervals: 0-1, 1-3, 3-5, 5-8, 8-12 and 12-20 centimetres.

(ii) Sediment pore waters

32. It was noted that there are two commonly used methods to obtain pore water from sediments: squeezing and centrifugation. Although squeezing appears to produce more pore water than centrifugation, it was determined that the quality of the data would be equally comparable as long as the extraction of the pore water and the analysis of its redox sensitive species were done in an inert atmosphere. The sediment pore-water parameters to measure are shown in Table 2.

33. Because of the need for high vertical resolution and the limited pore-water volume obtained at depth, the following depth intervals are recommended: 0-1, 1-3, 3-5, 5-8, 8-12 and 12-20 cm. Fluxes across the sediment/water interface can be approximated from Fickian diffusion calculations using concentrations from the bottom water and the 0-1 cm interval.[5]

Table 2. Chemical parameters in sediment pore waters.

Parameter	Purposes	Methodologies	Recommendations
Phosphate	Habitat	Spectrophotometric; ion-exchange chromatography (IEC), flow injection analysis (FIA)	Best possible method
Nitrate	Habitat	Spectrographic; IEC, FIA	Best possible method
Silicate	Habitat	Spectrophotometric; IEC, FIA	Best possible method
Nitrite	Habitat	Spectrophotometric; IEC, FIA	Best possible method
Carbonate alkalinity	Habitat and impact assessment	Titration; Spectrophotometric	Titration; Spectrophotometric
Eh	Impact assessment	Electrode	Electrode
PH	Impact assessment	Electrode	Electrode
Fe	Impact assessment	AAS; ICP-MS (mass spectrometry); Spectrophotometric	AAS; ICP-MS; Spectrophotometric
Mn	Impact assessment	AAS; ICP-MS; Spectrophotometric	AAS; ICP-MS; Spectrophotometric
Zn	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Cd	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Pb	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Cu	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Hg	Impact assessment	AAS; ICP-MS	AAS; ICP-MS

Source: Standardization of Environmental data and information: Development of Guidelines. Proceedings of the International Seabed Authority's Workshop held in Kingston, Jamaica 25-29 June 2001. ISA/02/02

[5] Fick's law. The law that the rate of diffusion of matter across a plane is proportional to the negative of the rate of change of the concentration of the diffusing substance in the direction perpendicular to the plane.

(iii) Water column

34. It is suggested that the water-column chemical analysis provide for monitoring of oxygen content and metal bioaccumulation as a consequence of the release of sediment and pore waters both to the bottom water and, via discharge, to the water column. Therefore, chemical parameters in the water column should preferably be measured at the following levels above the sediment bottom: 10, 20, 50 and 200 meters, and 1.2-2 times the elevation of the highest topographic feature in the area; and also in the oxygen-minimum zone, at about the depth of the forecasted discharge; and as well as at surface layer, base of the mixed layer and within the subsurface chlorophyll maximum. The chemical parameters to be measured are given in Table 3.

35. It is recommended that the analytical methods should be the standard, accepted methods, such as those utilized in the Joint Global Ocean Flux Study (JGOFS) and the Geochemical Ocean Sections Study (GEOSECS).

Table 3. Chemical parameters in the water column

Parameter	Primary purposes	Methodologies	Recommendations
Phosphate	Habitat	Spectrophotometric; FIA, IEC	Best available method
Nitrate	Habitat	Spectrophotometric; FIA, IEC	Best available method
Nitrite	Habitat	Spectrophotometric; FIA, IEC	Best available method
Silicate	Habitat	Spectrophotometric; FIA, IEC	Best available method
Carbonate alkalinity	Impact assessment	Titration; Spectrophotometric	Titration; Spectrophotometric
O2	Impact assessment	Winkler titration	Winkler titration
Zn	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Cd	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Pb	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Cu	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Hg	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
TOC	Habitat and impact assessment	CHN analyzer	CHN analyzer

Source: Standardization of environmental data and information: Development of guidelines. Proceedings of the International Seabed Authority's workshop held in Kingston, Jamaica. 25-29 June 2001. ISA/02/02

(iv) Trace metals in benthic, and epi-, meso- and bathypelagic organisms

36. It is recommended that trace metal concentrations be measured in dominant benthic and epi-, meso- and bathypelagic species. Analysis of the Zn, Cd, Pb, Cu and Hg concentrations should be performed for at least five individuals from each of the three most dominant species collected as zooplankton and microneckton among the pelagic communities, as well as benthic macro invertebrates and bottom fish. Metal clean sampling techniques are required.

B. BIOLOGICAL/ENVIRONMENTAL PARAMETERS

36. The Workshop adopted the recommendations of the working group on Benthic Biological/Environment. In addition to the key parameters identified by this group for measurement, the Workshop supported the working group's recommendation that experimental designs and sampling programmes, for both baseline studies and the detection of impacts from mining, should be statistically rigorous and their ability to detect impacts statistically defensible. Additionally, the Workshop supported the recommendation that levels of replication should be determined from a power analysis based on the expected levels of type I and type II errors.[6]

37. For the purposes of facilitating coordination on taxonomy and understanding of species distribution and rates of gene flow, it was recommended that biological samples, suitable for DNA sequence analyses, of a broad range of benthic species should be collected. It was suggested that duplicate benthic biological samples of all types should be preserved in DNA-grade ethanol for DNA analyses, in parallel with the fixation of samples in formaldehyde for morphological studies. It was further recommended that samples should be fixed and preserved in DNA-grade alcohol (at least 95 per cent non-denatured ethanol by volume). It was pointed out that special procedures might also be required during processing of samples (e.g., working in a cold room) to avoid degradation of DNA before fixation in ethanol.

38. The key biological parameters presented below were recommended for measurement. It was also recommended that the appropriate raw data should be provided for entry into the ISA database.

(i) Megafauna

39. It was recommended that data on megafauna abundance, biomass, species diversity, number of individuals per species and spatial distributions should be obtained from photographic surveys in such a way that organisms larger than 2 cm in smallest dimension can be readily identified.

40. It was suggested that techniques to be used should include quantitative photographic transects. It was also suggested that each photo should cover an area at least 2 m wide, within which the megafauna should be quantifiable. It was suggested that sampling stations for photo transects should be defined taking into account the various features of the bottom, such as topography, variability of sediment characteristics, abundance and type of nodule.

41. It was recommended that megafauna should be collected by epi benthic sled, trawl, baited traps and/or submersibles in order to identify species for molecular phylogenetic analyses and for voucher specimens. It was pointed out that it would be desirable to develop sled or trawl technology to collect epi benthic megafauna without nodules (which grind up specimens).

(ii) Macrofauna

42. It was recommended that data on macrofauna abundance, biomass, species diversity, number of individuals per species, sediment depth distribution (sample to 10-cm depth with some vertical sectioning) and spatial distribution should be obtained from 0.25-m2 box cores. It was also recommended that lowering box corers to the seabed should follow the protocols of Schriever and Borowski or Hessler and Jumars.[7] It was also recommended that samples should be gently sieved through nested 300- and 250-micron sieves.

[6] Type I errors are when a null hypothesis is wrongly rejected, Type II errors are when a null hypothesis is falsely accepted.

[7] R.R. Hessler and P.A. Jumars, 1974. Abyssal community analysis from replicate box corers in the central North Pacific, *Deep-Sea Research,* 21, pp.185-209.

(iii) Meiofauna

43. It was recommended that samples for data on meiofaunal (32-250 µm), abundance, biomass, species structure and depth distribution (suggested depths: 0-0.5, 0.5-1.0, 1-2 and 2-3 cm), as well as spatial distributions, should be collected from multiple (or mega-) corer tubes. It was also recommended that meiofaunal should be processed on nested sieves of 63, 45 and 32-µm mesh sizes. The focus will be on the most abundant identifiable taxa, which are the Nematoda and Harpacticoida.

(iv) Microbial biomass

44. It was recommended that microbial biomass should be determined using adenosine triphosphate (ATP) or other standard assay for 0-1 cm intervals of cores. It was recommended that one tube per station of a multiple corer-sampling pattern could be devoted for this purpose. Suggested intervals for sampling are 0-0.5, 0.5-1.0, 1-2, 2-3, 3-4 and 4-5 cm.

(v) Nodule fauna

45. It was recommended that the abundance and species structure of the fauna attached to or otherwise associated with nodules should be determined from selected nodules taken from the top of box cores. It was recommended that the techniques proposed by Thiel *et al.* should be followed.[8]

(vi) Demersal scavengers

46. It was recommended that baited camera studies and baited traps should be used to characterize the demersal scavenger community.

(vii) Habitat quality

47. It was recommended that a time-lapse camera should be installed at the study area for at least one year to examine the physical dynamics of surface sediment, to document the activity level of surface megafauna and to document the frequency of resuspension events.

(viii) Sedimentation

48. It was recommended that one set of sediment traps should be deployed on each of two moorings for at least 12 months. In this regard, it was suggested that a trap on each mooring should be at a depth of about 2000m to characterize mid-water particle flux, and another trap should be ~500m above the seafloor (and outside of the benthic boundary layer) to evaluate deep particle flux.

49. It was recommended that a current meter should also be deployed at the approximate level of each trap to evaluate the current regime at trap level. It was suggested that traps should sample sequentially at intervals of no longer than one-month, and should be deployed on the general current meter moorings. It was recommended that the variables to be measured on sediment trap samples should include the fluxes of total mass, particulate organic carbon, calcium carbonate, biogenic silica and excess Pb-210. It was also recommended that the published protocols of the Joint Global Ocean Flux Study (JGOFS) should be used for these analyses.[9]

[8] H. Thiel et al, 1993. Manganese nodule crevice fauna, Deep-Sea Research 40(2), 419-423.

[9] A. Knap et al. (Eds.), 1996. Protocols for the Joint Global Ocean Flux Study (JGOFS) Core measurements (JGOFS report 19), vi+170 pp. (reprint of IOC Manuals and Guides 29[UN Educational, Scientific and Cultural Organization, 1994].

(ix) Bioturbation

50. It was recommended that the rates and depths of bioturbation should be evaluated using excess Pb-210 profiles from multiple cores. Five replicate profiles per station are recommended, each from separate, randomly located, multiple core lowering. Excess Pb-210 activity should be evaluated at > 5 levels per core (suggested depths 0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.5 and 2.5-5 cm), and mixing intensities evaluated from standard advection-diffusion models.

C. WATER COLUMN PARAMETERS

(i) Required sampling

51. It was recommended that all contractors should routinely measure the following basic oceanographic variables:

a. Meteorological variables: sea state, wind speed and direction, cloud cover;

b. Conductivity-temperature-depth (CTD) profiles in the top 1000 m: conductivity and salinity, temperature, water depth, light level, chlorophyll *a*, dissolved oxygen;

c. Water samples to calibrate the CTD profiles and to determine nutrient levels to be taken at the surface, within the mixed layer, at the base of the mixed layer, and within the subsurface chlorophyll maximum and oxygen-minimum zones;

d. Measurements from water samples:

i. Nutrients (silicate, nitrate, phosphate)
ii. Dissolved oxygen
iii. Chlorophyll
iv. Salinity

e. An oblique tow for zooplankton from the sea surface to 200 m depth with a 200-micron mesh net. Use of a standard (60-cm-diameter mouth opening) bongo net with flow meter is recommended. Displacement volume will be measured at a minimum.

52. With regards to standards, it was recommended that CTD and water-sample analysis should follow the protocols of the Joint Global Ocean Flux Study (JGOFS). Zooplankton sampling should follow the protocols of the *Zooplankton Methodology Manual* of the International Council for the Exploration of the Sea.

(ii) Optional oceanographic sampling

53. It was pointed out that further useful information may be obtained from:

a. Epifluorescence-microscope counts of bacterial cell abundance and biomass, and of phytoplankton to assess species composition;

b. Inverted-microscope counts of settled micro zooplankton samples;

c. Analysis of particulate organic carbon (POC) and nitrogen (PON) from water samples;

d. Carbon-14 primary productivity measurements from the surface water and chlorophyll maximum;

e. Tritiated methyl thymidine measurement of bacterial productivity;

f. Estimation of micro zooplankton grazing rates;

g. Analysis of zooplankton tows to genus or species level;

h. Micro nekton tows from the surface to 200 m, 200 to 1000 m and 2000 m to near-bottom, using an opening/closing net with flow meter;

i. Observations of marine mammals, sea turtles and sea birds while underway between stations within the exploration area, based on standardized bridge watches following protocols of the International Whaling Commission (IWC);

j. Collection of deep zooplankton from near the seafloor to about 2000 m with an opening/closing net;

k. Measurement of currents in the upper waters with an acoustic Doppler current profiler (ADCP).

54. In relation to standards, it was pointed out that analysis of water chemistry, bacteria and phytoplankton would follow the JGOFS protocols. Zooplankton sampling would follow the protocols of the ICES *Zooplankton Methodology Manual*, and that the International Young Gadoid Pelagic Trawl (IYGPT) in combination with the Pearcy opening/closing net 6 is recommended for depth-stratified micro nekton sampling.

XI. ENVIRONMENTAL DATABASE REQUIREMENTS

55. Following discussions on the basic framework of a database for exploration, mining and assessment, there was general consensus that database development and management should include the following features:

- **Basic Station Data**. This would include essential information about sampling sites including the institution, contractor, program, claim area, vessel, cruise, principal investigator, station number, replicate number, date, longitude, latitude, depth and type of gear deployed.

- **Sampling Circumstances**. For evaluating the quality of data if comments were recorded on weather, sea state, and condition of samples, methods of deployment, gear failure and any other relevant circumstances that might bias data.

- **Location of Material**. The destinations (address and contact information) where biological, physical, geological materials are sent and archived should be recorded.

- **Variables**. It was pointed out that these would vary with sub discipline but would include those recommended for assessment within each sub discipline.

- **Integration**. It was pointed out that to understand the functioning of the ecosystem and impact assessment, it is important to combine information on the biology, chemistry and physics of both the benthic and pelagic environments into a single database.

- **Flexibility**. A relational database was recommended. The workshop was of the opinion that it is essential to be able to sort the data by taxon, time, location and environmental parameters or any other variable.

- **Interface with Analytical Tools**. It was recommended that the database should interface readily with software and hardware for statistical analysis, plotting, mapping and modelling.

- **Examination of Existing Models**. It was pointed out that there are currently several large database management systems for biodiversity and environmental surveys. These include **Biocean** at l'Institut français de recherche pour l'exploitation de la mer (IFREMER); **Linnaeus II** at the Expert Center for Taxonomic Identification (ETI), Amsterdam; and the **Irish Marine Data Center** in Dublin, supported by the European Union's Marine Science and Technology program (EU MAST). It was also pointed out that the **ENQUAD** (Environmental Quality Department) database, using Oracle, that was developed by the Massachusetts Water

Resources Authority (www.mwra.com), is extremely well managed, heavily used for both science and policy decisions, and comparable in size and complexity to the database contemplated for ISA. It was suggested that it would be very beneficial for ISA, in creating a database, to explore existing database models and consult with the developers and users of these databases.

- **Professional Development and Management**. Managing large, complex databases has become a highly complex and rapidly evolving specialty. It was therefore recommended that the ISA should establish a team of database managers who can interact readily with oceanographers and contractors in the interest of the Authority.

- **Web Site**. The Authority is urged to consider making the database available as part of its Web site. It is realized that contractors have proprietary rights to certain information and that the Authority may regulate the release of information (for example, to establish a lag time until the Authority has published data). In the long term, the interests of business, the scientific community, policy makers and the public will be served by making the database broadly and readily available.

- **Centralization**. The Authority has expressed an interest in managing the database, and has already made progress in this direction. It would be very valuable to include data that are currently available from early baseline studies and exploration by contractors as well as new data anticipated from continued baseline studies, exploration and exploitation.

- **Long-Term Benefits**. It is recognized that the Authority is the international regulatory structure for deep-sea mining and that the purpose of the workshop was to recommend standards for environmental assessment of commercial exploitation. The assessment studies will also provide vital new information on the earth's largest and least explored environment – the great abyssal plains of the world ocean. The database can make a major contribution not only to planning and regulating future commercial activity but also to our fundamental understanding of global biodiversity and ecosystem function.

56. A comparison between the data groups and parameters, as well as methods and standards for use in their measurement contained in document ISBA/7/LTC/Rev.1, Recommendations for the Guidance of the contractors for the assessment of the possible environmental impacts arising from exploration for polymetallic nodules in the Area, and the recommendations of the workshop to standardize environmental data and information is presented in annex 1.

NOTES AND REFERENCES.

1. International Seabed Authority (2000), Regulations on prospecting and exploration for polymetallic nodules in the Area (ISBA/6/A/18), *Selected Decisions and Documents of the Sixth Session* 31-68.

2. International Seabed Authority, Legal and Technical Commission, Recommendations for the guidance of the contractors for the assessment of the possible environmental impacts arising from exploration for polymetallic nodules in the Area (ISBA/7/LTC/1), 10 April 2001, with annex I, Explanatory commentary; further revised and approved by the Commission as ISBA/7/LTC/1/Rev.1 of 10 July 2001. On 12 July 2001, the ISA Council deferred consideration of the recommendations until its eighth session (August 2002).

3. *Deep-Seabed Polymetallic Nodule Exploration: Development of Environmental Guidelines* (1999), Proceedings of the International Seabed Authority's Workshop held in Sanya, Hainan Island, People's Republic of China (1-5 June 1998), ISA (Kingston, Jamaica), 289 pp. The recommended guidelines are in chapter 9, pp.

Annex I

Comparison between environmental data and information requirements contained in document ISBA/6/A/18 and ISBA/7/LTC/Rev.1, and those from the workshop

DATA GROUPS AND PARAMETERS	ISBA/7/LTC/1/REV.1	WORKSHOP ON STANDARDIZATION	DIFFERENCES
I. Physical oceanography: current conditions, temperature and turbidity			
1. Meteorological variables: sea state, wind speed and direction, cloud cover	Not specified	Required	Required by workshop
2. CTD profiles from the surface to the bottom with water samples at different level	Required in general	In the top 1000 m; Water samples – at the surface layer, within mixed layer, at the base of mixed layer, and within the subsurface chlorophyll maximum and oxygen-minimum zones.	Workshop specifies depths
3. Current measurements	Number and location depend of the size of the area, current regime, topography etc. 1st mooring –close to the seafloor (1-3 m), 2nd –1.2-2 times exceed the highest element of topography, and at 10, 20, 50 and 200m above the bottom.	Required in general Current meters at each sediment trap ADCP should be an optional measurement	Less required by workshop
4. Turbidity regimes	Required measurements	Not mentioned	Not required by workshop
5. Zooplankton	Not specified	Tow for zooplankton from the sea surface to 200m depths with a 200-micron mesh net.	Required by workshop
II. Chemical oceanography			
1. Levels to be measured	Not specified	10, 20, 50 and 200 m, and 1.2-2 times of the highest topography above the bottom; at the oxygen-minimum zone, at surface layer, base of the mixed layer and within the subsurface chlorophyll maximum. Suggested protocols from JGOFS and GEOSECS.	Workshop specifies depths

DATA GROUPS AND PARAMETERS	ISBA/7/LTC/1/REV.1	WORKSHOP ON STANDARDIZATION	DIFFERENCES
2. Dissolved oxygen concentration	Required	Required	No Change
3. Salinity	Required	Required	No Change
4. Nutrients (nitrate, nitrite, phosphate, and silicate)	Required	Required; best available methods	No Change
5. Carbonate alkalinity	Not specified	Required; by titration	Required by workshop
6. Trace metals	In general	Zn, Cd, Pb, Cu, Hg, by AAS; ICP-MS analysis	Workshop specifies requirements
7. Total organic carbon (TOC)	Required	Required; by CHN analyzer	Workshop specifies method
8. Chlorophyll-a	Required	Required	No Change
9. Trace metals in benthic, and epi-, meso- and bathypelagic organisms	Not specified	Required; Zn, Cd, Pb, Cu and Hg concentration at least five individuals from each of the three most dominant species. Metal-clean techniques required.	Workshop specifies requirements
III. Sediment properties			
1. Intervals to be measure both for sediment and pore water	Not specified Measure down to 20cm	Intervals: 0-1, 1-3, 3-5, 5-8, 8-12 and 12-20 cm.	Workshop specifies depths of measurements
A. From sediment:			
1. Specific gravity	Required	Required; Wet weight and volume methodology	Workshop specifies method
2. Bulk density	Required	Required; by Gamma-ray attenuation.	Workshop specifies method
3. Shear strength	Required	Vane shear; best available methods	No Change
4. Water content (porosity)	Not specified	Required; dry at 105 degrees Celsius; best available methods Porosity calculated from other measured parameters.	Required by workshop
5. Grain size	Required	Required; best available methods.	No Change
6. Depth of change from oxic to suboxic conditions	Required	Required by Eh/ORP electrode	Workshop specifies method
7. Organic and inorganic carbon	Required	Required; by CHN analyzer; acid dissolution – CO_2	Workshop specifies method

DATA GROUPS AND PARAMETERS	ISBA/7/LTC/1/REV.1	WORKSHOP ON STANDARDIZATION	DIFFERENCES
8. Chemical composition	Required	Required; best available methods	
B. From pore water			
9. Nutrients (phosphate, nitrate, nitrite and silicate)	Required except nitrite are not mentioned	Required; by best possible methods	Addition of Nitrite as a required measurement
10. Carbonate (alkalinity)	Required	Required; by titration	Workshop specifies method
11. Redox	Required	Required; pH and Eh by electrode	Workshop specifies method
12. Heavy metals	Required in general	Specified: Fe, Mn, Zn, Cd, Pb, Cu, Hg	Workshop specifies requirements
IV. Biological community			
1. Megafauna: abundance, biomass, species structure, and diversity	ID animals greater than 4 cm.Based on photographic transects of the different feature of the bottom. Photographs should cover at least 2m widths.	ID animals larger than 2 cm; by photographic transects.	Workshop reduces minimum size of animals for which identification is required
2. Macrofauna: abundance, biomass, species structure, and diversity and depth distribution	ID > 250μm;Suggested depth: 0-1, 1-5, 5-10 cm. Data based on box corers (0.25 m^2).	Sample to 10 cm depth with some vertical sectioning from 0.25 m^2 box corers; suggested protocols for lowering box corers.	Workshop does not require specific sediment horizons but gives more specifics on methods
3. Meiofauna: abundance, biomass, species structure, and diversity and depth distribution	ID 32-250μm; Suggested depth: 0-0.5, 0.5-1.0, 1-2, 2-3cm. Data based on corers, one tube per station of multiple corer-sampling patterns.	ID 32-250 μm; Suggested depth: 0-0.5, 0.5-1.0, 1-2, 2-3 cm from multiple (or mega-) corers. Focus on the most abundant identifiable taxa (nematodes and foraminifera)	Workshop specifies which taxa to focus on
4. Microfauna	ATP or other standard assay for following suggested intervals: 0-0.5, 0.5-1.0, 1-2, 2-3, 3-4, 4-5 cm; one tube per station of multiple corer-sampling patterns.	ATP or other standard assay for following suggested intervals: 0-0.5, 0.5-1.0, 1-2, 2-3, 3-4, 4-5 cm; one tube per station of multiple corer-sampling patterns.	No change
5. Nodule fauna: abundance and species structure	From selected nodules taken from the top of box corers.	From selected nodules taken from the top of box corers. Measure biomass Methods of Theil et al (1993)	Workshop requires measurement of biomass and suggests a method

DATA GROUPS AND PARAMETERS	ISBA/7/LTC/1/REV.1	WORKSHOP ON STANDARDIZATION	DIFFERENCES
6. Demersal scavengers	A time–lapse baited camera should be installed at a study area for at least one year to examine: physical dynamics, megafauna's activity and re-suspension events.	Both baited camera and traps should be used. A time–lapse baited camera should be installed at a study area for at least one year to examine: physical dynamics, megafauna's activity and re-suspension events.	Workshop requires traps in addition to cameras
7. Marine mammals	Monitor mammal sightings, recording species and behaviour	Only a monitoring suggestion, not required	Not required by workshop
8. Molecular analysis	Not specified	Require samples collected for DNA analysis	Workshop requires DNA suitable samples for standardization
V. Bioturbation	Rates and depth are to be evaluated by standard advection or direct diffusion models.	The rates and depths to be evaluated using excess Pb-210 profiles from multiple cores.	No change as Pb-210 mentioned in both later
1. Rate of bioturbation	Evaluated from profiles of excess Pb-210 activity from corers.	Evaluated from profiles of excess Pb-210 activity from corers	No change
2. Depth of bioturbation	At least 5 levels per core: 0-0.5, 0.5-1.0, 1-1.5, 1.5-2.5, and 2.5-5 cm	5 levels per core (suggested depths 0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.5 and 2.5-5 cm	No change
VI. Sedimentation	Deployment of moorings with sediment traps: one trap below 2000 m for particulate flux from euphotic zone; and one trap – about 500 m above the seafloor for the flux of materials reaching the seafloor.Sediment traps should be installed for at least a 12-month period and may share the same moorings with current meters.	One set of sediment traps should be deployed on each of two moorings for at least 12 months. One trap on each mooring should be at a depth of about 2000 m to characterize mid-water particle flux, and one trap on each mooring should be ~500 m above the seafloor (and outside of the benthic boundary layer) to evaluate deep particle flux	No change