Background document for Workshop:

Towards an ISA Environmental Management Strategy for the Area

Berlin, March 2017

Discussion paper on "Project-specific Environmental Impact Assessments"

Prepared by Malcolm R. Clark

Background

The Law of the Sea Convention (UNCLOS) has general provisions for States to protect and preserve the marine environment from activities (Articles 145, 192), and more specifically Article 206 states that when planned activities could cause significant and harmful changes, the potential effects of activities should be assessed and reported. Contractors, sponsoring States and other interested States or entities are also required during either prospecting or exploration to cooperate with the ISA in the establishment and implementation of programmes for monitoring and evaluating the impacts of deep seabed mining on the marine environment (ISA, 2013a). Best environmental practices need to be followed for deep-sea mining activities to proceed, and the need to assess environmental impacts requires the development and implementation of a robust Environmental Impact Assessment (EIA) process.

What is an EIA?

There are many definitions of EIA, but a commonly used one is that of The International Association for Impact Assessment (IAIA) (Senécal et al., 1999) which defines an EIA as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made." Following on from this, the IAIA describes four key objectives of an EIA:

- To ensure that environmental considerations are explicitly addressed and incorporated into the development decision-making process;
- To anticipate and avoid, minimize or offset the adverse significant biophysical, social and other relevant effects of development proposals;
- To protect the productivity and capacity of natural systems and the ecological processes which maintain their functions; and
- To promote development that generates less destruction and optimizes resource use and management opportunities.

EIA is not a single report, it is part of a wider process, with a number of general activities that an EIA process should include (Senécal et al., 1999):

- Screening: to determine if an EIA is required
- Scoping: identify the issues and impacts for an EIA
- Examination of alternatives: look at several options to achieve project objectives
- Impact analysis: identify and predict effects of the proposal

- Mitigation and impact management: establish measures to manage impacts
- Evaluation of significance: what are the residual impacts?
- Preparation of report: document all the issues and measures
- Review of the assessment: whether the EIA meets the criteria
- Decision making: approve, reject, or modify proposal
- Follow-up: if approved, ensure compliance and monitoring of conditions and impacts.

However, as environmental assessment for deep-sea mining is still developing, it is an appropriate time to evaluate what is required for a robust EIA process and the nature and extent of EIAs for the range of deep-sea mineral resources and environments.

Challenges/Problems

There is a wealth of international experience in these activities and reports carrying out EIAs (Glasson et al., 2012). However, whereas the EIA process is well developed in many terrestrial and coastal marine situations (Glasson et al., 2012; Petts, 1999), and for offshore hydrocarbon resources (Husky Oil, 2001), guidance for mineral resources is still developing (Ellis et al., 2014; Ellis et al., 2017). Although it can be tailored to specific national legislation (CEAA, 2012; US Department of Energy, 2004), there are a number of generic issues:

Procedural issues with EIA processes;

Preconditions for, and all steps to be taken during, an EIA process prior to permitting mining tests or operations need to be defined, including the overall scope of the EIA, roles, timelines, scoping procedures, public participation and review, as well as setting performance criteria for environmental reporting and assessment. Funding and institutional mechanisms and procedures need to be clarified in order to ensure an independent EIA. There are several models for EIA procedures in national legislation and international law, and the Griffith-ISA Workshop (ISA, 2017) considered some of these. There should be a single process where appropriate to make it easier for both applicants and the ISA managing the process.

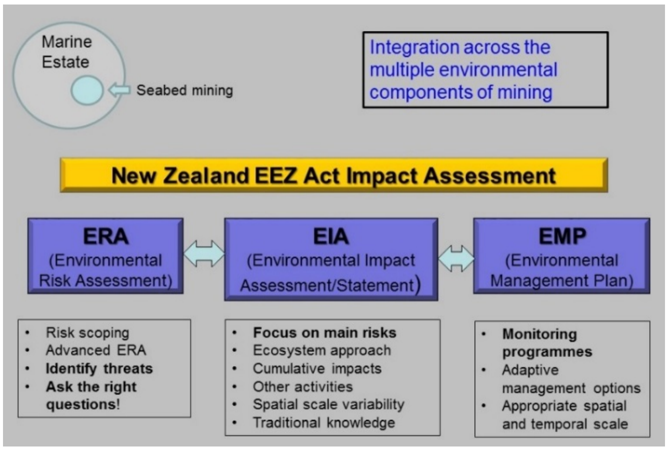
Technical issues

Too much description, not enough focus on key elements of impacts

The effectiveness of EIAs has been found to be limited when they have too much focus on overly descriptive baseline work and not enough emphasis on key impacts of the activity (Glasson et al., 2012). Too often it is difficult to wade through long-winded accounts of the environment that lack a good interpretation of the relevance to impacts from the proposed activities. In the development of impact assessments, key impacts from offshore mining activities should be structured by “receptor” and depth range to enable an understanding of the source and nature of impacts caused by the various components of the operation at the surface or seafloor, and help to focus the EIA and potential mitigation measures.

Insufficient account of a prior risk assessment

Linked with the above issue that EIAs are often too dominated by compilations of everything known about an area, rather than key impacts, an Ecological Risk Assessment (ERA) should be an integral part of the process. However, this is often not done early enough in the process to guide data collection during exploration that can inform a more robust EIA (Clark et al., 2014; ISA, 2017).



Available data shortcomings

Most EIAs suffer from incomplete data, or information that is inadequate to fully assess the impacts of activities on one or more receptors. A long list is possible of issues that EIAs can have in the deep sea, and in practical terms there is little one can do about some of them-we have to accept a data-limited situation. However, common and avoidable problems relate to:

- lack of standardization of data or sampling procedures
- poor integration of all available data
- no assessment of what is an adequate baseline dataset
- inadequate baseline survey design (often not enough thought)
- insufficient regional setting for studies done at a smaller-scale site of interest
- insufficient assessment of potential cumulative impacts
- limited expression or acknowledgement of uncertainty.

Lack of standard monitoring protocols

Every location, resource type, and habitat can have different characteristics. Hence EIAs have to be flexible to ensure they are fit for purpose. However, in collecting data during exploration to support the baseline definition, and subsequent monitoring, there should be a level of consistency so that core deep-sea ecological information demands are met, and these are comparable and can be combined between contractors to form a regional picture. Aspects include:

- what parameters should be measured from the outset, and how
- what is measured to acceptable standards (accuracy and precision)
- what are the key ecological indicators that need to be assessed in transitioning from the baseline data to measuring/monitoring future changes under the EMP

- what level of change might be acceptable in terms of mitigation (against generic ecological limits and thresholds, not management targets).

Variable formats and content

EIAs can come in all shapes and sizes, as different contractors, consultants and institutes have their own way of doing things. However, a degree of higher level structural standardization can make the task of contractors and the reviewing regulatory body much easier, because the former know what they need to provide, and the latter what to expect.

While an EIA essentially focuses on the biophysical environment, increasingly EIAs are considering economic, social and cultural factors as well as ecological and physical components. The social and economic factors can be considered within an EIA or as a separate report, depending on the detail required by the relevant legislation and regulations.

The ISA developed a provisional EIA template for deep-sea mining activities (ISA, 2012), partly based on the structure of an Environmental Impact Statement prepared for Seafloor Massive Sulphide (SMS) mining off Papua New Guinea (Coffey Natural Systems/Nautilus Minerals Ltd, 2008). The ISA template is intended to guide contractors to achieve consistency in EIA information. The ISA template has since been modified by Swaddling (2016), and it was also used in developing guidelines for EIAs that could bridge the international template and the requirements of the EEZ Act in New Zealand (Clark et al., 2014; Clark et al., 2017).

Uncertainty

There are numerous technical/scientific challenges for any deep-sea EIA. The underlying cause of this difficulty is the nature of the environment. The deep-sea is difficult to access because of its remoteness and depth. Ecosystems are open, both horizontally and vertically, and community definition and boundaries are difficult to establish. Many ecological processes are slow, and hence natural variability can take a long time to measure. So given these, and other, issues, data will invariably be limiting for an EIA in comparison with terrestrial or many inshore environments. This makes the issue of expressing uncertainty and confidence particularly important.

There are many kinds of uncertainty, and it can be helpful to define different sources of uncertainty so that they can be better understood and managed. These can be defined in several groups:

- Knowledge uncertainty arises where there is incomplete understanding of processes, interactions or system behaviours
- Unpredictability arises from chaotic (often random) components of complex systems or of human behaviour
- Structural uncertainty arises from inadequate models, ambiguous system boundaries, or over simplification or omission of processes from models
- Value uncertainty arises from missing or inaccurate data, inappropriate spatial or temporal resolution, or poorly known model parameters
- Uncertain interpretations, arise when values or terms are interpreted differently by different user groups.

These types of uncertainties may all be relevant to assessing what effect an impact may have. Many of the techniques used in preparing an EIA, such as models used to make predictions, will have the potential for associated uncertainty, as do monitoring programme measurements and information due to precision of instruments, or if new and less proven technologies are used.

Cumulative impacts

Policy and regulatory requirements in many countries include the requirement that EIAs identify, analyse and evaluate cumulative effects. However, although they have long been recognised as an important component of EIAs, they are poorly assessed as a rule (Burris and Canter, 1997). There are many stressors caused by anthropogenic activities that can affect the marine environment in a number of ways, and there is a large body of literature dealing with this field of research (Glasson et al., 2012; Solan and Whiteley, 2016). Results of numerous studies indicate that interactions between stressors can be variable, and hard to predict (Crain et al., 2008; Darling and Cote, 2008). Nevertheless, cumulative effects should be explored as much as possible given available data, and considered early on during the exploration phase so appropriate information can be collected.

The assessment of cumulative impacts needs to consider three key elements:

- Multiple sources of impact (either different types of mining operation, or different sectors)
- Additive or interactive processes (repetition leading to accumulation of impacts)
- Different types of cumulative effects (e.g., direct physical, indirect, natural).

There is now increasing guidance on what to describe and evaluate (Ban et al., 2010; Crain et al., 2008; Smit and Spaling, 1995). However, the key to improving EIAs lies in the ability to acknowledge and manage the residual (unavoidable) uncertainty. Rouse and Norton (2010) stress the need for greater use of statistical measures and probabilistic methods to estimate the likelihood of the predicted outcome happening.

A review by Sadler (1996), although a bit dated now, still serves as a good example of some of the good, the bad, and the ugly features found in EIAs, that the EIA process and structure can learn from.

Best-case performance

The EA process:

- facilitates informed decision-making by providing clear, well-structured, dispassionate analysis of the effects and consequences of proposed actions;
- assists the selection of alternatives, including the selection of the best practicable or most environmentally friendly option;
- influences both project selection and policy design by screening out environmentally unsound proposals, as well as modifying feasible action;
- encompasses all relevant issues and factors, including cumulative effects, social impacts and health risks;
- directs (not dictates) formal approvals, including the establishment of terms and conditions of implementation and follow-up;
- results in the satisfactory prediction of the adverse effects of proposed actions and their mitigation using conventional and customized techniques; and
- preserves as an adaptive, organizational learning process in which the lessons experienced are fed back into policy, institutional and project designs.

Worst-case performance

The EA process:

- is inconsistently applied to development proposals with many sectors and classes of activity omitted;
- operates as a 'stand alone' process, poorly related to the project cycle and approval process and consequently is of marginal influence;
- has a non-existent or weak follow-up process, lacking surveillance and enforcement of terms and conditions, effects monitoring, etc.;
- does not consider cumulative effects or social, health and risk factors;
- makes little or no reference to the public, or consultation is perfunctory, substandard and takes no account of the specific requirements of affected groups;
- results in EA reports that are voluminous, poorly organized and descriptive technical documents;
- provides information that is unhelpful or irrelevant to decision-making;
- is inefficient, time consuming and costly in relation to the benefits delivered; and
- understates and insufficiently mitigates environmental impacts and loses credibility.

Source: Sadler 1996

What are the questions to be discussed and solved?

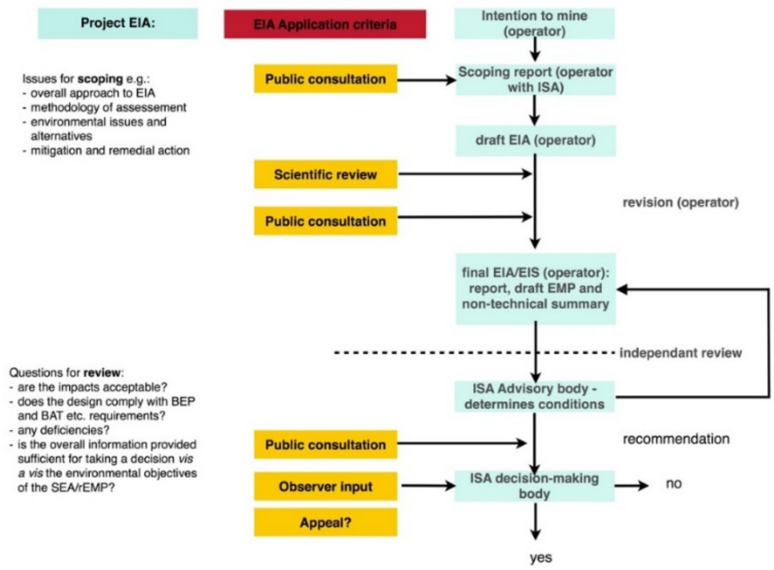
There are a lot of potential discussion points with EIAs that could be considered. However, in the workshop we propose to focus on some of the key aspects that are most relevant to deep-sea mining, and are tractable within a couple of sessions.

Legal/procedural issues

- Which specific form of EIA **process** should be initiated after exploration? Or should the process be integrated across exploration and exploitation
- What steps (by the ISA and interested parties) are required prior to submission of an application to mine, including public and scientific review?
- What is the governance framework associated with the decisions to be made on EIAs submitted with mining applications?
- What are the best ways to ensure sufficient transparency in the process?
- Should the requirements for an EIA related to test mining be the same as those related to exploitation operations?
- How do site-specific EIAs link with regional and/or strategic environmental assessments (SEA) or management plans?

Acceptance of an agreed EIA process

This needs to balance existing procedures and regulations of the ISA, with accepted international "standards". An option is presented below. An issue to consider is that scoping for the EIA must occur as early in the process as possible, and the scoping report in this scheme is perhaps better sited at the start of exploration. The scoping should include a preliminary ERA (or some assessment of risk) to ensure that data collection will support the EIA in focusing on the key elements of impact.



S. Christiansen, July 2016
Possible EIA procedure for exploitation operations in ISA context. Steps are modified from UNEP/CBD/ SBSTTA/14/INF5, 2010, based on (Secretariat of the Convention on Biological Diversity and Assessment, 2006).

Role of the ISA Secretariat in reviewing EIAs

The Scientific Review and Public Consultation steps are clear in the overall process outlined above, but how these are actually undertaken is not. The role of the ISA as an involved, regulatory, or facilitatory body, needs clarification. It has been suggested (ISA, 2017) that a fundamental change in the ISA will be required to undertake a greater regulatory function. This will need to include a number of administrative tasks ranging from defining step-by-step EIA submission procedures, through to determining whether the detailed review process is undertaken by the (expanded) ISA Secretariat (an Inspectorate section), a contracted multidisciplinary panel of experts convened when required by the ISA, or tendered out to an independent review body.

Role of umbrella assessments and plans

Although SEAs and regional plans are a relatively new consideration in the context of deep-sea mining in the Area, they are an important context for multiple EIAs that may need to be considered together. Hence the procedural and institutional setting of these activities at different scales and involving different agencies needs to be clarified (links with background document on Regional Governance).

Technical aspects

There are a number of technical environmental conditions for entering into, and carrying out, an EIA process. These include the need for:

Adequate environmental baseline information

Baseline data collection, and short-term monitoring studies, are important aspects of exploration activities, as they underpin the preparation of an EIA, prior to any application for a full mining permit. It is expected that some information will be available from an area before any exploration occurs, and desk-top studies will form the basis of initial scoping of the activity/project. However, available data will invariably be inadequate to describe and characterise the receiving environment of any likely mining site. Hence baseline surveys and targeted scientific studies will be needed to provide the pre-mining state of the environment, as well as some monitoring of conditions over time to understand temporal variability of key environmental factors. Such studies will need to cover a wide range of research aspects, and be carried out using current "best practice" approaches and methods. The ISA has published two reports that describe and give some advice on the sorts of studies, type of data, and nature of sampling required for both baseline measurements and ongoing monitoring. These cover manganese nodule (ISA, 1999), seafloor massive sulphide, and cobalt-rich crust resources (ISA, 2007), with an additional report on sampling standardisation (ISA, 2002). Protocols and standards have also been reviewed as part of the European MIDAS project (Billett et al., 2015). These sources have been updated and reworked in an SPC-EU-NIWA report (Swaddling et al., 2016), and ISA recommendations are currently being considered by the LTC.

The role of test mining has also not yet been trialled. This is an important element of the transition from exploration to exploitation, as without it there can be only limited understanding of the likely nature and extent of impacts because the spatial scale of most potential mining operations is very large relative to exploration. However, while test mining can be an important contribution to understanding impacts, it will not provide all the solutions to address the long-term sustainability of deep-sea ecosystems in the mined region. A fundamental question is whether baseline data, which in the deep sea will typically be incomplete or limited, will be adequate to support a robust EIA. Knowledge uncertainty will need to flow through into measures to be adopted in the environmental management process (see also: background documents on Pilot Mining Tests and Adaptive Management).

Requirement for prior ecological risk assessment (ERA)

As described earlier, an important component of the EIA process is to ensure the EIA focuses on the main sources of impact, and does not spend undue time on elements of little risk. There are many approaches and methods to ERA. A realistic approach at the beginning of the exploration phase, given the often limited amount of information available, is to conduct a qualitative (Level 1) assessment in line with accepted standards (AS/NZS ISO 31000, 2009). This type of assessment commonly uses an expert panel to consider the likelihood of an impact occurring, and the consequences if it does (MacDiarmid et al., 2012). The results of this risk assessment should guide data collection during exploration activities, as a more quantitative assessment is likely to be required before progressing to a mining licence application stage. So a level 1 assessment identifies the main issues, and a level 2 assessment applies a more rigorous evaluation of those identified as high risk.

Other options that embed a risk assessment of some form include environmental assessment scoping reports, or environmental hazard and impact identifications (ENVID)to identify both accidental events and planned operational procedures related to a mining operation that can impact the environment (Recommended Practice DNVGL-RP-O601, 2016).

Desired formal structure of the EIA/EIS report

This can build on input from several reports and draft templates (Clark et al., 2014; ISA, 2012; ISA, 2017; Swaddling, 2016). A review of existing EIA guidance was undertaken by MIDAS (Billett et al., 2015). Recently, Clark et al. (2017) have updated the template and guidance to align with the 2016 Griffith-ISA workshop, and it will be an aim of the Berlin Workshop to finalize this draft template.

Acceptable content of an EIA

There has been a developing trend to widen the scope of EIAs, possibly at the expense of their focus and the quality of each component. This trend is the case, for example, in New Zealand where the expectation is that an " Impact Assessment" will include a "whole of environment" approach, with a balanced consideration of both biophysical and socio-economic impacts (including cultural), or a triangular "integrated assessment" (biophysical, societal, economic assessments)), plus using EIA to identify environmental limits and constraints on the project rather than just identifying the projects' impacts on the environment (Glasson et al., 2012). Draft templates (Clark et al., 2017; ISA, 2017; Swaddling, 2016) currently include "social impact assessment" as well as consideration of cultural and economic factors, although these are less developed and extensive than environmental impacts. These may be less important in the Area than in national situations, but this is something the ISA will need to consider with developing exploitation regulations.

Given the variability in environmental characteristics between resource types and locations, there is a careful balance required between EIA guidelines being highly prescriptive (which may not fit certain situations) and being too general (where adequate standards aren't clear). Clark et al. (2017) provide more explanation on what should be included under the template headings, useful data and information sources, and advice on a number of general issues across EIAs (such as uncertainty, cumulative impacts, adaptive management). It has a focus on New Zealand legislative requirements, but is intended also to apply more internationally, and could be a base document to consider.

Adoption of procedural checks to ensure EIA criteria are acceptable

The key principles and criteria of an EIA are often not fulfilled, and it is relatively straight forward for an applicant to keep in mind the basics of an EIA, and check them off as they review the application. An EIA should be:

- Purposive: be informative for decision-making
- Rigorous: apply best practicable science
- Practical: result in useful information and outputs
- Relevant: provide useable information
- Cost-effective: achieve EIA objectives within acceptable resource and time limits
- Efficient: process should minimise cost burdens
- Focused: concentrate on significant issues

- Adaptive: adjustable to the specific situation but not compromise the process
- Participative: inform and involve interested and affected parties
- Interdisciplinary: involve multiple techniques and experts across a range of fields
- Credible: a professional process, subject to independent checks/verification
- Integrated: interrelationships of social, economic and biophysical aspects
- Transparent: an open and informative process
- Systematic: consider all relevant information and options.

Need for a compulsory standard environmental monitoring programme during exploration, test mining and the exploitation phase

There are two "categories" of monitoring to consider:

- Operational monitoring: including mining or drilling location and rate, volumes discharged, hazardous discharge events and quantity of mined material removed.
- Effects monitoring: including physical (e.g., clarity, sediment deposition), chemistry (e.g., analytical suite of contaminants, zone of initial mixing for guideline comparisons, relevant water and sediment quality guidelines, bioaccumulation assessment) and biological monitoring (e.g., sentinel species, survey approaches).

The second, which is focussed on environmental aspects, can build on available environmental assessment guidance (ISA, 2013b)and more recent work. The main aspects to be included, and parameters to be measured, for both baseline and monitoring survey programmes are described in the guidelines on scientific research developed by the SPC-EU DSM project and NIWA (Swaddling et al., 2016). This report covers survey design, sampling equipment, and "best scientific practices" for deep-sea sampling relevant to marine minerals. A summary table from that report on recommended scientific studies, their rationale, and methods, is reproduced as Annex 2, which provides a starting point for determining the studies that need to be conducted for monitoring impacts and environmental changes.

Recommendations, including potential next steps

The workshop discussions will undoubtedly produce many good ideas and action points. However, the sessions are short, and the focus needs to be constrained. Several things for which clear recommendations and ways to define the issues include the points below grouped in 3 "similar" clusters:

Cluster 1: The EIA process and structure

- A defined/adopted EIA process that is consistent with ISA responsibilities and can be incorporated into the developing exploitation regulations. This may include revision of the process where it links with existing exploration regulations (e.g., inclusion of an initial scoping report, with a preliminary risk assessment). This can start with the process scheme above, and be compared with other options given in ISA (2017).

- An agreed list of preconditions required for entering into an EIA process. This would specify the outputs of work undertaken during exploration that are essential for a robust EIA to be carried out (e.g., baseline surveys, test-mining results).
- Clarity on what an EIA contains in terms of its general (not detailed) scope. Does the EIA focus on just environmental issues, extend to include a general account of social, economic and cultural aspects where appropriate, or expand further to encompass all types of assessments.
- Agreement on an EIA/EIS template (to match defined scope). This can be taken from the latest ISA report, and supplemented by NIWA guidelines (Clark et al., 2017; ISA, 2017).
- Clarification of roles of various end-users and interested parties in the EIA process, especially public engagement and review processes. The latter could include procedures for evaluation of the results of the EIA.
- Definition of the consequences of the evaluation of an EIA. This links with issues of how residual risks and general scientific uncertainty are managed in the environmental management plan process. It is a large issue, and beyond the scope of this workshop. However, a plan forward to address the issue could be discussed, and potentially terms of reference scoped out for a specific workshop.

Cluster 2: Environmental monitoring

- Definition of the general nature of baseline data required during exploration that will support the EIA. This can draw on recommendations from ISA, SPC-NIWA, and MIDAS reports. An important aspect is the importance of temporal changes, as these are as critical as description of the spatial characteristics of faunal communities.
- Specification of the general nature of a standard monitoring programme for test mining and exploitation phases. This aspect links with baseline data requirements, and defining key environmental indicators to measure, together with consideration of frequency and duration. This will be site specific, but general principles and approaches (e.g., BACI-before-after-control-impact) can be determined. Relevant to this is as part of a review of the CCZ EMP, a workshop was recommended by the LTC to investigate the survey design and sampling requirements for Impact Reference Zones and Preservation Reference Zones.

Both these are unlikely to be resolved in detail during the workshop, and could require a further workshop/s to consider the development of standard baseline and environmental monitoring schemes. Taking this forward will also require consideration of how much data are required to support a full "ecosystem approach" and move more towards ecosystem structure and function than partial community descriptions.

Cluster 3: Development of terms of reference for expert working groups to consider:

- Tools to be used for environmental assessment. How much can we standardise the collection field data (survey design, sampling gear) as well as modelling approaches (e.g., species distribution models, hydrodynamic oceanographic models), as promoted by ISA (2002) and Swaddling et al. (2016).
- Can key environmental indicators of impacts be defined, together with criteria for identifying them, thresholds of acceptable levels of change, and how to recognize and measure cumulative impacts.

- How to determine best environmental practice and best available technologies. In combination with the preceding aspects, can existing baseline data reports provide sufficient guidance on current best practice?
- What are appropriate impact minimization strategies, how much can be reduced by mine design and technology versus options of spatial management, how do response expectations get incorporated into adaptive management and environmental management plans?
- Managing uncertainty in the EIA and subsequent EMP design is a critical issue for deep-sea environments where data limitations will always exist. Linked with sessions on environmental standards and adaptive governance, options of functional ecosystem role (rather than species-level biodiversity), species distribution modelling, risk assessment, and adaptive management can be developed.
- Development of a standard environmental assessment and monitoring scheme, linked to some of the considerations above in Cluster 2, and addressing defining valid baselines, identifying appropriate monitoring indicators, guidelines for adaptive management in decision making during monitoring, and performance criteria.

The above bullet points can rapidly become a long wish-list of things that should be done to satisfy data requirements under a full ecosystem approach. The workshop can hopefully keep some of these issues in mind and develop a road-map for governments and the ISA to consider in progressing along a practical path that uses the suite of tools under ERA, EIA and EMP options to develop a robust assessment process.

References

AS/NZS ISO 31000. (2009) Risk management – principles and guidelines on implementation Standards New Zealand.

Ban N.C., Alidina H.M., Ardron J.A. (2010) Cumulative impact mapping: Advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study. Marine Policy 34:876-886. DOI: http://dx.doi.org/10.1016/j.marpol.2010.01.010.

Billett D., Jones D., Murphy K., Gjerde K., Calaco A., Morato T., Cuvelier D., Vercruijsse P., Rolin J.F., Ortega A. (2015) Review of existing protocols and standards applicable to the exploitation of deep-sea mineral resources. Deliverable 8.2 of MIDS project. pp. 148 p.

Burris R.K., Canter L.W. (1997) Cumulative impacts are not properly addressed in environmental assessments. Environmental Impact Assessment Review 17:5-18. DOI: http://dx.doi.org/10.1016/S0195-9255(96)00082-0.

CEAA. (2012) Canadian Environmental Assessment Act.

Clark M.R., Rouse H.L., Lamarche G., Ellis J.I., Hickey C. (2014) Preparing Environmental Impact Assessments: provisional guidelines for offshore mining and drilling in New Zealand, NIWA Client Report pp. 86.

Clark M.R., Rouse H.L., Lamarche G., Ellis J.I., Hickey C. (2017) Preparing Environmental Impact Assessments: General guidelines for offshore mining and drilling with particular reference to New Zealand, NIWA Science and Technology Series [https://www.niwa.co.nz/coasts-and-oceans/research-projects/enabling-management-of-offshore-mining]. pp. 107.

Coffey Natural Systems/Nautilus Minerals Ltd. (2008) Environmental Impact Statement. Solwara 1 Project. Volume A. Main report. pp. 226.

Crain C.M., Kroeker K., Halpern B.S. (2008) Interactive and cumulative effects of multiple human stressors in marine systems. Ecology Letters 11:1304-1315. DOI: 10.1111/j.1461-0248.2008.01253.x.

Darling E.S., Cote I.M. (2008) Quantifying the evidence for ecological synergies. Ecology Letters 11:1278–86.

Ellis J., Clark M.R., Rouse H., Lamarche G., Britton R. (2014) Enabling management of offshore mining literature review of environmental management frameworks, NIWA client report. pp. 89.

Ellis J.I., Clark M.R., Rouse H.L., Lamarche G. (2017) Environmental management frameworks for offshore mining: insights from experience in New Zealand's Exclusive Economic Zone. Marine Policy in press.

Glasson J., Therivel R., Chadwick A. (2012) Introduction to environmental impact assessment UCL Press Ltd, University College, London.

Husky Oil. (2001) White Rose Oilfield Comprehensive Study Report, Husky Oil Operations Ltd. pp. 94.

ISA. (1999) Deep-Seabed Polymetallic Nodule Exploration: Development of Environmental Guidelines, Report of an International Seabed Authority workshop. pp. 289.

ISA. (2002) Standardization of environmental data and information-development of guidelines. Proceedings of the ISA's workshop, Kingston, Jamaica, 25–29 June 2001, ISA, Kingston, Jamaica.

ISA. (2007) Polymetallic sulphides and cobalt-rich ferromanganese crust deposits: Establishment of environmental baselines and an associated monitoring programme during exploration International Seabed Authority; (http://www.isa.org.jm/en/documents/publications), Kingston, Jamaica. .

ISA. (2012) Regulations on prospecting and exploration for cobalt-rich ferromanganese crusts in the Area. International Seabed Authority, Kingston, Jamaica.

ISA. (2013a) Decision of the Council of the International Seabed Authority relating to amendments to the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area and related matters.

ISA. (2013b) Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area ISA.

ISA. (2017) Environmental assessment and management for exploitation of minerals in the Area. ISA Technical Study No 16:66.

MacDiarmid A., Beaumont J., Bostock H., Bowden D., Clark M., Hadfield M., Heath P., Lamarche G., Nodder S., Orpin A., Stevens C., Thompson D., Torres L., Wysoczanski R. (2012) Expert Risk Assessment of Activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf, NIWA Client report. pp. 106.

Petts J. (1999) Handbook of environmental impact assessment Wiley-Blackwell, Oxford, UK.

Rouse H.L., Norton N. (2010) Managing scientific uncertainty for resource management planning in New Zealand. Australasian Journal of Environmental Management 17:66-76.

Sadler B. (1996) Environmental assessment in a changing world: evaluating practice to improve performance, final report of the international study of the effectiveness of environmental assessment.

Senécal P., Goldsmith B., Conover S. (1999) Principle of Environmental Impact Assessment Best Practice. pp. 4.

Smit B., Spaling H. (1995) Methods for cumulative effects assessment. Environmental Impact Assessment Review 15:81-106. DOI: http://dx.doi.org/10.1016/0195-9255(94)00027-X.

Solan M., Whiteley N.M. (2016) Stressors in the Marine Environment Oxford University Press, Oxford, UK.

Swaddling A. (2016) Pacific-ACP States regional environmental management framework for deep sea minerals exploration and exploitation, Noumea. pp. 100.

Swaddling A., Clark M.R., Bourrel M., Lily H., Lamarche G., Hickey C., Rouse H., Nodder S., Rickard G., Sutton P., Wysoczanski R. (2016) Pacific-ACP States regional scientific research guidelines for deep sea minerals, Noumea. pp. 123.

US Department of Energy. (2004) Recommendations for the preparation of Environmental Assessments and Environmental Impact Statements.

Annex 1:

Tab. 1: Summary table of recommended scientific methodologies, including the aspect to be covered during the survey programme, parameters to be measured, and appropriate methods to consider given the local environmental conditions (Swaddling et al., 2016)

	Aspect	Reason	Main Parameters	Sampling
Geology	Topography	Seabed characteristics, classification of habitats for assessment, survey stratification, selection of test and control areas	Bathymetry, morphometry, seafloor type	Shipboard/towed acoustic systems, optical sensors, dredges, box-corer, drilling equipment
	Backscatter	Seabed characteristics, classification of habitats for assessment, survey stratification, selection of test and control areas	Acoustic reflectivity	Shipboard/towed acoustic systems; sidescan sonar, hyperspectral imaging
	Sub-seafloor	Petrology, geochemistry, and mineralogy for resource characterisation	Penetration layers, rock properties, mineral and chemical composition	Seismic, drilling, rock sampling (dredges, coring)
Sediment characteristics	Sediment properties	Sediment plume dynamics, classification of habitats	Substrate type, sediment and pore water measurements: water content, grain size, specific gravity, porosity, depth of oxic layer, carbon content, chemical composition (trace and heavy metals)	Sediment cores (box corer or mulitcorer)
	Bioturbation rates	Natural mixing of sediments	Bioturbation depth, faunal zonation, Pb210 activity	Sediment cores (box corer or mulitcorer)

	Sedimentation rates	Distribution and concentration of natural suspension, settlement rates	Particle flux, suspended particle concentrations, settlement rates	Moorings and sediment traps
Pelagic community	Deepwater pelagic (plankton and nekton)	Impacts of sediment plume and discharges on midwater communities, vertical migrators, and near-bottom hyper-benthos	Species composition, distribution, abundance. Biological characteristics (sensitivity, recoverability parameters)	Opening/closing nets for plankton (Remotely Operated Vehicle (ROV) also possible). Pelagic trawls/commercial records for fish
	Surface fauna	Effects of surface discharges, presence of vessels and equipment	Species composition, distribution, abundance. Biological characteristics (sensitivity, recoverability parameters)	Opening/closing nets, surface plankton nets, remote-sensed data
	Marine mammals/sea birds	Effects of surface discharges, presence of vessels and equipment	Species composition, distribution, abundance. Biological characteristics (sensitivity, recoverability parameters)	Marine Mammal Observer protocols
Seafloor community	Megafauna	Impacts on benthic communities	Species composition, distribution, abundance. Biological characteristics (sensitivity, recoverability parameters)	Photographic surveys from ROV/towed camera; direct sampling from dredge/sled/trawl/ROV
	Macrofauna	Impacts on benthic communities	Species composition, distribution, abundance. Biological characteristics (sensitivity, recoverability parameters)	Muliticorer or box corer, and epibenthic sled; photographic surveys from ROV/towed camera; direct sampling from dredge/sled/trawl/ROV

	Meiofauna	Impacts on benthic communities	Biodiversity, distribution, abundance	Multicorer or box corer; direct sampling from dredge/sled/trawl/ROV
	Microfauna	Impacts on benthic communities	Biodiversity, distribution, abundance	Sediment cores (box corer or mulitcorer)
	Specific resource fauna	Endemic species or communities, sensitive habitats (including biogenic habitats)	Species composition, distribution, abundance	ROV/towed camera, epibenthic sled; direct sampling by ROV, box corer for nodule environments
	Scavenger/demersal fish	Impacts on benthic communities	Species composition, distribution, abundance	Baited lander, fish trawls, traps, ROV observations
	Ecotoxicity	Impacts of heavy metals/contaminants on benthic communities, accumulation through food chain potential	Tissue samples from representative and abundant fauna	Various direct sampling methods (as above)
Physical oceanography	Currents	Dispersal of impacts, biological connectivity	Current speed, direction, depth variation, tidal dynamics, Sea Surface Temperature (SST), Sea Surface Height (SSH), ocean colour	Conductivity Temperature Depth profiler (CTD), current meters, Acoustic Doppler Current Profiler (ADCP), remote-sensed data, profiling moorings
	Hydrodynamic modelling	Dispersal of impacts, sediment plume dynamics, biological connectivity	Oceanographic parameters (temperature, salinity, current flow and direction), turbulence, turbidity, bathymetry	Various models applicable: e.g. Regional Ocean Modelling System (ROMS), Hybrid Coordinate Ocean Model (HYCOM), CORMIX (discharges)

Chemical oceanography	Water quality	Effects of discharges, sediment plume	Chemical composition (including heavy metals and toxic contaminants), turbidity, suspended sediment, dissolved oxygen, pH	Water samples (from CTD), surface remote-sensed data, core samples, nephelometer, transmissiometer, optical backscatter sensors
	Visual characteristics	Effects of discharges, sediment plume	Optical backscatter, light attenuation, black disc distance	Transmissiometer, optical backscatter sensors, remote sensing
	Bottom water chemistry	Effects of sediment/rock disturbance, release of chemicals, effluent discharge	Elutriation for chemical and toxicity testing, pH, trace and heavy metal concentrations, dissolved oxygen	Water samplers (CTD-Niskin bottles), core samples
	Water column chemistry	Effects on chemical characteristics due to sediment plume and discharges	Nutrients (P, N, Si, C), dissolved oxygen, trace and heavy metal concentrations	Water samplers (CTD-Niskin bottles)