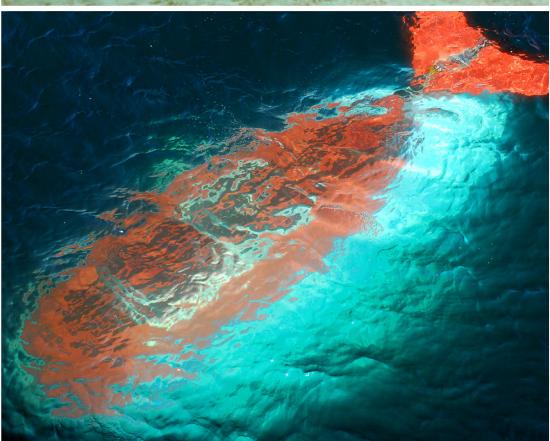




ISA TECHNICAL STUDY NO. 21



Report of ISA Workshop on the Design of “Impact Reference Zones” and “Preservation Reference Zones” in Deep-Sea Mining Contract Areas





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ISA TECHNICAL STUDY NO. 21

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27-29 September 2017
Berlin, Germany

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CONTENTS

Acronyms	4
Background: the Legal Basis for IRZs and PRZs	6
Introduction: Workshop Objectives	14
Statement by Michael W. Lodge, Secretary-General, International Seabed Authority (ISA)	15
Summary of Presentations	17
Session 1: Background	17
Session 2: Impacts	23
Session 3: Previous Zoning Experience	25
Session 4: Monitoring Challenges	30
Session 5: Stakeholder Concerns	32
Summary of the Workshop Discussion on Designing and Monitoring of PRZ and IRZ	34
I. Polymetallic Nodules area	34
II. Polymetallic Sulphides area	35
III. Cobalt-Rich Crusts area	36
List of Participants	39

ACRONYMS

ADCP	Acoustic Doppler Current Profiler
APEI	Area of Particular Environmental Interest
BACI	Before-After-Control-Impact
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
CCZ	Clarion-Clipperton Zone
CIIC	Cook Islands Investment Corp.,
Co	Cobalt
COMRA	China Ocean Mineral Resources Research and Development Association
CRC	Cobalt-Rich Crust
CRZ	Control Reference Zone
CTD	Conductivity-Temperature-Depth
Cu	Copper
DNA	Deoxyribonucleic -Acid
DORD	Deep Ocean Resources Development
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
Fe	Iron
GSR	Global Sea Mineral Resources NV
ICES	International Council for the Exploration of the Sea
IFREMER	Institut français de recherche pour l'exploitation de la mer
IOM	Interoceanmetal Joint Organization
IRZ	Impact Reference Zone
ISA	International Seabed Authority
IUCN	International Union for Conservation of Nature
JOGMEC	Japan Oil, Gas and Metals National Corporation
LTC	Legal and Technical Commission
KIOST	Korea Institute of Ocean Science and Technology
Mn	Manganese
MNRE	Ministry of Natural Resources and Environment of the Russian Federation
Ni	Nickel
NIWA	National Institute of Water and Atmospheric Research
NOAA	National Oceanic and Atmospheric Authority



NORI	Nauru Ocean Resources Inc.
PDF	Portable Document Format
PMN	Polymetallic Nodule
POC	Particulate Organic Carbon
PRA	Preservation Reference Area
PRZ	Preservation Reference Zone
REMP	Regional Environmental Management Plan
SE	Southeast
SEA	Strategic Environmental Impact Assessment
SMS	Seafloor Massive Sulphide Deposit
SRA	Stable Reference Area
SW	Southwest
TOML	Tonga Offshore Mining Limited
UK	The United Kingdom of Great Britain and Northern Ireland
UKSRL	UK Seabed Resources Ltd.,
UNCLOS	United Nations Convention on the Law of the Sea
WOA	World Ocean Assessment
YMG	Yuzhmorgeologiya

BACKGROUND: THE LEGAL BASIS FOR IRZs AND PRZs

Prepared by the ISA Secretariat for the International Seabed Authority Workshop on the Design of Impact Reference Zones (IRZs) and Preservation Reference Zones (PRZs), Berlin, 27-29 September 2017.

1. The purpose of this briefing note is to provide the legal basis for IRZs and PRZs being one item in the toolkit of environmental management and monitoring activities in the Area. The note also highlights some ambiguities and potential lack of consistency in the language and approach adopted to date, in a number of documents.
2. The notion of the use of reference zones and/or areas in the context of seabed mining can be traced to the early 1980s. *The Deep Seabed Hard Minerals Resources Act* (U.S.) provides for the establishment of "stable reference areas...to be used as a reference zone or zones for purposes of resource evaluation and environmental assessment of deep seabed mining in which no mining shall occur".¹ The Act contemplates a negotiation with all nations in establishing international

stable reference areas (SRAs). To advance discussion on SRAs, the National Oceanic and Atmospheric Administration (NOAA) requested the National Research Council's Ocean Policy Committee (OPC) to study the SRA provision, its intent and validity. These discussions further developed the concept of such SRAs and recommended the inclusion of two types of SRAs, namely preservational reference area and impact reference area, and reported on their scientific validity.² These concepts have been incorporated in the United States *Deep Seabed Mining Regulations for Commercial Recovery Permits* under the heading "At-sea monitoring".³

3. In 1992, the draft final report of Special Commission 3 of the Preparatory Commission for ISA and for the International Tribunal for the Law of the Sea, which was charged with preparing draft regulations for the future Authority prior to entry into force of the Convention, proposed draft article 107 relating to "environmental reference areas".⁴ This would require the Council,

1. Sec. 109(2) (f) 30 U.S.C. 1401. This sub-section also stipulates that the subsection shall not be construed as requiring any substantial withdrawal of deep seabed areas from deep seabed mining authorized by this Act.

2 See *Deep Seabed Stable Reference Areas: Report of a Study*, National Academy Press, Washington D.C. (1984). This report is an interesting study, and identifies a number of questions and issues that remain valid today. Available at http://www.gc.noaa.gov/documents/gcil_062711-161244.pdf.

3 §971.603 Deep Seabed Mining Regulations for Commercial Recovery Permits (U.S.), 15 CFR Part 971. See annex for text.

4 Part VIII, Draft regulations on prospecting, exploration and exploitation of PMNs in the Area, Preparatory Commission for the International Seabed Authority and for the International Tribunal for the Law of the Sea, Special Commission 3, New York, 10-21 August 1992, LOS/PCN/SCN.3/1992/CRP.17, 22 July 1992.

based on recommendations of the Legal and Technical Commission (LTC), to set aside parts of areas covered by a plan of work, to be used exclusively as PRZs and IRZs.⁵ The concepts were likely sourced from earlier U.S. regulatory discussions and development.

4. This notion of the function and characteristics of IRZs and PRZs flowed through to the *Regulations on Prospecting and Exploration for Polymetallic Nodules (PMNs) in the Area*⁶ with guidance subsequently provided by the LTC in its *Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area*.⁷
5. Under the 1982 United Nations Convention on the Law of the Sea (UNCLOS), ISA is required to adopt appropriate rules, regulations and procedures prescribing the necessary measures to be taken to ensure the effective protection for the marine environment from harmful effects which may arise from such activities. Such rules, regulations and procedures are designed to prevent, reduce and control pollution and other hazards to the marine environment which have the potential to interfere with the ecological balance of the marine environment, as well as to protect and conserve the natural resources of the Area, preventing damage to the flora and fauna.⁸
6. Under the 1994 Agreement relating to the Implementation of Part XI of the UNCLOS of 10 December 1982, ISA must, prior to the approval of the first plan of work for exploitation, focus on the adoption of rules, regulations and procedures incorporating applicable standards for the protection and preservation the marine environment.⁹
7. Additionally, and in connection with marine environmental protection, the Convention places a number of obligations on the LTC. In particular, the Commission must:¹⁰
 - (a) make recommendations to the Council on the protection of the marine environment, taking into account the views of recognized experts in that field;
 - (b) formulate and submit to the Council the rules, regulations and procedures taking into account all relevant factors including assessments of the environmental implications of activities in the Area;
 - (c) keep such rules, regulations and procedures under review; and
 - (d) make recommendations to the Council regarding the establishment of a monitoring programme to observe, measure, evaluate and analyse, by recognized scientific methods, on a regular basis, the risks or effects of pollution of the marine environment resulting from

5 For this purpose, PRZs were defined as “areas in which no mining shall occur to ensure representative and stable biota of the seabed in order to assess any changes in the flora and fauna of the marine environment”; IRZs as “areas to be used for assessing the effect of each contractor’s activities in the Area on the marine environment and designated in each mining site so as to be: (a) representative of the environmental characteristics of the site; and (b) located in a portion of the site scheduled to be mined early under the contract”.

6 Regulation 31(6). ISBA/19/C/17, 25 July 2013.

7 ISBA/19/LTC/8, 1 March 2013.

8 Article 145, annex III, art. 17(1)(b)(xii) & 17(2)(f).

9 Annex, section 1, para. 5(f).

10 Article 165(e)-(h).

- activities in the Area, ensure that existing regulations are adequate and are complied with and coordinate the implementation of the monitoring programme approved by the Council.
8. States must also endeavour, under the Convention, and as far as reasonably practicable, either directly or through competent international organizations, "to observe, measure, evaluate and analyse, by recognized scientific methods, the risks or effects of pollution of the marine environment".¹¹ This wording is repeated in article 165(h), as set out above.
9. As to rules, regulations and procedures formulated for the protection of the marine environment, and making reference to IRZs and PRZs, the *Regulations on Prospecting and Exploration for PMNs in the Area*, state:
- Contractors, sponsoring States and other interested States or entities shall cooperate with ISA in the establishment and implementation of programmes for monitoring and evaluating the impacts of deep seabed mining on the marine environment. When required by the Council,
- such programmes shall include proposals for areas to be set aside and used exclusively as IRZs and PRZs. "IRZs" mean areas to be used for assessing the effect of activities in the Area on the marine environment and which are representative of the environmental characteristics of the Area. "PRZs" mean areas in which no mining shall occur to ensure representative and stable biota of the seabed in order to assess any changes in the biodiversity of the marine environment.¹²
10. The Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area, provide some further guidance, albeit cursory, on:
- (i) the delineation of impact reference areas and preservation reference areas for the purposes of mining tests,¹³ and
 - (ii) the recommended notification of proposed IRZs and PRZs during the mining tests.¹⁴
11. Section 5 of the standard clauses for exploration contracts targets environmental monitoring by contractors of their activities in the Area. In particular, section 5.4 obliges a contractor to, "in accordance with the regulations, establish and carry out a programme to monitor and report on such effects on the marine

11 Article 204(1).

12 An equivalent regulation is contained in the *Regulations on Prospecting and Exploration for PMSs in the Area* (ISBA/16/A/12/Rev.1) and the *Regulations on Prospecting and Exploration for Cobalt-rich Ferromanganese Crusts in the Area* at (ISBA/18/A/11) at regulation 33(6).

13 Para. 26(d).

14 Para. 53. It is assumed that "zone" and "area" are synonymous in this context.

15 Section 5.5 provides for a reporting obligation on the contractor in relation to the implementation and results of such a monitoring programme. The Recommendations for the guidance of contractors on the content, format and structure of annual reports (ISBA/21/LTC/15) of 4 August 2015 at annex I, para 10(c) requires the contractor to provide "information on the environmental impact of test-mining activities as measured in the IRZs".

- environment" and to cooperate with ISA in the implementation of such monitoring.¹⁵ Section 13.2(b) requires the contractor to, *inter alia*, comply with the applicable obligations created by the provisions of the Convention and the rules, regulations and procedures of ISA. Section 13.2(e) requires the contractor to, "observe, as far as reasonably practicable, any recommendations which may be issued from time to time by the LTC".
12. The current *Draft Regulations on Exploitation of Mineral Resources in the Area*¹⁶ make reference to IRZs and PRZs in annex VII to the draft (content of an environmental management and monitoring plan) in terms of location and planned monitoring of such zones, and not within a regulatory text. Annex VII requires expert review. There is no reference to IRZs and PRZs within an environmental assessment context in annex V to the draft (Environmental Impact Statement Template) which has been subject to expert preparation.
13. Neither the Convention nor the Agreement makes specific reference to either the IRZ or PRZ concepts. Their legitimacy (depending on their specific purpose and objective) flows from the adoption of appropriate rules, regulations and procedures, which should reflect applicable standards, relating to monitoring programmes.
14. As part of best environmental management practice, environmental monitoring will be an essential component to: validate the assessments made in an environmental impact statement; contribute to an evaluation of mitigation strategies and management responses as new information and knowledge come to light, and ensure compliance with the terms and conditions of a contract. The significance of a monitoring programme in assessing the effects of activities is recognised by articles 165(h) and 204(1) of the Convention.
15. To this end, IRZs and PRZs have been incorporated into the respective sets of exploration regulations as an integral part of programmes for monitoring and evaluating the impacts of deep seabed mining. The first part of regulation 31(6) of the PMN exploration regulations requires various actors to cooperate in the establishment and implementation of programmes for monitoring.¹⁷ The second part of the regulation specifies that monitoring programmes must include proposals for the designation of IRZs (to be used for assessing the effect of activities) and PRZs (to assess any changes in the biodiversity). IRZs and PRZs are, thus, explicitly associated with the regulations on monitoring activities, but only "where required by the Council".
16. The stipulation in regulation 31(6) states that IRZs and PRZs will only be part of monitoring programme proposals "where required by the Council" can be traced back to the development of the sulphides and crusts regulations. The language originally adopted in the nodules regulations provided for the contractor to propose IRZs and PRZs only where it applies for exploitation rights.¹⁸ In the context of sulphides and crusts, the obligation to propose these set-aside areas (an obligation on all contractors) was brought forward to the exploration phase, and

16 ISBA/23/LTC/CRP.3*, 8 August 2017. See also ISBA/25/C/WP.1, 25 March 2019.

17 The language fulfils the requirements of article 204(1).

18 Draft regulation 31(7), Draft Regulations on Prospecting and Exploration for PMNs in the Area ISBA/6/C/8. Adopted by the Council on 13 July 2000 (ISBA/6/C/12).

the wording "where required by the [Council]" added. This was considered justified by the lack of knowledge of the characteristics of the marine environment at potential exploration sites for sulphides and crusts.¹⁹ It was only in 2013, at ISA's 19th session, that the nodule regulations were amended in line with the sulphides and crust regulations to require the consideration of IRZs and PRZs at an earlier phase of activities in the Area.²⁰

17. Notwithstanding the regulations, the Commission's *Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area* (see para. 11 above) appear in some situations to bring the requirement to delineate IRZs and PRZs back to even earlier phases of exploration activities. However, the notion of IRZs and PRZs is not fully embodied in a comprehensive manner in the text and recommended requirements of the recommendations; that is, they appear isolated from the Commission's main recommendations for environmental assessment, suggesting that neither their objective(s) nor functioning is fully understood.
18. The language adopted in regulation 31(6)²¹ suggests that, in addition to requiring monitoring programmes at the project level, this regulatory provision has the potential to operate

at a wider scale even beyond contract areas, provided such programmes are approved by the Council on the basis of recommendations by the Commission. Consequently, it is arguable that there exists the possibility for the Council to require designation of the respective zones outside contract areas through cooperation with the relevant actors contemplated by paragraph 31 (6) of the Regulation. This may be necessary where mining areas are adjacent to third party contract areas or areas remaining vested in ISA.

19. In terms of its contractual obligations, a contractor must "observe, as far as reasonably practicable, any recommendations which may be issued from time to time by the LTC" (see para. 12 above). It is accepted that it would be challenging currently to observe the recommendations for IRZs and PRZs given the lack of criteria for their development; hence the need for a workshop to develop agreed criteria for the design of such zones. Equally, and in the context of the exploration regulations, it is important to note that a contractor's obligation in observing the recommendations applies only as *far as reasonably practicable*. That is, there needs to be a balance between the effort and cost²² associated with monitoring programmes. The design and implementation of IRZs and PRZs, in particular their monitoring objective, spatial and temporal extent, and associated monitoring programmes, should balance the needs and cost-

¹⁹ Analysis of the draft regulations on prospecting and exploration for PMSs and cobalt-rich ferromanganese crusts in the Area. Part II: Provisions relating to the protection of the marine environment, ISBA/12/C/2 PART II, 24 May 2006.

²⁰ Decision of the Council of the International Seabed Authority relating to amendments to the Regulations on Prospecting and Exploration for PMNs in the Area and related matters, ISBA/19/C/17, 22 July 2013.

²¹ It is interesting to note that the regulations on prospecting and exploration for PMNs in the Area, adopted by the Assembly on 4 October 2000 (ISBA/6/A/18) provided at regulation 31(7), that IRZs means "areas to be used for assessing the effect of each contractor's activities in the Area".

²² The Western Australia Environmental Protection Act 1986 defines practicable as meaning reasonably practicable having regard to, among other things, local conditions and circumstances (including costs) and to the current state of technical knowledge.

- effectiveness of such monitoring, including obligations arising under a closure plan. Consequently, contractors should be provided with reasonable parameters within which to adopt reference zones, but the flexibility to adjust their monitoring programmes and reference zones accordingly.
20. In the course of researching the content for this paper, the development of IRZs and PRZs has led to some confusion and ambiguity, particularly in connection with the role and purpose of PRZs or preservation reference areas (PRAs).
21. Early discussions stemming from the U.S. legislation, indicate that the concept of a PRA was akin to ISA's concept of an Area of Particular Environmental Interest (APEI), as formulated in the Environmental Management Plan for the Clarion-Clipperton Zone (CCZ). Indeed, a 1984 report²³ contemplated a need for a set of nine characteristic environments, with each containing one provisional PRA. Furthermore, an academic article written in 2008 by expert participants in the workshop to *Design Marine Protected Areas for Seamounts and the Abyssal Nodule Province in Pacific High Seas*, Oct 23-26, 2007, University of Hawaii at Manoa, observed that "the setup of a regional system of PRAs will remove the burden of designing their own PRAs from individual contractors, and will initiate conservation management of the CCZ as a whole, an approach necessitated by the space and time scales of expected nodule mining impacts."²⁴ It was suggested that the workshop would consider whether APEIs planned at regional scale, with associated monitoring mechanisms, could be used in appropriate circumstances to modify the requirement for smaller-scale PRAs.
22. There remains a concern, given the historical development of PRZs, ambiguous language, and lack of clear objectives and operational needs that some stakeholders will wish to attach a degree of permanency to PRZs that is not implicit from their monitoring function. For example, they may be seen by some stakeholders as *de facto* marine protection areas within a contract area, designed to serve the function of providing a potential source of representative biodiversity to repopulate mined areas. This, however, is the principal role and function of APEIs, acting as "bank accounts" for regional biodiversity. The use of the word "preservation" could inevitably drive a preservationist approach toward conservation measures.
23. The US regulations provide for the study of two types of areas, including an "interim preservational reference area located in a portion of a permit area tentatively determined to be non-mineable, *not to be scheduled for mining during the commercial recovery plan, or to be scheduled for mining late in the plan*". The language of this regulation provides for the necessary degree of permanence during the term of the recovery plan.
24. The wording of regulations dealing with IRZs and PRZs must be carefully considered to ensure that it is clearly understood that their use and function do not go beyond their primary purpose of serving as monitoring reference/control sites. For example, in the context of the environmental

23 See note 2.

24 Smith CR, Gaines S, Friedlander A et al., "Preservation Reference Areas for Nodule Mining in the Clarion Clipperton Zone: Rationale and Recommendations to the International Seabed Authority", February 2008, <http://bit.ly/2wH2pHu>.

management plan for the CCZ, it is stated that one of the management objectives for the contract areas is that:

Contractors will provide in their environmental management plans the designation of the required impact and PRZs for the primary purposes of ensuring preservation and facilitating monitoring of biological communities impacted by mining activities.²⁵

Here, it is suggested that the language of "preservation" is not helpful in terms of the intended purpose of the IRZ and PRZ, and fails to convey that a PRZ is intended to be a control area for comparison against an impact zone.

25. There are other examples where the terminology of IRZs and PRZs has been used by the scientific community to support "set-aside" areas for the purposes of recruitment and re-establishment of biota.²⁶ That said, the Managing Impacts of Deep Sea Research (MIDAS) Project concluded that: "the need to include multiple PRZs and IRZs within mining claims, as well as larger scale no-mining "areas of particular environmental interest" across nodule fields",²⁷ implies a recognition that PRZs are not intended to provide the degree of permanence attached to regional scale APEIs.

26. Whether additional set-aside areas (field-specific APEIs) will be required for conservation measures, including those for recolonization purposes, is a separate discussion, and potentially resource specific. In the context of PMNs, and the CCZ, it should be noted that under an exploitation contract, a contract area will be equivalent to a current exploration area (+- 75 000 km²). Only some 10-15 per cent of a contract area will likely be identifiable as mineable areas, mined within a foreseeable time frame (+- 30 years). Consequently, areas within a contract area will, by default, be "set-aside" with any consequential conservation benefits, including connectivity channels. The spatial distribution of these areas will be evident from the mining plan. There remains, however, a public perception of "vast" mining areas, on an unprecedented scale and magnitude, and it is important to recognize that this will simply not be the case.

27. There is a need for clarity and harmonization in the terminology used to date. For example, given that the words "zone(s)" and "areas" appear to be used interchangeably, is there an intended distinction between the use of the word "zone(s)" and that of "area(s)", and indeed that of "site(s)"²⁸? Zones and areas imply a scale in terms of size. Arguably, larger areas would require more resources and time to monitor. The size of the IRZs and PRZs

25 Para 41(c), Environmental Management Plan for the Clarion-Clipperton Zone, ISBA/17/LTC/7, 13 July 2011. See also Review of the implementation of the environmental management plan for the Clarion-Clipperton Fracture Zone, ISBA/22/LTC/12, 17 June 2016 at para. 10(h) repeating the same text.

26 Boschen RE et al, Mining of deep-sea seafloor massive sulphides: A review of the deposits, their benthic communities, impacts from mining, regulatory frameworks and management strategies, 2013 (84) Ocean & Coastal Management 54-67.

27 MIDAS, Report on the implications of MIDAS results for policy makers with recommendations for future regulations to be adopted by the EU and the ISA, Deliverable 9.6, WP 9, 16 December 2016 at 1.3.

28 ISBA/19/LTC/8 at para. 26(d) states: The reference site will be important in identifying natural variations in environmental conditions. Which or what "reference site"? A reference site within an IRZ and / or PRZ, i.e. a monitoring station(s)?

must be proportionate to their needs, and provide a cost-effective solution. Equally, where it is considered that multiple zones or areas are necessary for statistically robust sampling needs, technology and cost should also be factored in to any discussion.

28. There is currently an inconsistency between the regulations and the Commission's recommendations for the guidance of contractors. The Council has yet to determine the requirement for IRZs and PRZs, whereas the Commission's recommendations are suggesting the delineation of IRZs and PRZs at a much earlier stage than envisaged by the regulations. It may be assumed that as soon as the necessary design and implementation criteria for IRZs and PRZs are determined, the Commission will make recommendations to the Council on the basis of recognized scientific methods, appropriate monitoring programmes, including fit-for-purpose reference areas. The development of such programmes should also reflect technical and economic constraints.²⁹ Equally, recommendations should provide general parameters and guidance for such programmes, and related monitoring tools, thus offering a degree of flexibility to contractors to suit project-specific needs.
29. There is also a danger of "re-inventing the wheel". In a monitoring context, there are plenty of examples, for instance, from the UK dredging industry, and

oil and gas regimes,³⁰ as to the implementation of environmental monitoring programmes, and the need for impact reference sites and preservation reference sites, and their respective purposes, design and implementation.

30. As analysed above, the primary function served by IRZs and PRZs is as part of a monitoring programme. Their spatial and temporal extent should be proportionate to that function. Their legitimacy is based on the recognition of the need for monitoring programmes in accordance with the Convention, and through the use of recognized scientific methods for such monitoring.
31. It is recommended that prior to any discussion on defining selection and implementation criteria,³¹ the clear objectives and rationale for the respective zones, and their association and relationship with APEIs, are discussed and properly formulated. While one of the aims of this workshop was to ensure a consistent application of IRZ and PRZ concepts, the concepts themselves could also benefit from further elaboration and clarification. Since IRZs and PRZs are essentially monitoring tools, the requirements of a monitoring programme should drive the appropriate monitoring tools, and be based on existing best practice within parallel industries, adjusted for unique needs of the Area.

29 This is supported by the language of article 204(1).

30 E.g. Guidelines for offshore environmental monitoring: The petroleum sector on the Norwegian Continental Shelf, October 2011.

31 See Review of the implementation of the environmental management plan for the Clarion-Clipperton Fracture Zone, ISBA/22/LTC/12, 17 June 2016 at para. 23 setting out the aims of the workshop on developing guidelines for contractors to use in setting up IRZs and PRZs.

INTRODUCTION: WORKSHOP OBJECTIVES

With the background note provided in the previous section, the workshop on the Design of "Impact Reference Zones" and "Preservation Reference Zones" in Deep-Sea Mining Contract Areas was convened by ISA in Berlin, 27-29 September 2017. The workshop focused on setting out a replicable and transparent procedure for establishing minimum requirements to:



Describe, categorise and map the contract areas



Select impact and preservation reference zones



Deliver baseline information on the selected zones to ISA



Perform the assessment of impacts



Perform monitoring from initiation of IRZs and PRZs designations, including post-mining monitoring as part of closure plans



Guarantee public accessibility of environmental data



Submit reports on the monitoring activities in a timely manner

STATEMENT BY MICHAEL W. LODGE, SECRETARY-GENERAL, INTERNATIONAL SEABED AUTHORITY (ISA)

I would like to welcome all participants to Berlin and thank you for giving up your time to contribute to ISA's work.

I am sure that to many outside observers, the subject matter of this workshop appears to be highly esoteric but it seems to me that it is a necessary step to resolve a problem that has been pre-occupying us for some time and to allow us to move forward in preparation for deep seabed mining. It was, in fact, identified as a recommended priority action in the last review by the LTC of the CCZ EMP in 2016. So, I am very pleased that we have been able to convene the workshop before the end of 2017 and I sincerely hope that we will be able to produce clear recommendations at the end of the three days.

The concept of IRZs and PRZs as effective tools for environmental monitoring has been around for a long time. The background is well covered in a note prepared by ISA's legal office which has been circulated and which I recommend that you read (see background note at the beginning of this report). It makes it clear that, over time, the concept has become somewhat divorced from what was originally intended. Furthermore, what is currently contained in the recommendations issued by the LTC is possibly more confusing than it needs to be. The current recommendations also



do not reflect the reality of the way in which exploration is being conducted and likely scenarios for exploitation and do not provide contractors with a clear way forward.

We need to bear in mind that IRZs and PRZs are tools to be used as part of an environmental monitoring programme. They are not marine protected areas and they are not intended as vehicles to meet broader conservation objectives. Their legitimacy flows from the recognition of a need for environmental monitoring programmes in accordance with UNCLOS and ISA's Regulations, and through the use of recognized scientific methods for such monitoring. Their spatial and temporal extent should therefore be proportionate to their true function.

I expect that by the time you get into working groups you will have a very specific list of questions to consider, but this morning I just want to make a few general points to help frame the discussions.

First, we need to make sure that we are not reinventing the wheel. There is already plenty of good practice from the oil and gas, dredging and mining industry that can be used, and I would particularly point you towards the UK and Norwegian legislation on offshore environmental monitoring. In many ways, National Oceanic and Atmospheric Administration's (NOAA) programmatic environmental impact statement for deep sea mining of 1982 remains an excellent starting point.

Second, we need to consider what is practical and feasible in terms of the anticipated scale and magnitude of actual mining operations. Whilst we may see multiple mining operations decades from now, it is likely that we will start with only one or two operations. Certainly, as far as PMNs are concerned, only a small proportion of current contract areas is likely to be mined within the foreseeable future. The mining plan, will, therefore, be a very important document for purposes of environmental management. For example, to help identify opportunities to establish connectivity channels between unmined areas. In this regard, I would like to emphasize the importance of contractors helping all of us to understand the likely magnitude and scale of different mining scenarios as well as telling us what is realistically achievable in practice and commercially as far as monitoring is concerned.

Third, we should not be afraid of going back to basics. There is a great danger of letting the tail wag the dog by looking at the environmental management tools in the current recommendations and trying

to make them fit. We cannot change the Convention, or the Regulations, but we can change the recommendations. So, we should approach the problem by looking at what we need to achieve, and then considering what the best methods are to deliver that result.

Fourth, and in a similar context, it is important to give clear and consistent guidance to contractors. The current recommendations are not clear either in terms of the objectives and criteria for IRZs and PRZs or in terms of their timing. I think there is a particular problem in terms of so-called 'test mining', where we are not speaking the same language. It is just not realistic to expect full-scale integrated tests prior to commercial operations. Contractors need to tell us what is intended in terms of testing of equipment and components, as well as timing, and how that testing can contribute to understanding environmental impacts. Monitoring requirements should balance scientific needs and cost effectiveness. The value of collaboration should also be considered.

The participation of both the scientific community and the contractors in this work is essential. Indeed, increased exploration activity is essential to better understanding the deep-sea environment. I see nothing incompatible therefore, in proceeding both to develop the regulatory environment and at the same time develop regional environment management plans (REMPs). In this regard, the Assembly also emphasized that the highest importance must be attached to the implementation of ISA's mandate to promote and coordinate marine scientific research in the Area and encouraged me to consider how to engage more effectively with the scientific community and deep-sea science projects and initiatives related to the Area.

SUMMARY OF PRESENTATIONS³²

Session 1: Background

1. Historical and Legal Background of IRZ and PRZ

*Laleta Davis Mattis, Attorney-at-Law/
Environmental Legal Consultant*

The protection of the marine environment beyond the areas of national jurisdiction has had a long history of legal discourse and practical application. The Law of the Sea Convention encapsulates a coalescence of ideas, principles and practices that are effectively designed to sustainably manage the global marine space and its associated ecosystems.

The crafters of the Convention were very careful in their articulation of the roles of States with respect to the protection of the marine environment generally and in particular, the management of the marine environment in the specified maritime zones.

The Law of the Sea Convention

The Law of the Sea Convention dubbed 'the constitution of the oceans' is no trite nomenclature for constitutions globally form the framework within which other laws are constituted, formulated and enforced. Constitutional provisions determine rights, responsibilities and obligations and represent the standard against which

all other legal provisions are measured. They determine the veracity and validity of enabling laws and are the enablers themselves. The Law of the Sea Convention with its comprehensive, multifaceted approach to oceans management is not only an enabler but provides such wide discretion to facilitate new and emerging concepts and scientific tools to ensure the implementation of its precepts and policies.

In examining the genesis of terms and concepts "IRZs" and "PRZs", regard must be given for the terms of the Convention itself and their intended application. The following discourse will examine the legal origins and references within the general and specific framework of the Convention.

At the onset, the presenter concluded that the incorporation of the concepts "IRZs" and "PRZs" were legitimate, and necessary and fully supported by the Convention in its purest form without the employment of any scientific elaboration to justify their use and application.

Genesis of the Concepts

The concepts "IRZs" and "PRZs" may be creations of activities associated with deep-seabed mining, but the nature of the concept may be traced as far back as Principle 21 of the Stockholm Declaration which states:

32 Copies of the workshop presentations are available at: <https://www.isa.org.jm/workshop/workshop-design-impact-reference-zones-and-preservation-reference-zones-area>.

States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

The provision uses the conjunction 'or', and arguably includes activities conducted by States that are under their control but not necessarily confined to areas within their national boundaries. The scope of the principle has been expanded to include jurisdiction not only over resources in its own territory, EEZ or continental shelf but also a State's competence to regulate activities conducted by its nationals over areas beyond national jurisdiction. Whereas former formulations were restricted to *inter se* relations, its present elaboration protects the environment of international areas as well as making it *erga omnes*. Principle 2 of the Rio Declaration is the *ipsissima verba* of the Stockholm provision.

The PRZ[s] should be carefully located and large enough so as not to be affected by the natural variations of local environmental conditions. The zone[s] should have species composition comparable to that of the test mining area[s]. The PRZs should be located upstream of the test mining area[s]. The preservation zone[s] should be outside of test mining area[s] and areas influenced by the plume."

A requirement of Regulation 31, Part V of the *Regulations on Prospecting*

and Exploration for PMNs in the Area includes proposals for areas to be set aside and used exclusively as IRZs, and the preservation of these zones. A similar provision is replicated in the *Regulations on Prospecting and Exploration for PMSs and Cobalt-rich Crusts*:

If a contractor applies for exploitation rights, it shall propose areas to be set aside and used exclusively as IRZs and PRZs. "IRZs" mean areas to be used for assessing the effect of each contractor's activities in the Area of the marine environment and which are representative of the environmental characteristics of the Area. "PRZs" mean areas in which no mining shall occur to ensure representative and stable biota of the seabed in order to assess any changes in the flora and fauna of the marine environment.

Thus, ISA guidelines stipulate that prior to test mining and mining, PRZs must be erected in areas beyond any potential influences of mining. The PRZs should be designed (as a whole) to sustainably preserve representative biota for all mining claim areas in terms of species composition and biodiversity. Thus, the full range of habitat and community types potentially found in mining claim areas must be represented in PRZs, and the scale of PRZs must be large that these community types are "stable", i.e., sustainable.

IRZs and PRZs are currently referred to in the exploration regulations for all mineral resources (ISBA/19/C/17, ISBA/16/A/12/Rev.1 & ISBA/18/A/11) and the recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area (ISBA/19/LTC/8).

2. Species Composition and Taxonomy: Critical Knowledge in Considerations of Impact Reference Zones (IRZs) and Preservation Reference Zones (PRZs).

Judith Gobin & Diva Amon, University of the West Indies, St. Augustine, Trinidad and Tobago, West Indies.

For effective IRZs and PRZs, we need to know the species composition (taxonomy) for the different habitats - what fauna inhabit the areas to be mined? What fauna inhabit the reference areas? In this respect, taxonomic units are the fundamental units of biology (as the elements in chemistry). If we cannot identify and distinguish species, then we will never fully understand the biology.

Fauna differ among habitats. The three or four key heterogeneous habitats which are important reservoirs of mineral deposits all support unique assemblages described below.

- **CRCs** found on seamounts, are highly heterogeneous in terms of habitat. It's not just about protecting the fauna on the crust deposits themselves, but also the fauna from the mosaic of habitats that could be indirectly impacted (mining vehicle tracks along the seafloor, plumes, etc.).
- **PMNs** found in the CCZ, in the north-eastern equatorial Pacific, is of great commercial interest. Nodules themselves represent important (micro-)habitats for sessile biota (e.g. xenophyophores, antipatharian corals, sponges), as well as several meiofaunal and microbial taxa found inside the sediment-filled nodule crevices. More than half of megafaunal species in the CCZ depend on nodules as a hard substrate. Nodule areas seem to contain higher densities of mobile megafauna compared to those lacking nodules.

- **PMSs** habitats include hydrothermal vent sites, sites of endemic species (found nowhere else on earth).
- **Inactive Vent sites** such as the inactive vent chimney within the Proteus 1 SMS deposit, approximately 1440m depth, on Rumble II West Seamount, Kermadec Arc. It features *Solenosmilia variabilis* scleractinian corals, *brisigid* seastars and *Dermechinus horridus* sea urchins. These species, together, were part of a 'unique' assemblage only found on inactive chimneys. It should also be noted that the *S. variabilis* corals in this image are thought to be approximately 160 years old, so that recovery at these sites, if it occurs post-mining, is thought to be very slow indeed (Boschen et al. 2016b).

It is necessary to appreciate the different scales at which heterogeneity exists in deep-sea environments - from cm to metres, to 100m, to km, to hundreds of kms. Organisms respond differently, at different scales. There are also differences within each heterogeneous habitat: substrate type, geological origins, physico-chemical, geochemistry, topography, activity levels and so on. Mining operations might impact different areas differently. The species composition and diversity that might be affected by the plume, for example, is not necessarily the same as by the mining itself.

The presentation concluded with the following points.

- Environmental objectives for the IRZs and PRZs must directly inform the sampling methodology.
- It is imperative that species composition (and their taxonomy) are known in order to design effective IRZs and PRZs.
- A series of IRZs and PRZs (a network) may be needed to be ecologically relevant. The protected area network concept is more than just a single IRZ/ PRZ designated per contractor (or within each contract area).
- IRZ/PRZs designation must be seen

- as part of a coherent framework accounting for: existing APEIs, heterogeneity (multiple scales) and connectivity, etc.
- IRZ and PRZ placement must be part of a strategic environmental plan

3. Ecosystem Characteristics of Abyssal Nodule Fields, Especially the Clarion Clipperton Zone, Relevant to IRZs and PRZs

Craig R. Smith, Diva Amon, Iris Altamira, Andreas Thurnherr, with input from many others; University of Hawai'i at Manoa, Honolulu, HI, USA

The presentation covered (1) physical characteristics, (2) ecological characteristics and (3) regional patterns of abyssal nodule regions focusing on the CCZ. Physically, the CCZ is characterized by substantial heterogeneity on scales of 10-100km, with a background of rolling ridges and troughs (vertical scales of 100s of meters), punctuated by volcanic seamounts, outcrops and transform faults. The seafloor (located away from seamounts and transform faults) is comprised mostly of silt-clay sediments with heterogeneous occurrence of nodules over scales of 1m-10km; there can also be substantial vertical sediment heterogeneity ("soupy" surface, backfilled burrows, etc.) on scales of 5-10cm. Nodule abundance also varies dramatically (0 to less than 50% seafloor cover) on scales of meters to 100s of kms. In conclusion, IRZs will need to address impacts over large scales (10-100km) to be physically representative, IRZs and PRZs must integrate (and replicate) this full physical heterogeneity over scales of 1m-100km.

Hydrodynamically, the CCZ abyssal seafloor is characterized by low energy and stable; maximum instantaneous velocities (more than 20 cm/s) do not exceed critical-erosion velocities for the sediments. Over time scales of weeks, flow can be

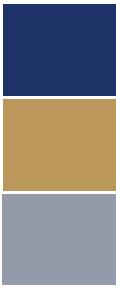
in any direction dominated by mesoscale eddies; over months and up to one to two years, mean advection is weak and larval and plume transport is dominated by eddy diffusion. In conclusion, PRZs will need buffer zones of over 50-100km on all sides; IRZs will need to address impacts over large scales (10-100km).

Ecologically, benthic communities in nodule fields are very food limited, stable and characterized by very low resilience and rates of recovery following physical disturbance. Nodules have a distinct, obligate fauna. In conclusion, to evaluate recovery rates and processes, IRZs and PRZs will need to be monitored for decades.

The most fully studied CCZ communities have high local diversity in all benthic size classes, microbes to megafauna, typically with a very long list of rare and undescribed species. Some of these CCZ communities have extraordinary benthic faunal diversity by global standards. In conclusion, high diversity and long list of rare species will require intensive sampling to monitor changes/recovery of much of diversity.

Regionally, abyssal ecosystem structure/function is correlated with annual particulate organic carbon (POC) flux and thus varies along and across CCZ. Over scales of ~100km, macrofaunal and megafaunal appear be similar. On scales of 1000km, community structure, even the occurrence of family-level taxa vary with more than two times difference in POC flux to the CCZ floor. In conclusion, sampling intensity, design, and even "indicator species", for monitoring IRZs/PRZs will need to vary across the CCZ due to differences in faunal abundance and community structure.

Species range show positive range-abundance relationships across benthic size classes (prokaryotes to megafauna); this may be due to under-sampling and/



or restricted ranges in rare species. In conclusion, rare species constituting most of diversity and possibly with highest extinction risk (i.e., with narrow ranges) will be most difficult to monitor. Common species may be generalists with wide distributions and poor indicators of extinction risk for most of the biodiversity in the CCZ.

4. Characteristics of Vent Ecosystems Relevant to the Design of Reference Zones

Anna Metaxas, Department of Oceanography, Dalhousie University, Halifax, Canada

Vent ecosystems can support high biomass because they are fueled by microbes which use the hydrothermal fluid to derive energy. Most organisms live on vents with some exceptions. These ecosystems are spatially constrained and most vent fields cover areas of 10s-100s sq. m. Most of the species that live in and around vents show complex life cycles: different stages look different and have different levels of motility. In the case of complex life cycles with different stages, the adults are sessile, and they release propagules/larvae that are planktonic. Larvae are very small and thus poor swimmers. They are, therefore, transported by currents. They spend

months in the plankton and when they are mature enough they find a place to settle and grow. Vent ecosystems are typically characterized by the adult populations. Very different communities can occur on scales of ocean basins, ridge segments and individual vents fields (10s-1000s km). How much these communities evolve, over time, is related to the level of disturbance they experience which, in turn, is related in part to the spreading rate. Within a vent field, patchworks of biological assemblages emerge on scales of metres. The distribution of the patches depends on the immediate chemical and physical environment. Any changes in distribution are, firstly, the result of changes in the environment. The magnitude of change varies from segment to segment and also, within a segment, with frequency of disturbance. For example, at Endeavour faunal changes can be seen over one to three years, whereas at Lucky Strike very little, if any, change occurred over 14 years. It can be assumed that the potential of community recovery from a large perturbation will depend on their exposure (and likely adaptation) to natural disturbance. We only have data from four studies on recovery potential, and they were all done at segments with intermediate spreading rates. For species such as those that live on vents, the only possible mechanism for recolonization

of a disturbed habitat is through larval dispersal because vent habitats are not continuous and larvae are the only stage that is mobile. How far larvae will travel depends on how long they survive, how fast the current is moving and how the topography of the seafloor steers the water. Models combine all this information to predict where larvae will disperse. An example on dispersal of mussels on the Mid Atlantic Ridge suggested that larvae will disperse only as far as 100km. Once the larvae are mature enough, they seek a suitable place to settle on, grow and turn into reproductive adults. Larvae are quite selective and will only settle at locations with the right chemistry, seafloor type and species composition.

Processes that occur at all life stages need to be considered when designing reference zones. The size of each unit should ensure coverage of all habitat types, population viability, and self-recruitment. Site specific baseline data on the distribution of habitats is required. The number of units must ensure adequate replication of all represented habitats and must include multiple populations to ensure diversity and resilience. Site specific baseline data on the variability in abundance and diversity can be used to determine what constitutes adequate replication using standard statistical approaches. Baseline data on ocean circulation will assist with the siting of the zones. The maximum distance between units will be determined based on larval dispersal; based on the literature should be 100km. These units will need to be monitored for sufficiently long periods to capture recovery which may range from 10-100 years, depending on rate of disturbance. Site specific baseline data on the natural rate of community change is required to determine this period. Most importantly, the design must create a network of well-connected units.

5. Cobalt-rich Crusts: Ecosystem

Characteristics of Seamounts Relevant to Zone Design

Malcolm Clark, National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand

In this talk, background to seamount characteristics (resource topography and geology), seamount biodiversity, and seamount mining is given briefly to set the context for focusing on key aspects of spatial (and to a lesser extent temporal) environmental scale and variability relevant to providing guidance on IRZ and PRZ design have to be considered as follows:

Topography and geology comprise highly diverse environments, with substrate and small-scale topographic features (valleys, ridges, peaks, slopes) being important. These operate at scales of 10-100s m. It is unclear if crust composition affects biodiversity.

Oceanography is highly variable around seamounts, depending on whether isolated, in clusters, and on their height and shape. Turbulence, up-welling, down-welling, tidal flows, Taylor columns, temperature variability, internal waves of variable speed can all affect sediment and faunal composition and distribution. Detailed knowledge of oceanographic characteristics is critical for plume modelling, and hence how to plan the size of zones, and buffering required for plume rather than direct effects.

Faunal composition and distribution: Faunal communities can differ substantially between seamounts, and within seamounts. There are few studies specifically on cobalt-rich crusts (CRC) seamounts (rather than seamounts per se), but it is clear that there is high variability on small scales among seamount communities, and even

within seamounts. An important element for planning is an awareness that distance separation is not a good predictor of community similarity; this drops off rapidly with distance, and then evens out. Key drivers of depth and substrate need to be controlled in IRZ-PRZ design. The inherent variability implies multiple IRZs and PRZs may be required to include representative and stable fauna.

Connectivity: While larval dispersal can be considerable, reproductive mode and dispersal distances cannot be inferred. Seamount corals demonstrate a contrast between highly localised and highly dispersed population structures. Knowledge of source-sink dynamics at scales of an individual seamount are unclear, with most studies indicating that this occurs at 10s-100s km distances.

Recovery: Many dominant taxa on seamounts are long-living and slow-growing. This means that any recovery will be slow, and it has not yet been demonstrated in deep-sea fisheries studies.

Session 2: Impacts

6. Potential Impacts of Mining on Deep-sea Benthic Habitats, with a Special Focus on Abyssal Nodule Habitats

Andrew K. Sweetman, The Lyell Centre for Earth and Marine Science and Technology, Heriot-Watt University, Edinburgh, UK

Increasing interest in deep-seabed mining has raised many questions surrounding its potential environmental impacts in areas where abundant seafloor massive sulphides (SMS) crust and PMN resources are found. The effects from deep-sea mining on seafloor habitats are likely to be case-specific, but will include removal of habitat and the associated loss of

organisms and biodiversity, smothering of the seafloor by sedimentation, sediment excavation by collection devices and eco-toxicological effects. Over the past few years, a number of targeted research projects focusing on hydrothermal vent, seamount and abyssal seafloor ecosystems have attempted to explore the impacts of habitat removal, sedimentation, sediment excavation and eco-toxicological stressors in deep-sea habitats/ on deep-sea organisms.

The presentation provided a synopsis of some of these results, and discussed the potential impacts of deep-sea mining on the seafloor, with a specific focus on abyssal nodule habitats.

7. Biogeographic Remarks and Spatial Scales

Andrey Gebruk, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences

Deep-sea mineral resources include manganese nodules, Co-rich Fe-Mn crusts and SMS. They occur in three different deep-sea environments: abyssal plains, seamounts and mid-ocean ridges correspondingly. Abyssal plains lie within the abyssal bathyal zone (3,500-6,500m depths), minable crusts and SMS occur mainly within the bathyal zone (800-3500m). Global biogeographic patterns in the abyssal and bathyal are different. Based on the distribution of species, the CCZ (with most of the manganese nodule resources) lies within a single Central-Pacific biogeographic province. In the bathyal zone, important faunistic boundaries (of non-hydrothermal vent fauna) stretch along mid-ocean ridges, where most SMS occur. The region of the tropical West Pacific is an area of most interest for the mining of crusts. In global biogeography this region is close to the hotspot of species richness in the world ocean, where the ratio of endemic

species can be elevated. Assessing species composition and the level of species endemism in areas with potential for mining is essential for environmental management planning.

The scale of deep-sea habitats where the three types of resources occur differs significantly. Abyssal plain habitats extend over 100s and 1,000s km. Flat-topped guyots with cobalt crusts vary in size from 10-100s km. SMS deposits (at inactive sites) occur at hydrothermal vent fields ranging in size from ~100m to first kilometres across. The scale of area for potential mining will be critical for the design of PRZ and IRZ. Also critical will be the size of the sediment plume generated by mining. At present there is no clear understanding of the plume scale. Estimations vary from 10-50km. In light of the scale of a plume and the scale of the corresponding habitats, locating PRZs on mid-ocean ridges which comply with the main concept principles can be problematic. Vent fields vary greatly in size and occur in a wide bathymetric and topographic range. Locating a habitat similar to the potentially mined one with a similar suite of species will be a challenge.

8. Connectivity using DNA – the Basics

Greg Rouse, Scripps Institution of Oceanography, San Diego, California, USA

The presentation covered the following elements:

- What are species? Not easy to define in a consistent way across the diversity of life.
- Evolutionary trees (phylogenies) versus populations; a matter of scale.
- DNA barcoding advantages and pitfalls.
- DNA barcoding 'gaps' and delimiting species.
- Biogeography versus phylogeography;

also a matter of scale.

- Visualizing phylogenies versus populations equal to trees versus networks.
- Some examples from deep sea organisms.
- Scaling up the data acquisition beyond DNA barcodes. Is it necessary?

9. A Systematic and Adaptable Design for Area-based Management of Mid-ocean Ridges in the Context of Deep-Sea Mining

Dunn, D.C., C.L. Van Dover, R.J. Etter, C.R. Smith, L.A. Levin, T. Morato, A. Colaço, A.C. Dale, A.V. Gebruk, K.M. Gjerde, P.N. Halpin, K.L. Howell, D. Johnson, J.A.A. Perez, M.C. Ribeiro, H. Stuckas, P. Weaver and the SEMPIA workshop participants.

Ecosystem structure and function in the deep sea remain poorly understood, yet large seafloor areas are being approved for exploration of seafloor minerals. Representative networks of no-mining areas is the key to regional management strategies to conserve deep-sea ecosystems in the face of mining. Ideally, such networks would systematically consider spatially explicit information on biodiversity, biogeography, ecosystem function/services and climate-change stressors, among other factors. Because contracts are already being granted across large, data-poor regions, a precautionary approach to conservation in this context is to design networks of no-mine areas based on the best available science. Here we develop, apply, and evaluate network design principles for benthic ecosystems on mid-ocean ridges, where contractors are exploring for SMS deposits. As a case study, a suite of metrics to measure network performance relative to conservation targets and to the Convention on Biological Diversity's network criteria is applied to three design scenarios on the northern

and equatorial Mid-Atlantic Ridge. We find that a latitudinally distributed network of no-mine areas, with core dimensions extending 200km along the ridge axis and 500km to either side of the ridge axis, perform well at capturing ecologically important areas, 30-50% of the spreading ridge, and a broad representation of habitat types. Such networks should maintain along-ridge population connectivity, include replication of representative areas, and protect areas potentially less impacted by climate-related changes. Critically, the network design should be adaptive, allowing for refinement based on new knowledge, so long as design principles and conservation targets are maintained. This approach can be applied along all mid-ocean ridge systems, and potentially to other seafloor features, to protect biodiversity and ecosystem functions from regional losses due to SMS mining.

Session 3: Previous Zoning Experience

10. Zoning Experiences from Solwara 1

Dr Samantha Smith, Blue Globe Solutions (Toronto, Canada)

Solwara 1 is a SMS deposit located in 1,600m water depth in the Bismarck Sea, Papua New Guinea (PNG). It is a weakly-active hydrothermal vent site.

Solwara 1 is part of the Su Su Knolls hydrothermal vent system, which is comprised of Solwara 1, South Su (another SMS site approximately 2km to the southeast of Solwara 1) and North Su, an active subsea volcano located between Solwara 1 and South Su which often emits a plume (i.e. "ash cloud") over both Solwara 1 and South Su between ~900 and 1100m water depth.

Solwara 1 contains high grades of copper, gold, zinc and silver and the Papua New

Guinea Government has awarded a mining lease to Nautilus Minerals to develop the Solwara 1 deposit. At the time of writing, mining is expected to commence in the first half of 2019, subject to financing.

Between 2005 and 2008, Nautilus conducted environmental baseline studies and completed an environmental impact assessment (EIA) as compiled in an environmental impact statement (EIS) for the Solwara 1 Project. The EIS was submitted to the Papua New Guinea (PNG) Government in September 2008. After undergoing a thorough public review period and an independent review commissioned by the PNG Government, the EIS was approved in August 2009. This led to Nautilus being granted an environment permit in December 2009 and subsequently a mining lease in March 2011. Environmental baseline studies have continued since 2008.

The approach taken to conduct the studies for the Solwara 1 EIS remains a very good example of a successful industry-academic partnership. Nautilus worked closely with the scientific community to identify, design and conduct the EIA studies and to develop strategies aimed at avoiding, where possible or reducing the impacts of the proposed extraction activities. Of importance, Nautilus accepted every recommendation made by an international team of scientific experts to minimise the ecological impact of mining at Solwara 1.

Impact-reducing strategies listed in the EIS - and committed to by Nautilus - include:

- establishing temporary 'refuge areas' within Solwara 1;
- relocation of animals out of the path of mining to mined areas (once mining occurs); and
- establishing artificial substrates to aid in the recolonisation of Solwara 1.

An additional key commitment that Nautilus Minerals made was to establish South Su as a set-aside area for a number

of reasons, including the:

- protection of an assemblage of animals representative of what would be impacted by mining at Solwara 1;
- provision of a reference site where natural environmental variability could be studied away from the impact of mining;
- provision of a stock population of animals to aid in the recolonisation (passive recovery) of Solwara 1; and
- maintenance of biodiversity and ecosystem health and function on a more regional level (related to the first bullet point).

What was known when the decision was made to set aside South Su?

- Animal assemblages at South Su and Solwara 1 were similar - the main habitat zones at both sites were the same;
- Biodiversity was higher at South Su;
- While the animal assemblages were similar at both sites, they were not identical. For example, the mussel *Bathymodiolus manusensis* was found at South Su but not at Solwara 1;
- Net bottom-water current flow is in a southeast to northwest direction (i.e. from South Su to Solwara 1), supporting the idea that passive drift of organisms/larval dispersal would occur in that direction too.

Critically, plume modelling of steady-state mining conditions and modelling a number of failure scenarios demonstrated that South Su would not be impacted by plumes derived from mining activities.

What did we learn post-EIS?

In partnership with Duke University USA, Nautilus set out to better understand gene flow and connectivity within Manus Basin sites. A third SMS site, Solwara 8, was added to the study to understand gene

flow on a larger regional scale. Solwara 8 is located approximately 40km to the northwest of Solwara 1.

In this study, six species were chosen to represent the numerically dominant taxa found at Manus Basin vents, including a mix of sessile, mobile and attached organisms. An additional two species (limpets) were opportunistically sampled and studied. DNA barcoding and microsatellite analysis was performed. The study showed that all species are panmictic throughout the Manus Basin; there was no directionality to gene flow for any of the species.

Following the completion of this work, the intention was that no further sampling would be conducted at South Su and that future surveys would be done visually and/or without impacting the seafloor; the idea being that South Su should now be in a state of operational protection.

How transferable is this approach to other sites?

The approach taken to establish a reference area for Solwara 1 may be transferable to other SMS sites, but probably not for nodule sites, for a few key reasons:

- Hydrothermal vents support large communities fueled by chemoautotrophic primary production - in contrast to the relatively low biomass found on the deep seafloor, including nodule sites.
- At Solwara 1, relatively high biomass, along with low biodiversity and a small mine site (0.11 km^2), enabled a high sampling effort for key species with minimal complications.
- The same level of sampling effort may not be practical at nodule sites as at Solwara 1.
- The remote locations would make accessing nodule sites relatively difficult.

11. Zoning Experiences from New Zealand: Some Selected Aspects of Design and Monitoring of Deep-sea Sites

Malcolm R. Clark, NIWA, Wellington, New Zealand

This presentation explored three examples of studies undertaken in New Zealand to highlight some of the issues experienced that are relevant to aspects of carrying out, and applying, IRZ-PRZ concepts.

SMS mining vs reference site

Was the site selection adequate?

This study was undertaken in a prospective SMS region on a seamount on the Kermadec Arc, northeast of New Zealand. A potential deposit was identified by Neptune Minerals, as was a nearby reference site. This was effectively an IRZ-PRZ design. An ROV survey found that, despite the two sites being only 200m apart and similar in topography, area, and depth, benthic assemblages were significantly different. The mining site had more distinct assemblages than the reference site, implying multiple PRZs would be needed. The reference site was selected to be close to the mined site to minimise possible faunal differences, but it would have been too close to the impacted area and at risk from effects from sediment plumes.

Protected area network inside a phosphorite nodule licence area

Was spatial planning useful?

A spatial planning approach was applied by Chatham Rock Phosphate in proposing a network of "no-mining" areas to protect biodiversity and act as reference sites within the mining licence area for which they were applying. Zonation software

was used as a decision support tool to structure zoning on objective grounds, in a transparent process using as much data as possible. Various measures of biodiversity value were input (e.g., sensitive benthic communities, protected coral distribution, commercial fish species nursery areas), as well as a resource "cost" (mining prospectivity, bottom trawl intensity). This was seen as an important step in the process of generating management options for mitigating impact, as well as for longer-term monitoring. However, it was recognised that such planning needed to be nested within a larger regional management approach, implying that for IRZs and PRZs consideration should also be given of their roles relative to that of the APEIs.

Monitoring recovery, post closure to bottom trawling on seamounts

Can we measure changes over time?

In 2001 three small seamount features off the east coast of New Zealand were closed to fishing. Within the seamount cluster, this enabled comparisons over time of changes in the benthic fauna between fished-fished, fished-closed, and unfished-closed situations. Four monitoring surveys were completed between 2001 and 2015 using towed cameras close to the seafloor along set transect lines. The abundance of most taxa was found to increase over time. Despite efforts to maintain consistency between surveys, and using the same image analysts, "technology creep" was evident with improved resolution of cameras, and increased ship control with dynamic positioning. It proved very difficult to "dumb-down" improved data quality without losing a lot of valuable information. The changes between seamounts within a survey were consistent between surveys, highlighting the value of multiple surveys and multiple sites in order to have confidence in separating human-induced from natural changes over time.

The presentation was concluded with the following points:

- Each resource and location has its own environmental and faunal characteristics. Detailed biological surveys are necessary to confirm IRZs and PRZs. Physical proxies may be inadequate.
- The complex spatial scale patterns evident in many benthic communities need to be described and incorporated into the design. There are both regional-scale and local-scale issues.
- Spatial planning software can be a useful tool to aid selection of PRZs, especially for long-term biodiversity protection
- Replication of sites (so several PRZs) may be needed to confirm the nature and extent of natural changes.
- Careful planning is required to ensure time series data are consistent and can support robust comparisons.

12. Status of the Designation of PRZs and IRZs in DORD's Contract Area

Akira TSUNE, Manager of Environmental Survey, Deep Ocean Resources Development Co, Ltd

Deep Ocean Resources Company Limited (DORD) has set a PRZ in our contract area in the CCZ, since 2016, which includes a high abundance (HA) area. The HA area was identified prior to designation of the PRZ.

The HA area, which is located at the northwest of the West Area, was set as a mining-targeted area in 2011 after obtaining data of nodule abundance and the other geological data which covers the entire West Area. Taking into account the key points stated in some ISA documents for the identification of a PRZ, e.g. "no-mining shall occur" in the area and the area shall have "ecological similarity," a

candidate PRZ was selected. Consideration was also given to the geological similarity and location of the HA area. DORD's next step was to examine the kind of environmental data required to collect further environmental baseline data to confirm ecological similarity between HA area and the designated PRZ.

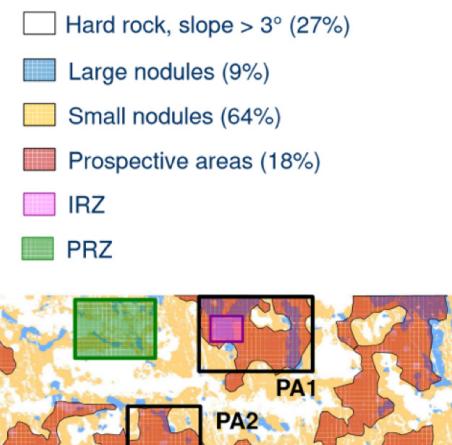
Although an IRZ has not yet been designated in the West Area, it is likely to be located somewhere in the HA area, and its location and size need to be decided together with a concrete test-mining plan. In parallel, it requires development of mining technologies, as well as clarification of IRZs through ISA's Guidelines.

14. Delineation of IRZs and PRZs in the German Manganese Nodule Contract Area in the CCZ: Criteria and Environmental Characteristics

Annemiek Vink, Carsten Röhleman, Thomas Kuhn, BGR Hannover, Germany; Annika Janssen, Katja Uhlenkott, German Centre for Marine Biodiversity Research (DZMB) Wilhelmshaven, Germany

In the framework of the exploration activities of the Bundesanstalt für Geowissenschaften und Rohstoffe - Federal Institute for Geosciences and Natural Resources (BGR) and in compliance with the exploration regulations, the contractor delineated one IRZ and one PRZ in its larger eastern contract area. In the absence of clear guidelines for the delineation of such reference zones, the most important criteria for their selection were: the representativeness of geological and environmental characteristics, the biota and their habitat as well as the locations of the sites in relation to expected future mining activities. In this regard, it is important to mention that the PRZ was chosen "for the primary purposes of ensuring preservation and facilitating

monitoring of biological communities impacted by mining activities" according to the CCZ EMP, i.e. with a clear protective function. The IRZ is situated within a nodule field in a prospective area (PA1) that was selected for a potential future mining test, and the PRZ is located about 50km to the west of this field, leeward of a small seamount chain. The second prospective area (PA2) is located about 50km to the southeast of the PRZ. Long-term bottom water current data derived from PA1 shows a predominant SE-SW direction of current flow. Furthermore, modelling exercises of industrial-scale plume dispersion in PA1 predict a sediment deposition of less than 1mm within a maximum distance of approximately 20km from the source after a year of mining. Thus, a mining-related sediment plume would not be expected to have an impact on the PRZ.



(Source: Speaker's presentation copy)

In contrast to the contiguous nodule fields of PA1 and PA2, the PRZ is not a typical mineable area and is characterised by a greater heterogeneity in topography, nodule coverage and size ("nodule facies"). However, there is, generally, a high degree of spatial variability in geological/geochemical conditions among all three areas (also between PA1 and PA2), which is reflected by differing nodule coverage, size and composition as well as by variable faunal assemblages. In PA1 (IRZ), Cu-Ni-rich diagenetic components prevail in the predominantly large nodules of the

area, whereas hydrogenetic components prevail in the predominantly small nodules of PA2. In contrast, nodules of the PRZ are often characterised by large amounts of Cu-Ni-poor diagenetic components. Geochemically, the sediments of the PRZ are characterised by lower rates of organic matter degradation and Mn turnover rates, than PA1 and PA2. Geochemical profiles are still lacking from the sediments of PA2 and the PRZ.

Temporal and spatial macrofaunal analyses of the IRZ and PRZ over four consecutive years (2013-2016) show that community composition at higher taxonomic levels is similar at both sites and that there is sufficient gene flow between the populations of both areas (i.e. no geographical barriers are present that could impede recolonization of the most abundant macrofaunal taxa after mining activities). Total macrofaunal abundances are higher in the PRZ. Genetic analyses of polychaetes and isopods of the IRZ and PRZ show that approximately 12% of all analysed specimens are singletons for both groups of organisms. Roughly one-third of all putative species live in both areas, whereas many more putative species were found exclusively in the PRZ than in the IRZ. Overall, similarity levels of e.g. isopod species are very low both between and within the sampling areas. This is because many species are restricted to one or two sampling sites only, i.e. there is a high degree of faunal patchiness which is also, almost certainly, a reflection of insufficient spatial coverage and small sample size. Similar results appear to hold for meiofaunal distributions. Total abundances are highest in the PRZ, and similar traits of the meiofaunal communities are found between the PRZ and IRZ in consecutive years.

In conclusion, the delineation of the PRZ as a functional area for ensuring representative and stable biota of the seabed and in terms of representing a protected area containing a wide range

of nodule facies and habitats from where organisms can recolonise mined areas (PA1 or PA2) may be verified for the time being. However, the high degree of spatial variability found in geological, geochemical and ecological conditions even within prospective areas at small scales of several hundreds of metres (nodule composition, size, coverage, biodiversity) shows that, at the size scales of IRZs and PRZs (> 50km apart), the definition of a PRZ as being "... as ecologically similar as possible to the impact zone, and ...removed from potential mining impacts..." (CCZ EMP) may be a contradiction in itself and a difficult goal to reach even under the best circumstances.

Session 4: Monitoring Challenges

18. Experimental Design in the Deep sea to Answer Basic Deep-sea Mining Questions: an Initial Power Analysis

Jeff Ardon, Daniel Jones & Erik Simon-Lledó

In the deep sea, the patterns of distributions of animals differ greatly from those which are generally found on land. It is therefore worth asking the question of how these differences could translate to different practicalities when designing an environmental monitoring regime for deep-seabed mining.

In this presentation, we take a preliminary look at data collected from the CCZ with regard to three statistical considerations:

1. Sample size: how large a sample is 'enough'?
2. Replication: how many samples are 'enough'?
3. Sensitivity: what statistical "effect size" is 'important'?

Using standardised photo surveys taken in the CCZ, where there is the most interest in beginning manganese nodule mining, we looked at the abundance of megafauna using visual and machine-learning detection techniques. Faunal compositions differ according to the geomorphic features on which they were found, and were divided into three classes: flats, ridges and troughs.

Although the megafaunal distributions differed for these three features, they shared the common statistical feature of hosting a large percentage of rarely occurring organisms. In all three cases, the species-area curves continued to gradually climb; even after more than 4km of surveying a single 1m wide transect, species new to the survey continued to be found. This first finding suggests that assessing species 'biodiversity' using direct sampling techniques that rely upon an assessment of species richness will be very challenging in the CCZ.

Using Bray-Curtis auto-similarity analysis, differences in community composition began to be resolved after about 500-1000 1-metre square photographs. This second finding suggests that while assessing biodiversity may be extremely challenging, assessing changes in community structure may be more tractable (e.g. using 1km long survey transects).

The cumulative mean density of the megafaunal species associated with three geomorphic classes (flats, ridges, and troughs) becomes clear by around 150 photographs. This third initial result suggests that cumulative mean density could be an efficient indicator (of a suit of indicators) in an environmental monitoring programme. However, it must be emphasised that assessing the densities of individual species will usually require many more samples. The issue of rarity being common thus asserts itself. To assess the density of a species of median

commonality would, according to our initial examinations, still require more than 1,500 photographs (i.e. 1.5km transects). Statistical 'power' is a measurement of the likelihood that a study will detect an effect when there is an effect to be detected. In other words, the more power, the less chance there is of concluding there is no effect when, in fact, there is one. Given the low densities of species in the CCZ, the ability to detect change is hampered, and thus statistical power (i.e. avoiding 'type II errors') is of particular concern. For our initial assessment, we used 'Cohen's d', which is commonly found in the published literature across a wide variety of disciplines, which can be summarised as the difference in means of two populations, divided by their pooled standard deviation. The value of Cohen's d needs to be interpreted alongside the desired level of effect to be detected, because large changes are easier to detect than smaller ones. However, in all cases, increased replication means increased power to detect smaller changes. In our initial assessment we looked at a statistical power of 0.8; i.e. an 80% chance that the actual effect would indeed be detected. To detect a large difference, of one standard deviation, approximately 15 replications might be required, whereas to detect a relatively subtle change of a quarter standard deviation, more than 200 replications may be required. Detecting a half standard deviation may require about 75 replications. Bearing in mind the earlier findings that each sample could be a transect of several kilometers in length (depending on what is being measured), the need to replicate these measurements several dozens of times will be time-consuming.

As illustrated by the above discussion, a key factor in the design of a monitoring regime for deep-seabed mining will determine beforehand what level of effect one wishes to detect; i.e. how much of a change in species numbers or community structure

or density is important to our management of that area? How this question is answered will have very real ramifications on the contractor's cost and time spent surveying. On the other hand, not detecting ecologically significant changes when they are in fact occurring, due to a lack of statistical power, is very concerning as well. Thus, the determination of the relevant statistical 'effect size' will be a policy-science interface question, requiring both good science of the proposed mining area, and good governance to set in place the adequate level of monitoring, so that informed management decision-making can proceed.

In summary:

- Measuring change in the CCZ will require much larger sample plots than commonly used on land.
- Measuring some parameters (e.g. 'biodiversity') will much require larger sample areas than others.
- Selection of parameters will be a balance of cost versus criticality (composed of legal obligations and ecological risk).
- Power analyses are necessary to separate meaningful from statistically 'trivial' or inconclusively significant results.
- Power analyses will need to be done, beforehand, to determine the appropriate experimental design, especially the number of samples replicated.
- Power analyses require comprehensive baseline data.
- Determining what is a meaningful effect size for a given variable is both a scientific and a policy question. Answers will vary according to the definition of 'serious harm'.

Thus, agreement on effect sizes will be necessary in order to determine the experimental design and management responses, before mining proceeds. To do

so will require extensive baseline surveys with sufficient sample sizes and replication to scope out the statistical properties of the ecology of the area. Finally, adaptive management would suggest that there should also be the ability to refine those initial results and their associated monitoring requirements, based on ongoing statistical analyses of the influx of new monitoring data.

Session 5: Stakeholder Concerns

19. International Law and Policy Perspectives

Kristina M. Gjerde, IUCN Global Marine and Polar Programme, Middlebury Institute of International Studies at Monterey, California and Deep Ocean Stewardship Initiative

International rules for deep sea mining, including those for monitoring deep sea mining impacts, will need to be set in the larger context of international legal requirements in the United Nations Convention on the Law of the Sea (UNCLOS). These requirements include the obligation under UNCLOS Article 145 to take the "necessary measures" and "adopt appropriate rules, regulations and procedures" to ensure the "effective protection of the marine environment from harmful effects" that might arise from mining. Any requirements for IRZs and PRZs should, accordingly, enable measurements that can ensure a timely response in the face of evidence of "harmful effects" before these can cause serious harm. Accordingly, a timely response will entail a combination of: 1) precautionary design, thresholds and indicators for measuring impacts; and 2) environmental objectives set within regulatory limits on impacts (see Gjerde and Jaekel, 2017, Code Project Issue Paper #1 Effective Protection available at: <http://www.pewtrusts.org/~/media/>

[assets/2017/08/first-report-of-the-code-project-developing-international-seabed-authority-environmental-regulations.pdf](http://www.pewtrusts.org/~/media/assets/2017/08/first-report-of-the-code-project-developing-international-seabed-authority-environmental-regulations.pdf)). Such aims, requirements and precautionary limits will need to be viewed from a global, regional and site-specific perspective (see Jones and Weaver, 2017, Code Project Issue Paper #4: Strategic Environmental Assessment <http://www.pewtrusts.org/~/media/assets/2017/08/first-report-of-the-code-project-developing-international-seabed-authority-environmental-regulations.pdf>).

Recent international research projects such as Managing Impacts of Deep-sea Resource Exploitation (MIDAS) and Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) are helping to shed light on potential impacts of deep sea mining. Despite the knowledge gained (see e.g., <http://www.eu-midas.net/>), much remains unknown. Many key questions will need to be understood to inform the spatial scale of IRZs and PRZs (see Weaver, Billett, Gebruk, Jones, Morato, 2017. Code Project Issue Paper #12 Recommendations for Further Research available at: <http://www.pewtrusts.org/~/media/assets/2017/08/first-report-of-the-code-project-developing-international-seabed-authority-environmental-regulations.pdf>).

Important categories of unknowns include plumes, ecotoxicology, species connectivity, ecosystem function, ecosystem recovery, and wider issues such as noise, light and vibration, impacts on water column and adjacent sites, and effectiveness of any mitigation strategies (id.). As a result of these large unknowns, IRZs will need to be large enough to effectively measure and monitor the full range of potential environmental effects. PRZs will, similarly, need to be sufficient in number and size to serve as effective controls for the full range of potential impacts over time and space. These measures will also need to be complemented by a system of no-mining

sites inside and beyond mining claim areas to secure protection for ecologically sensitive, scientifically significant and other important areas.

20. Stakeholder Concerns about Scientific Developments

Matthew Gianni, Deep Sea Conservation Coalition

Where should IRZs and PRZs be located? How many IRZs and PRZs should there be within each contract area? How large do IRZs and PRZs need to be? What types of monitoring are needed, for what and how is the monitoring to be done? To address these questions, it is important to agree on clear conservation objectives to be established in the mining regulations. This allows for a determination of which types of impacts need to be monitored and whether ecologically and biologically meaningful limits risk being (or may be) exceeded can be set.

Recent correspondence published in June 2017 in *Nature Geoscience* concluded that biodiversity losses from deep-sea mining are unavoidable and possibly irrevocable and that ISA must recognize this risk to inform discussions about whether deep-seabed mining should proceed, and if so, what standards and safeguards need to be put into place to minimize biodiversity loss (van Dover et al., 2017, *Nature Geoscience*)

If biodiversity loss is inevitable, then the following questions come to mind: How much biodiversity loss will ISA regulations allow or permit? Over what time frame will the loss be permitted given that in most cases the loss is likely to be irreversible over human timescales? Can limits - measurable and biologically or ecologically meaningful, enforceable

limits - be placed and enforced to be sure that the 'permissible' loss is not exceeded? And, how will ISA justify the biodiversity loss - e.g. what is the benefit to humanity that would justify the loss of biodiversity in the Area - designated by UNCLOS as the "common heritage of mankind"?

Deep-sea ecosystems are already under stress from the effects of climate change - e.g. deoxygenation, acidification, changes in temperature, POC flux etc. (Sweetman et al., 2017; Levin et al., 2016); pollutants such as plastics and persistent organic compounds (Jamieson et al., 2017); and the impacts of bottom fisheries from 200m to deeper than 200m (1st UN WOA; Clark, ICES, others) among other stressors. To conclude, it is important to ensure a coherent international approach to the conservation and protection of biodiversity in areas beyond national jurisdiction.

UNCLOS Article 145 requires the adoption of measures by ISA to "ensure effective protection for the marine environment" and "the need for protection from harmful effects...and the prevention of damage to the flora and fauna of the marine environment. UN Sustainable Development Goal 14.2 calls on States to: By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.

Effectively monitoring the environmental impacts of seabed mining through, *inter alia*, establishing IRZs and PRZs is critical but decisions need to be made about what types of impacts and the degree of the impacts need to be monitored, which impacts the monitoring should be designed to prevent and how to do so.

SUMMARY OF THE WORKSHOP DISCUSSION³³ ON DESIGNING AND MONITORING OF PRZ AND IRZ

I. Polymetallic Nodules areas

Design:

1. Design criteria should be simple and generic.
2. Each PRZ will be suitable to serve as a reference area containing a stable biota (within the natural range of variation) with representative habitats, biodiversity and ecological function potentially impacted by mining in the IRZ.
3. The (total) PRZ area(s) should be large enough to include representative biota, habitats, biodiversity and ecological function potentially impacted by mining, and take into account the geographical ranges of the biota present.
 - a. A PRZ may be a single large area. In this case, the PRZ should cover representative biota, habitats, biodiversity and ecological function potentially impacted by mining, and take into account the geographical ranges of the biota present.
 - b. A PRZ may be a series of smaller areas. In this case, the total PRZ areas cover representative biota, habitats, biodiversity and ecological function potentially impacted by mining, and take into account the geographical ranges of the biota present.

4. The timeframe of the PRZ should be for the duration of the exploitation contract, which includes the closure plan period.
5. The PRZ should be an appropriate distance away from any environmental impacts from seabed activities.
6. PRZs can be established in cooperation between adjacent contractors.
7. Where specific habitats under impacts of mining activities cannot be replicated within an appropriate contractor PRZ, a set of smaller PRZs, representing those specific habitats, can be considered.
8. The IRZ shall be defined as any area determined to be impacted by mining.

Monitoring:

9. Experiences from other sectors may be leveraged in the development of monitoring approaches and designs.
10. Biological samples collected need to be appropriately archived.
11. Data standards should be backward compatible.
12. Considerations for monitoring should focus on its outcomes, rather than prescribing its methodologies or technologies.
13. Further refinement is needed for monitoring variables to be measured in keeping with the spatial and temporal

³³ The workshop noted a suggestion to rename the term PRZs as "Control Reference Zones". The summary provided here does not imply a consensus by all participants.

- nature of the monitoring.
14. Impacts predicted in the EIA should be monitored at sites using stratified sampling design within IRZs to assess impact across all habitat types, direct and indirect impacts, and spatial scales. The contractor shall consider, *inter alia*, the following key impacts to be monitored:
- physical removal/direct alteration of substrate, sediment and biota;
 - change in geochemistry of the seabed substrate;
 - changes to seafloor integrity;
 - release of heavy metals and other contaminants as well as potential accumulation through the food chain;
 - effects on the organisms and communities by plumes (e.g. smothering, effects on suspension feeders);
 - potential effects on plankton or nekton and mesopelagic fishes from the seafloor or discharge plumes;
 - turbidity reducing visibility in the water column for predatory fish;
 - potential impacts on commercial fish, fisheries, marine mammals, and migratory vertebrates such as turtles and sharks;
 - noise and light; and
 - changes in water column properties.
15. The contractor shall consider, *inter alia*, assessing changes in:
- composition, abundance of benthic and pelagic communities;
 - sediment properties (e.g. particle size and chemical composition) and geochemical characteristics;
 - water column characteristics (e.g. turbidity, dissolved oxygen, temperature, salinity, sedimentation rates, noise, etc.). Furthermore, the contractor shall undertake regular CTD casts in both, IRZs and PRZs throughout the water column;
 - concentrations of heavy metals and contaminants in the sediment and the water column;
- biodiversity; and
 - ecological function.
16. Contractors must consider variance and statistical power in IRZ and PRZ monitoring.
17. The contractor shall monitor IRZs and PRZs for, at least, the duration of any mining activity. In the context of the closure plan, the relative significance of mining impacts and any longer term effects need to be assessed for any further need for monitoring.

II. Polymetallic Sulphides area

Design:

1. Criteria to operationalise the objectives of impact and PRZs at a PMS area should be defined. These should not yet be prescriptive, but guided by general principles in the absence of more site-specific information, and should be updated in light of new information.
2. Comprehensive environmental baselines and the environmental impact assessment must provide a basis for monitoring programmes to assess effects of mining activities on the marine environment. The design of the monitoring programmes shall include the designation of IRZs and PRZs which should be on a site-specific basis to account for high heterogeneity between and within PMS deposit habitats.
3. Reference zone design should follow current best-environmental and statistical practice, e.g. a before-after-control impact (BACI) design.
4. The IRZ shall be defined as any area determined to be impacted by mining,

- extending to a distance where impact can no longer be detected.
5. A PRZ is a control area to measure natural variability against which future changes in the IRZ are to be compared. It should not be changed or abandoned until the monitoring programme is complete.
 6. To capture a range in natural variability across heterogeneous environments and replications to allow for statistical robustness, a consideration can be made for multiple PRZs that can collectively include all habitats and their connections. The use of multiple control sites is best-environmental practice that can be considered for designing PRZs.
 7. Each new mining site shall have its own IRZ, and may be compared with existing PRZs, subject to it being ecologically representative of all habitats impacted by mining activities.
 8. The PRZs shall not be impacted by any mining activities. The IRZ shall not be a source population for the PRZ. PRZs shall not be designated in an area that has been previously impacted by mining.

Monitoring:

9. The contractor shall monitor IRZs and PRZs for, at least, the duration of any mining activity. In the context of the closure plan, there should then be a review to assess the relative importance of mining impacts and an evaluation of whether any longer-term effects need to be monitored for a reasonable period after the closure of the activities in a mining area.
10. Stratified sampling design to monitor within IRZs and PRZs should be used to assess impact across all habitat and impact types.

11. IRZs shall be designated and monitored to assess all impacts from mining activities within and outside the contract area.
12. Stability of PRZs should be defined as persistence of the natural patterns of variability including those due to natural levels of disturbance. Stability should be determined by monitoring the physical, chemical and biological characteristics and shall be determined before mining activities commence.
13. Impacts predicted in the EIA should be monitored at sites using stratified sampling design within IRZs to assess impacts across all habitat types, direct and indirect impacts, and spatial scales. It is recommended that contractors consider monitoring, *inter alia*, the following:
 - Substrate removal
 - Plume - operational and discharge
 - Noise
 - Light
 - Changes in fluid flux
 - Sediment alteration/removal
 - Faunal removal
 - Trophic ecology
 - Habitat loss or change
 - Homogenization of habitat
 - Taxonomic composition change
 - Smothering
 - Ecotoxicology
 - Sediment restructuring
 - Marine mammal populations
 - Community structure
 - Community function
 - Productivity

III. Cobalt-Rich Crusts area

Design:

1. The IRZ shall be defined as any area determined to be impacted by mining.
2. The contractor shall ensure that the PRZs are sufficient in size, e.g., covering

10-20% of the total claim area with stable communities and ecological functions (within natural range of variation). This proportion may change with increasing scientific knowledge.

3. The contractor shall ensure that the IRZs and associated PRZs are ecologically as similar as possible and located at a similar water depth, substrate type and topography.
4. The placement of PRZs should be based on detailed current measurements to describe potential hydrographic complexity of the seamount. Care must be taken that the PRZ is well clear of any effects of the variability in current flow affecting the dispersal of the sediment plume.
5. The patchiness of the benthic fauna requires a detailed benthic survey to determine community distribution and guide appropriate placement of PRZs.
6. Where possible, each seamount should be treated as an ecological unit and managed as a single entity with its relevant PRZs and IRZs located on it.
7. Oceanographic characteristics of seamounts may extend impacts into the water column, and IRZs and PRZs need to cover this three-dimensional aspect.
8. The contractor should note that the design will be affected by the characteristics of the individual seamount.

Monitoring:

9. Impacts predicted in the environmental impact assessment should be monitored at sites using stratified sampling design within IRZs to assess impact across all habitat types, direct and indirect impacts, and spatial

scales. The contractor shall consider the following key impacts, *inter alia*, to be monitored:

- a. Physical removal of crusts, sediment and animals
- b. Change in texture and geochemistry of the seabed substrate
- c. Release of heavy metals and other contaminants as well as potential accumulation through the food chain
- d. Smothering or other effects on the biology of benthic animals by sediment from the plume
- e. Potential effects on plankton, nekton, and mesopelagic fishes from the seafloor or discharge plumes
- f. Turbidity reducing visibility in the water column for predatory fish
- g. Potential impacts on commercial fish, fisheries, marine mammals, and migratory vertebrates such as turtles and sharks
- h. Noise and light
- i. Changes in water column properties

10. The contractor shall consider, *inter alia*, assessing changes in the following key metrics:

- a. Composition, abundance and condition of epibenthic species, sediment properties such as physical (e.g., sediment thickness, particle size) and geochemical characteristics.
- b. Water column characteristics such as turbidity and dissolved oxygen measured by sensors on CTDs or moorings (landers) with a variety of sensors (such as turbidity sensors, dissolved oxygen, temperature, salinity, current meter or ADCP, sediment traps and hydrophone for acoustic monitoring of a change in behaviour or distribution of marine mammals). Furthermore, the contractor shall undertake regular CTD casts in both IRZs and PRZs

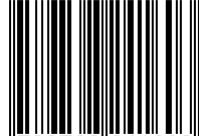
- throughout the water column.
- c. The concentrations of heavy metals and contaminants in the sediment and the water column.
 - d. Composition and abundance of plankton if there are oceanographic retention situations such as closed-circulation cells (Taylor columns) which may also lead to increased bioaccumulation in sessile filter-feeders, plankton and predatory fish.
11. The contractor shall monitor IRZs and PRZs for, at least, the duration of any mining activity. In the context of the closure plan, there should then be a review to assess the relative importance of mining impacts and evaluate possible need for longer-term effects to be monitored for a reasonable period after the closure of the activities in a mining area.

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