



PACIFIC-ACP STATES REGIONAL SCIENTIFIC RESEARCH GUIDELINES FOR DEEP SEA MINERALS

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PACIFIC-ACP STATES REGIONAL SCIENTIFIC RESEARCH GUIDELINES FOR DEEP SEA MINERALS

Prepared under the SPC-EU EDF10 Deep Sea Minerals Project, by the Pacific Community (SPC) and the National Institute of Water and Atmospheric Research (NIWA) of New Zealand



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The authors of this Pacific-ACP States Regional Scientific Research Guidelines for Deep Sea Minerals are:

- Alison Swaddling (SPC)
- Malcolm Clark (NIWA)
- Marie Bourrel (SPC)
- Hannah Lily (SPC)
- Geoffroy Lamarche (NIWA)
- Chris Hickey (NIWA)
- Helen Rouse (NIWA)
- Scott Nodder (NIWA)
- Graham Rickard (NIWA)
- Philip Sutton (NIWA)
- Richard Wysoczanski (NIWA)

FOREWORD

With increasing anthropogenic pressures on ocean environments, it is now more important than ever to conserve and sustainably use the oceans, seas and marine resources. This is clearly acknowledged by the United Nations General Assembly in its annual resolutions on oceans and the law of the sea, the 2012 United Nations Conference on Sustainable Development, the Small Island Developing States Accelerated Modalities of Action (SAMOA) Pathway adopted in 2014 and, more recently, by the Sustainable Development Goals. This is vitally relevant to Pacific Island States, which have vast ocean areas already contributing to national economies through fisheries, tourism, maritime transport and trade.

Ocean policy and management is best implemented when adequately informed by science. Science is an important component, providing input to many areas concerning the sustainable use of marine resources, such as through environmental impact assessments, monitoring, enforcement and conservation.

With interest in deep sea minerals (DSM) resources in the Pacific Islands region, there is a pressing need for strong scientific research in the deep-sea environment. This is becoming increasingly crucial to fill knowledge gaps about potential human impacts on deep-sea ecosystems, and allow informed decisions to be made that enable Pacific Island countries to effectively govern and administer these resources.

While it is clear that more, and ongoing deep sea research is needed, many Pacific Island States may not currently have the capacity to perform such research. Under the United Nations Convention on the Law of the Sea, States and competent international organisations have an obligation to promote and facilitate marine scientific research; for example by an academic institution. They also have the prerogative to decide if they wish to allow commercial prospecting and exploration. As most deep sea research on deep-sea mineral resources and ecosystems is likely to be conducted by external parties, it is essential that national guidelines, policies and/or legislation be put in place to facilitate this research to ensure it is performed to standards suitable for informing national and regional decisions.

It is anticipated that the Regional Scientific Research Guidelines will assist Pacific-ACP States by providing an overview of key legal and science considerations that are necessary for national legal and technical instruments. Importantly, the guidelines will also be available to a wider audience, including scientific researchers to assist them in the adoption and undertaking of current best practices in DSM scientific research. It is part of the DSM management series of frameworks.

It is our fervent hope that this document will be used extensively by Pacific-ACP States and will significantly contribute to the responsible and sound management of DSM research in the region.

M. J. Petterson

Professor Michael Petterson Director, Geoscience Division Pacific Community

Dr Rob Murdoch General Manager, Research National Institute of Water and Atmospheric Research

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ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
ABNJ	Areas Beyond National Jurisdiction
ACP	African Caribbean Pacific
ADCP	Acoustic Doppler Current Profiler
AS/NZS	Australian and New Zealand risk assessment standard
ATP	Adenosine Triphosphate
AUV	Autonomous Underwater Vehicle
CBD	Convention on Biological Diversity
CCZ	Clarion-Clipperton Zone
CDOM	Coloured Dissolved Organic Matter
COP	Conference of Parties
CRC	Cobalt Rich Crusts
CS	Continental Shelf
CTD	Conductivity Temperature Depth
DGT	Diffusive Gradients in Thin Films
DISCOL	Disturbance and Recolonisation
DOALOS	(United Nations) Division for Ocean Affairs and the Law of the Sea
DSM	Deep Sea Minerals
DTM	Digital Terrain Model
DVM	Diel Vertical Migration
EAM	Ecosystem-based approach to management
ECS	Extended Continental Shelf
EDS	Energy Dispersive Microanalyser
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ENSO	El Niño–Southern Oscillation
EPMA	Electron Probe Microanalyses
ERA	Environmental Risk Assessment
EU	European Union
FFA	Forum Fisheries Agency
FIA	Flow Injection Analysis
GOTM	General Ocean Turbulence Model
HYCOM	Hybrid Coordinate Ocean Model

IEC	Ion Exchange Chromatography
IMMS	International Marine Minerals Society
IOC	Intergovernmental Oceanographic Commission of the UNESCO
IPO	Interdecadal Pacific Oscillation
IRMS	Ratio Mass Spectrometer
ISA	International Seabed Authority
JGOFS	Joint Global Ocean Flux Study
JNCC	Joint Nature Conservation Committee
LA-ICPMS	Laser Ablation (LA) Inductively Coupled Plasma (ICP) Mass Spectrometer (MS)
MBES	Multibeam Echo-Sounders
MMO	Marine Mammal Observer
MN	Manganese Nodules
MOCNESS	Multiple Opening/Closing Net and Environmental Sensing System
MSR	Marine Scientific Research
NIWA	National Institute of Water and Atmospheric Research, New Zealand
OBS	Optical Backscatter
OSPAR	The Convention for the Protection of the marine Environment of the North-East Atlantic
OTU	Operational Taxonomic Units
PICs	Pacific Island countries
POC	Particulate Organic Carbon
PON	Particulate Organic Nitrogen
QA	Quality Assurance
ROMS	Regional Ocean Modelling System
ROV	Remotely Operated Vehicle
RSRG	Regional Scientific Research Guidelines
S.A.M.O.A.	SIDS Accelerated Modalities of Action
SIDS	Small Island Developing States
SMS	Seafloor Massive Sulphides
SPC	The Pacific Community
SSH	Sea Surface Height
SST	Sea Surface Temperature
SVP	Sound-Velocity Profiles
UNCLOS	United Nations Convention on the Law of the Sea
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNGA	United Nations General Assembly

USBL	Ultra-Short Baseline
US EPA	United States Environmental Protection Agency
USP	University of the South Pacific
WDS	Wavelength Dispersive Spectrometer
XRF	X-Ray Fluorescence

EXECUTIVE SUMMARY

DSM scientific research¹ plays a critical role in the sustainable development of the oceans and their resources, including by supporting informed decisions on their conservation and sustainable use. Many Pacific Island countries (PICs) are approached by third parties, whether scientific institutions or commercial enterprises, seeking permission to conduct scientific research related to deep sea minerals (DSM) within their national waters. There are important considerations and international standards that PICs should take into account when issuing such permission, and in ongoing supervision of such research activities. Many PICs do not currently have clear written national rules and procedures to govern these processes.

These guidelines provide regulatory advice and practical scientific methodology – the combination of which support a thorough understanding of DSM scientific research and enable informed development of national guidelines/regulations and decisions. The content is based on a combination of existing literature (especially several documents produced by the International Seabed Authority); the authors' experiences with assisting PICs in the development of relevant regulatory frameworks for sustainable management of DSM activities and; scientific research carried out in the deep sea, with various mineral resources, as well as discussion with PICs as to their needs and requirements.

The guidelines focus on the three resources of most commercial interest in the Pacific region: manganese nodules, seafloor massive sulphides, and cobalt-rich crusts. This commercial interest is recognised as a key driver for DSM scientific research.

National rules should set out what DSM marine research will be permitted and what procedure should be followed by the researcher. Governments typically wish to be informed and involved with activities taking place within national maritime jurisdiction, to ensure such activities are restricted to acceptable environmental impacts. This also ensures the inclusion of information-gathering that can assist environmental management work in the future, and secure national access to the scientific information and any financial benefits, arising from such research. The applicable international law requirements for DSM scientific research differ depending on who the researcher is, what they want to do and where the activities are going to be conducted (within areas of national jurisdiction or beyond). National permission and management of activities may also differ accordingly. Table 1 provides a summary of these components. Templates for a permit application form (Annex 1), a Marine Scientific Research (MSR)/prospecting permit (Annex 2) and an exploration licence (Annex 3) are provided, in which PICs can use to develop national templates.

Science is a critical component that informs policy development, regulatory decisions, monitoring, and conservation objectives. It is important for PICs to gather baseline information on their DSM resources. Understanding the existing environment is crucial if States wish to engage with deep sea mining in the future. Having such information streamlined and accessible can enable informed decision making if applications for deep sea mining are received. Having a detailed understanding of the scientific process and current best practice will enable PICs to make appropriate determinations of proposed DSM scientific research programs, as well as assist in the review of submitted data and reports. Many core scientific requirements are common to the three mineral types, and a major section of the report describes aspects of fundamental survey design, emphasising the need to have clear objectives, which then dictate aspects such as sampling scale, spatial design, sampling unit size, sample number, and sampling gear. Annex 4 provides current best practice methodology for conducting scientific research, which when adopted into national rules, and followed by researchers, enables PICs to have greater confidence in the quality of data collected, and the robust nature of the scientific research carried out during exploration activities. It is also recommended that PICs require preliminary environmental impact assessments/risk assessments prior to issuing permits/licences as this is a key component of the approvals process and informed decision making.

¹ For the purpose of these Guidelines DSM scientific research means all scientific research and investigations conducted at deep sea mineral sites during marine scientific research, prospecting or exploration.

The desired outcomes of this document are that policy makers and regulators are more familiar with international requirements and scientific standards, and that the value of science in the policy making process is entrenched.

Key recommendations for PICs are given throughout the document and include:

- Put in place strong and effective legislation through which the role and responsibilities of the DSM operators and relevant national agencies, as well as terms and conditions, for operating in the EEZ or continental shelf beyond 200 nm are clearly set;
- National DSM regulatory regimes should contain provisions reflecting this set of general obligations with particular consideration for art.249 of UNCLOS, noting limitations to protect proprietary confidential information;
- Ensure that safeguards are made available for Governments to sanction any breach to the terms of the DSM research title (MSR or prospecting permit or exploration licence); and
- Compliance and reporting in relation to conventions governing areas beyond national jurisdiction (UNCLOS, CBD, Noumea).

	REGULATORY CONSIDERATIONS	Considering that States are obliged under international law to facilitate MSR, it is commonly agreed that there is a presumption towards permitting an MSR application; however, it is important to ensure that:	MSR activities are conducted with minimal environmental impact in accordance with international law and national environmental regulations, and exclusively for peaceful purposes; and	 cruise reports and the research data is shared back with government, and is able to be internationally published. 	MSR in the Area does not require a permit. However, if the area of research is inside an existing licensed area issued by the International Seabed Authority (ISA).	MSR shall be carried out (United Nations Convention on the Law of the Sea's (UNCLOS') requirements):	 exclusively for peaceful purposes; 	 for the benefit of mankind as a whole; 	 in accordance with other relevant parts of UNCLOS governing MSR and other international and national laws and regulations on the protection and preservation of the marine environment; and 	 where results of research and analysis shall be effectively disseminated when available through the ISA or other international channels when appropriate.
	WHERE	Exclusive Economic Zone (EEZ) / CS			The Area					
egulatory components.	WHAT	Marine scientific research (does not constitute the legal basis	tor any claim to any part of the marine environment or its resources likely to be small-scale lower-impact activities)							
Table 1. Summary of re	OHM	ÐS	r to increas	in orde)	noitutiten egnibnit da Wond aititi	i oimeba researr nal scien	Ac Vublish Proation	to ta afri	i mis əzorlı	ν)

	(See above)	There is no international law requirement for a government to facilitation prospecting and/or exploration; this will be a matter of individual nation policy for each country. However signatories to UNCLOS are bound by	UNCLOS to implement environmental protection and preservation measure and capacity building and data sharing at least up to the standards of th	ISA.	Where permitted, it will be important for governments to ensure that:	 the activities are conducted so as to protect the marine environment, accordance with international law and national mining and environment, regulations: and 	• the second data are chosed that was an and and the the	 The research data are shared back with government, and any data in are not confidential (for commercial reasons) are able to be international published. 	Where higher-impact activities are envisaged (e.g. an exploration project or proof-of-concept test mine that will involve large-scale sampling of miner ore), proportionately higher levels of regulation and monitoring will be required	 Activities in the Area may only be carried out under a contract with the ISA 	 Prospecting or exploration in the Area can only be carried out by the State Parties to UNCLOS, or State enterprises, and natural and juridic persons sponsored by a State Party. 	 Prospecting and exploration in the Area may only take place accordance with Part XI of UNCLOS and the rules, regulations an procedures of the ISA.
						EEZ / CS				The Area		
MSR	(to find minerals deposits for further mining at a profit potentially	institutions)		Prospecting	(seeking potential mineral deposits	 - usually over a wide area, and likely to be small-scale lower-impact activities) 	Exploration	(conducting in-depth research at a specific DSM deposit site	to determine economic viability and environmental baselines. An exploration permit provides exclusive rights over the site, and a	preretential right to apply for mining of the site, in the future)		
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INTRODUCTION

1 Background

The international community has prioritised the importance of conserving the ocean and its living resources. Many national and regional agencies acknowledge that protection and sustainable use of the ocean is best served by a fundamental understanding of its complex systems, and this can only be achieved through robust marine research. Despite their global significance, there is a basic lack of knowledge about deep sea minerals (DSM) geology, the processes responsible for creating the various habitats within which they occur, and the structure and function of associated deep-sea ecosystems.

As a consequence, the role of scientific research is critical for describing the physical and biological nature of the environment to inform decision-makers, and to assist with the development of impact mitigation strategies and effective environmental management plans for any proposed DSM activities, including mining. Collection of data about the environment before any impacts occur is necessary in order to be able to measure and understand the effects and, accordingly, anticipate the potential risks and liabilities or costs that may arise.

Additionally, laws and regulations influence how scientific research is to be conducted and, as such, the two components are inextricably linked.

For the purpose of these guidelines, 'DSM scientific research' means any scientific research and investigations conducted at DSM sites, including marine scientific research, prospecting and/ or exploration. Such activities are conducted with the purpose to find and understand mineral deposits for future mining at a profit.

2 Deep-sea minerals

DSM resources occur within the national jurisdiction of many Pacific Island countries (PICs), and are increasingly being regarded as a future source of revenue and economic development. There are three main mineral types of interest; seafloor massive sulphides (SMS)², manganese nodules (MN)³, and cobalt-rich ferromanganese crusts (CRC) (See Table 2).

Table 2. A summary of characteristics of the three major marine mineral deposits. Source SPC.									
	SMS	MN	CRC						
Occurrence	Mid-ocean ridges, and fore-arc and back-arc basins	Deep ocean basins	Summit and slope of seamounts, as well as flanks of volcanic islands						
Form	Massive sulphide and oxide deposits on the seafloor and seabed sub-surface	Potato-sized Nodules and encrustations	Thin encrustation on the rock surface						
Depth (m)	1,500 – 5,000	4,000 - 6,000	400 - 4,000						
Thickness	10s of metres	Top 10 cm	Patchy, up to 25 cm						
Extent	100s of metres	1000s of metres	100s of metres						
Major Minerals	Copper, Lead, Zinc	Manganese, Iron	Manganese, Iron						
Minor Minerals	Gold, Silver	Nickel, Copper, Cobalt	Nickel, Cobalt, Platinum						

The distribution of these resources varies between countries (Figure 1). In addition, their physical and chemical characteristics, as well as ecological and biological environments can differ. This has important implications for the type of research that is required, and the ways in which it will be carried out.

SMS are also known as polymetallic sulphides in other literature

MN are also known as polymetallic nodules in other literature

More detail in relation to the different DSM deposit types and associated environmental issues can be found in the SPC-EU DSM Project/UNEP-Grid Arendal reports 'Deep Sea Mining', available online: http://gsd. spc.int/dsm/index.php/publications-and-reports.



Figure 1. Deep sea environments associated with the three types of mineral deposits found in the western Pacific. The abyssal areas – where manganese nodules may be found, seamounts – where ferromanganese crusts can form, and hydrothermal vents – the site of seafloor massive sulphides. Source SPC.

3 Drivers for DSM scientific research

DSM scientific research is largely driven by the potential for future deep sea mining. Commercial companies wish to locate potential sites, determine the extent of mineral deposits and define existing environmental baselines in order to assess potential environmental impacts. Academic research institutions are interested in continuing to gather information about these environments and the potential effects of mining to answer fundamental questions and increase general knowledge.

There is growing literature on the potential impacts of mining operations in the deep sea (e.g. Morgan et al. 1999, Ellis 2001, ISA 2007, Smith et al. 2008a, Fukushima & Okamatsu 2010, Boschen et al. 2013, and papers therein). These impacts are summarised in Table 3 and are often drivers for research.

Acknowledging the lack of resources of developing countries, international law provides incentives and mechanisms for PICs to engage in DSM related activities, i.e. exploration and marine scientific research with the view of developing exploitation of DSM in the Area through the International Seabed Authority (see section 4.3 of Part 1).

Table 3. A selec	ction of key deep-sea mining environmental impacts. (based on Clark et al. 2014).
Location	Impact
e)	Increased vessel activities and potential pollution (includes risks associated with extreme weather events and accidents)
Surface	Reduction in primary production through shading by return-water discharges (if near-surface discharges occur in photic zone)
0,	Effects on behaviour of surface mammals, fish and birds through changes in water composition and clarity, noise and lights from vessel activity
_	Effects on behaviour of mammals, mesopelagic or migratory fish and plankton through changes in water composition (such as chemical contamination) and clarity
Jum	Bioaccumulation of toxic metals though food chain
col	Sediment plume through water column from seafloor operations or midwater discharges
/ater	Local changes in pH
3	Nutrient and trace mineral enrichment (if near-surface discharges occur in photic zone)
	Potential oxygen depletion
	Direct physical impact of mining/sampling gear
	Smothering/burying of animals by sediment
oor	Change in seafloor sediment characteristics post mining (e.g. removal of hard substrate suitable for attached species colonisation)
beafl	Clogging of suspension feeders
0)	Toxic effects with metal release (and other contaminants)
	Loss of essential habitat (spawning/nursery grounds)
	Likely time periods for recolonization and recovery of key species groups

4 General principles

There are a number of general overarching principles that should guide the conduct of marine scientific research (MSR) and form the framework of these guidelines.

First, under the United Nations Convention on the Law of the Sea (UNCLOS), marine scientific research should be conducted in accordance and compliance with all relevant national or regional policies and regulations (see Part 1 of these Guidelines).

Second, the impact of many scientific activities on the marine environment is likely to be low in comparison to the potential disturbance from natural processes (e.g. volcanic event, earthquakes, landslides) or other human activities (mining, fishing, etc.). Nevertheless, research activities may have significant impacts on a small and localised scale, or cause unforeseen effects. Hence, the Precautionary Approach should also be applied to scientific activities if their nature or scale is likely to have substantial environmental implications.

Third, scientific research should apply the best practical procedures for collecting the required data and information without causing excessive impact (e.g. IMMS 2011).

Fourth, scientific research is both a prerequisite and an integral component of the ecosystembased approach to management (EAM). This requires that research should be designed and carried out to integrate information from a range of disciplines, across different levels of ecological organisms, and from a range of temporal and spatial scales (e.g. SPC 2013a).

Fifth, marine scientific research should, where appropriate, be carried out in a cooperative manner, involving industry, government, and other stakeholders (e.g. Madang Guidelines, SOPAC 1999).

5 This document

The Pacific Community (SPC), through the SPC-European Union (EU) Deep-Sea Minerals Project (DSM Project), has collaborated with the National Institute of Water and Atmospheric Research (NIWA) of New Zealand in the development of this document, the Pacific-ACP States Regional Scientific Research Guidelines for Deep Sea Minerals (RSRG). The RSRG is part of a group of frameworks for DSM management developed over the years by the SPC-EU DSM Project (See Box 1).

The goal for this guideline is to inform PICs in the development of their respective national marine scientific guidelines and/or regulations aimed to ensure that activities relating to DSM scientific research within national jurisdiction are performed in accordance with international standards and best practice.

It is designed to assist governments to manage such activities within national jurisdiction and ensure environmental research is conducted to appropriate scientific standards that can ultimately inform a robust Environmental Impact Assessment (EIA). It is not intended to lay out a comprehensive ecosystem-level scientific research plan, but focuses on guidance for the collection of essential baseline data and initial monitoring that should be performed to underpin the subsequent preparation of an EIA. The guidelines are not prescriptive in their detail, but are designed to support the formulation of a scientific work plan for DSM that will (i) be appropriate to the particular resource and site characteristics, (ii) can be tailored to available resources, (iii) and will be scientifically sound in a broader regional context.

Drawing from international law and best-practice, these guidelines aim to set out parameters for the regulation and management of DSM scientific research projects. These guidelines are meant to be used by Pacific Island governments (technical officers, decision-makers) that want to permit DSM scientific research activities in their waters, by providing them with a legal and scientific foundation of knowledge. The guidelines are designed to inform and operate alongside national policy and laws about DSM development, environmental management, and marine space management.

Box 1. Documents in the DSM Management Series.



Regional Financial Framework (RFF)⁵



Fiscal regime and revenue management options. It covers design, establishment of regimes that integrates planning and budgeting, and strengthening of existing mechanisms, as well as the importance of sovereign wealth funds.

Regional Legal and Regulatory Framework (RLRF)⁴

Overview of the relevant legal framework for DSM, with a particular emphasis on the Pacific region. Clear and comprehensive guidance for interested States to make informed decisions, develop robust regulatory regimes and facilitate harmonisation of national approaches throughout the region.

Regional Environmental Management Framework (REMF)⁶



Overview of DSM environments, potential impacts, strategic and project-specific environmental management components which States can implement, including a template for environmental impact assessment report. Regional Scientific Research Guidelines (RSRG)⁷



Scientific and regulatory guidelines for establishing national guidelines and/ or regulations for marine scientific research, prospecting and exploration activities, relating to deep sea minerals research.

- ⁴ SPC (2012). Pacific-ACP States Regional Legislative and Regulatory Framework for Deep Sea Minerals Exploration and Exploitation. Secretariat of the Pacific Community. http://dsm.gsd.spc.int/public/files/2014/RLRF2014.pdf
- ⁵ SPC (2016). Pacific-ACP States Regional Financial Framework for Deep Sea Minerals Exploration and Exploitation. Pacific Community. http://dsm.gsd.spc.int/images/public_files_2016/RFF2016.pdf
- ⁶ SPC (2016). Pacific-ACP States Regional Environmental Management Framework for Deep Sea Minerals Exploration and Exploitation. Pacific Community. http://dsm.gsd.spc.int/images/public_files_2016/REMF2016.pdf
- ⁷ SPC (2016). Pacific-ACP States Regional Scientific Research Guidelines for Deep Sea Minerals. Pacific Community. http:// dsm.gsd.spc.int/images/public_files_2016/RSRG2016.pdf

PART 1: LEGAL CONSIDERATIONS

1 Introduction

UNCLOS establishes that States have sovereign rights over the DSM located within the seabed underlying their country's waters. However, under international law⁸, States also have obligations, including duties to (SPC 2012):

- protect and preserve the marine environment and rare or fragile ecosystems and habitats;
- prevent, reduce and control pollution from seabed activities, or caused by ships, or by dumping of waste and other matter at sea;
- prevent trans-boundary harm;
- conserve biodiversity;
- employ best environmental practice⁹;
- apply the Precautionary Approach¹⁰;
- conduct prior environmental impact assessment of activities likely to cause significant harm;
- take measures for ensuring safety at sea; and
- for activities undertaken in the EEZ, not interfere with rights and freedoms of other States, such as the installation of submarine pipelines and cables, and marine scientific research, unless this interferes with the sovereign rights of the coastal States for the purpose of exploring, conserving and managing their natural resources (living and non-living)¹¹.

Under international law, it is of critical importance for governments to exercise effective control over any prospecting and exploration activities within their national jurisdiction and on DSM vessels flying their flag, operating on the high seas, by way of laws and rules which are implemented, monitored and enforced. The aim is to both minimise the risk of unacceptable damage to the environment or to human health and safety, and to reduce the government's exposure to liability for damages, should such incidents occur. These guidelines seek to provide some guidance on how such regulation may be approached.

Box 2. The United Nations Convention on the Law of the Sea - UNCLOS

UNCLOS is the result of the third United Nations Conference on the Law of the Sea, which occurred between 1973 and 1982 and the culmination of over 14-years work by more than 150 countries from around the world.

UNCLOS was opened for signature on 10 December 1982 and came into force on 16 November 1994.

UNCLOS sets out a comprehensive regime of law and order, which defines the rights and responsibilities of States for the world's oceans and seas. It addresses sovereignty, rights of usage in maritime zones, navigational rights, marine scientific research, economic and commercial activities, conservation and usage of resources in the marine environment and the settlement of disputes relating to ocean matters.

As at February 2015, 167 parties (166 States and the European Union) have ratified, acceded to or succeeded to UNCLOS.

All PICs have ratified UNCLOS and have enacted legislation to make its main provisions effective (such as delimitation of maritime boundaries, marine pollution, fisheries, protection and preservation of the marine environment, etc.).

¹⁰ Ibid. See also the SPC-EU DSM Project Information Brochure on the application of the precautionary principle: http://gsd. spc.int/dsm/images/pdf_files/dsm_brochures/DSM_Brochure13.pdf

⁸ Including those contained in UNCLOS, the 1986 Noumea Convention, the 1992 Convention on Biological Diversity, and various treaties administered by the International Maritime Organization, e.g. Convention for the safety of life at sea ('SOLAS') and for the prevention of pollution from ships ('MARPOL').

^a More discussion of this duty can be found in the Advisory Opinion of the Seabed Disputes Chamber of the International Tribunal on the Law of the Sea (Case no. 17): www.itlos.org/index.php?id=109&L=0.

¹¹ UNCLOS, art. 56 and 58.

2 General provisions of UNCLOS

UNCLOS (art. 240) identifies several general principles for the conduct of MSR, including that MSR must:

- be conducted exclusively for peaceful purposes;
- be conducted with appropriate scientific methods and means compatible with UNCLOS;
- not unjustifiably interfere with other legitimate uses of the sea compatible with UNCLOS; and
- be conducted in compliance with all relevant regulations adopted in conformity with UNCLOS, including those for the protection and preservation of the marine environment.

Additionally, MSR activities shall not constitute the legal basis for any claim to any part of the marine environment or its resources (UNCLOS, art. 241). This echoes similar principles that can be found in UNCLOS, establishing the non-appropriation of the high seas¹² and the Area¹³.

Furthermore, UNCLOS expressly provides the right for all States, irrespective of their geographical location, and competent international organisations¹⁴ to conduct MSR¹⁵. However, such right is not absolute as it is subject to the rights and duties of other States, as provided for in UNCLOS (Caflisch and Piccard 1976; Pavliha and Martinez Gutierrez 2010).

3 The Importance of establishing maritime boundaries

Exercising effective control over any MSR or DSM activity that may be carried out within their national jurisdiction is key for all governments. It is, therefore, important that national maritime boundaries are formally established and declared. In the absence of such legitimation, any national regulatory regime governing research activities within national maritime jurisdiction, may present incertitude and ambiguity that may lead to conflicting actions. In some cases, such a situation might potentially lead to a dispute with another State, and possibly result in proceedings before an international court or tribunal.

UNCLOS defines zones of areas (Figure 2) measured from the State's baseline (territorial sea, EEZ) or continental shelf (CS) contours that have differing implications for regulation of research activities (DOALOS, 1989).



¹² UNCLOS, art. 89 and 90.

¹⁴ Although the term 'competent international organizations' is not defined by UNCLOS, it is commonly agreed that it includes intergovernmental organizations, which are empowered by their constituting instruments or other rules to undertake, coordinate, or promote and facilitate the development and conduct of MSR (DOALOS, 2010). An indicative list of such organizations is provided in Annex VIII, art. 2 of UNCLOS.

¹³ UNCLOS, art. 137 (1) and (3).

¹⁵ UNCLOS, art. 238.

4 Specific rules for defined maritime areas

4.1 Internal waters, archipelagic waters and in the territorial sea

Coastal States, in the exercise of their sovereignty, have exclusive rights to regulate, authorise and conduct MSR in their internal waters and in their territorial sea. Therefore, MSR activities carried out within these areas may only be conducted with the express consent of, and under the conditions set by, the coastal States through the relevant national legislation¹⁶.

In straits used for international navigation and in archipelagic sea lanes, foreign vessels (including MSR and hydrographic survey vessels) cannot carry out any research or survey activities without the prior authorisation from the States bordering straits during their transit passage¹⁷ or archipelagic sea lanes passages¹⁸.

4.2 The EEZ and the Continental Shelf beyond 200 nm

Coastal States, in the exercise of their jurisdiction, have exclusive rights to regulate, authorise and conduct MSR in their EEZ and continental shelf (CS) beyond 200 nm. MSR activities in these areas can only be conducted with the consent of the coastal State¹⁹.

It is worth noting that UNCLOS explicitly states that it is the duty of any coastal State to grant consent to MSR activities to be carried out in these areas in order "to increase scientific knowledge of the marine environment for the benefit of all mankind²⁰. However, UNCLOS acknowledges the right of any coastal State, in its discretion, to withhold its consent to the conduct of MSR activities in its EEZ or CS beyond 200 nm in four specified cases²¹, which are if the MSR project:

- (i) is of direct significance for the exploration and exploitation of natural resources, whether living or non-living resources²²;
- (ii) involves drilling into the continental shelf, the use of explosives or the introduction of harmful substances into the marine environment;
- (iii) involves the construction, operation or use of artificial islands or stationary (fixed or anchored) installations and structures²³; and
- (iv) contains information communicated pursuant to the requirement of UNCLOS²⁴, regarding the nature and objectives of the project which is inaccurate or if the researching State or competent international organisation has outstanding obligations to the coastal State from a prior research project.

States and competent international organisations that intend to undertake MSR in the EEZ or CS beyond 200 nm of a coastal State are required by UNCLOS to provide the coastal State a full description of the research project required under UNCLOS (Box 3) not less than six months before the starting date of the MSR activities. All communications are to be made

- ¹⁹ UNCLOS, art. 246 (1) and (2).
- ²⁰ UNCLOS, art. 246 (3).
- ²¹ UNCLOS, art. 246 (5).
- ²² It is generally agreed that such projects be considered as those that are reasonably expected to produce results, enabling resources to be located, assessed and monitored with respect to their status and availability for commercial exploitation (DOALOS, 2010).

¹⁶ UNCLOS, art. 245.

¹⁷ UNCLOS, art. 40.

¹⁸ UNCLOS, art. 54.

²³ Including those penetrating the surface of the sea, as well as those remaining entirely sub-surface. Those installations and structures are specified under art. 60 and 80 of UNCLOS.

²⁴ UNCLOS, art. 248.

through appropriate official channels, unless otherwise agreed²⁵. The coastal State is entitled, within a specific timeframe set out by UNCLOS, to require supplementary information²⁶.

Box 3. Information that must be submitted to the costal State (UNCLOS, art. 248)

- a. The nature and objectives of the project.
- b. The method and means to be used, including name, tonnage, type and class of vessels and a description of scientific equipment.
- c. The precise geographical areas in which the project is to be conducted.
- d. The expected date of first appearance and final departure of the research vessels, or deployment of the equipment and its removal, as appropriate.
- e. The name of the sponsoring institution, its director, and the person in charge of the project.
- f. The extent to which it is considered that the costal State should be able to participate or to be represented in the MSR project.

With regards to DSM scientific research activities undertaken within national waters, conditions and processes to be followed by DSM operators will be set in national regulatory regimes. It is, therefore, a prerequisite that governments that want to permit such activities have in place strong and effective legislation through which roles and responsibilities of the DSM operators and relevant national agencies, as well as terms and conditions, be clearly set.

The consent of the coastal State to a request to conduct MSR activities in its EEZ or CS beyond 200 nm, can be granted either expressly²⁷ or implicitly²⁸. It is worth noting that if the coastal State does not respond at all, consent may be presumed²⁹.

Box 4: Protection of the interest of scientific research

In accordance with UNCLOS, States must establish rules or procedures in order to not delay or unreasonably deny the granting of consent for 'pure' research³⁰ (Treves 2012; Treves 1983).

Researching States or competent international organisations that undertake MSR activities in these areas, must comply with a set of general obligations including³¹:

- the obligation to ensure the right of the coastal State to participate in or be represented in the MSR project;
- the obligation to provide the coastal State, at its request, with preliminary reports, final results and conclusions;
- the obligation to provide the coastal State access, at its request, to all data and samples;
- if requested, the obligation to provide the coastal State with an assessment of such data, samples and research results or assistance in their assessment or interpretation;
- the obligation to make internationally available the research results; and
- the obligation to remove the research installations or equipment after the research is completed.

It is highly recommended that national DSM regulatory regimes contain clear provisions reflecting this set of general obligations, taking into account that limitations could be set to protect proprietary confidential information.

- ²⁸ UNCLOS, art. 252.
- ²⁹ UNCLOS, art. 252.
- ³⁰ UNCLOS, art. 246(3).
- ³¹ UNCLOS, art. 249.

²⁵ UNCLOS, art. 250.

²⁶ UNCLOS, art. 252(c).

²⁷ UNCLOS, art. 246.

Any MSR project may be suspended or cancelled³² on request of the coastal State if the activities are not conducted in accordance with the information initially provided, and upon which the consent of that State was based and, if the researching State or competent international organisation fails to comply with the provisions of UNCLOS concerning the rights of the costal State with respect to MSR³³.

Any national regulatory regimes developed to regulate and manage DSM scientific research activities should also ensure that such safeguards are made available for governments to be able to sanction any breach to the terms of the DSM scientific research title (research or prospecting permit or exploration licence).

4.3 Areas Beyond National Jurisdiction

All States, irrespective of their geographical location, and competent international organisations have the right to conduct MSR in the water column beyond the limits of the EEZ³⁴ and in the Area³⁵.

For MSR undertaken in the high seas, the key principle is the freedom of scientific research in the Area, which is expressly stated in UNCLOS as a freedom of the high seas³⁶. However, such freedom is to be exercised with due regard for the interest of other States in their exercise of the freedoms of the high seas (freedom of navigation, freedom of overflight, freedom to lay submarine cables and pipelines, freedom to construct artificial islands and other installations, freedom of fishing) and also with due regard for the rights related to activities in the Area³⁷. MSR activities undertaken in the Area must be conducted in conformity with the specific provisions contained in UNCLOS³⁸, and exclusively for peaceful purposes and for the benefit of mankind as a whole. The International Seabed Authority (ISA) has a general responsibility to promote and encourage the conduct of research, and to coordinate and to disseminate the results of such research and analysis, when available, with particular emphasis on research related to the environmental impact of activities in the Area.

The ISA may carry out MSR relating to the Area and its mineral resources and enter into contracts for that purpose³⁹.

Box 5: The International Seabed Authority - ISA

The ISA is an autonomous international organization established under UNCLOS and through which State Parties to the Convention shall, in accordance with the international regime for the Area, organise and control activities in the Area, particularly with a view to administering the resources of the Area.

The ISA established an Endowment Fund in 2006 with the aim of promoting and encouraging collaborative MSR in the Area through supporting the participation of qualified scientists and technical personnel from developing countries in MSR programmes and activities, and by providing opportunities to these scientists to participate in relevant initiatives (Lodge 2008).

The Secretariat of the ISA is facilitating these activities by creating and maintaining an ongoing list of opportunities for scientific collaboration, including research cruises, deep-sea sample analysis, and training and internship programmes.

- ³² UNCLOS, art. 253.
- ³³ UNCLOS, art. 249.
- ³⁴ UNCLOS, art. 257.
- ³⁵ UNCLOS, art. 256.
- ³⁶ UNCLOS, art. 87(1)(f).
- ³⁷ UNCLOS, art. 87(2).
- ³⁸ UNCLOS, art. 256.
- ³⁹ UNCLOS, art. 143(2); Agreement relating to the implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982, Annex, sect. 1(5)(h).

The ISA has also published a set of regulations on prospecting and exploration for mineral resources in the Area: for MN in 2000, updated and adopted in 2013, for SMS in 2010, and for CRC in 2012. These regulations provide for contractors to anticipate and mitigate actual or potential conflicts, or interference with existing or planned MSR activities, in accordance with the relevant future guidelines in this regard.

Applicants are required to provide a description of the programme for oceanographic and environmental baseline studies in accordance with the Regulations to enable an assessment of the potential environmental impact on biodiversity and the marine environment in general. Furthermore, the regulations stipulate the gathering of environmental baseline data, against which to assess the likely effects of the exploration programme. For more detail, refer to reports ISBA/19/A/9, ISBA/19/C/17, ISBA/a6/A/12/rev1, and ISBA/18/A/11 (see https://www.isa.org.jm/).

Requirements of UNCLOS on the promotion of international cooperation⁴⁰ and the creation of favourable conditions for the publication and dissemination of information and knowledge⁴¹ are of critical importance for all MSR activities undertaken in the Area. For instance, according to art. 143(3) of UNCLOS, State Parties are required to promote international cooperation in MSR by:

- "a. participating in international programmes and encouraging cooperation in marine scientific research by personnel of different countries and of the Authority [the ISA];
- b. ensuring that programmes are developed through the Authority or other international organizations, as appropriate, for the benefit of developing States and technologically less developed States with a view to:
 - i. strengthening their research capabilities;
 - ii. training their personnel and the personnel of the Authority in the techniques and applications of research; and
 - iii. fostering the employment of their qualified personnel in research in the Area; and
- c. effectively disseminating the results of research and analysis when available, through the Authority or other international channels when appropriate".

Table 4. Summary of International Conventions that apply to MSR								
Conventions	Relevance to MSR	How to comply	Pacific countries who are Parties to the Conventions (and dates)					
United Nations Convention on the Law of the Sea (UNCLOS)	 Part XIII is specifically on MSR and covers the following areas in detail: principles for the conduct and promotion of MSR; scientific research installations/equipment in the marine environment; responsibility and liability; settlement of disputes, etc. Also, PART XII: protection and preservation of the marine environment. 	 Ensure that domestic legislations reflect UNCLOS provisions; States must cooperate to facilitate MSR. 	Cook Islands 1995 Fiji 1982 Kiribati 2003 RMI 1991 FSM 1991 Nauru 1996 Niue 2006 Palau 1996 PNG 1997 Samoa 1995 Solomon Islands 1997 Timor Leste 2013 Tonga 1995 Tuvalu 2002 Vanuatu 1999					

⁴⁰ UNCLOS, art. 242.

⁴¹ UNCLOS, art. 244.

¹² Salpin, C., Onwuasoanya, V., Bourrel, M., Swaddling, A. (2016). Marine scientific research in Pacific small Island developing States. Marine Policy. In press

Convention	The following Articles are	Article 26 of the CBD	Cook Islands 1993
Diversity (CBD)		at intervals and as	Fiji 1992
	Art 12: Research and	determined by the Conference of Parties (COP), shall report on	Kiribati 1994
	training		RMI 1992
	 Art 14: Impact assessment and 	measures taken for the implementation	FSM 1992
	minimizing adverse	of the CBD and its effectiveness.	Nauru 1993
	Art 15: Access to genetic		Niue 1996
	resources		Palau 1999
	• Art 17: Exchange of		PNG 1993
			Samoa 1992
	 Art 18: Technical and scientific cooperation 		Solomon Islands 1992
	 Art 19: Handling of 		Timor Leste 2007
	biotechnology and distribution of its bonefits		Tonga 1998
			Tuvalu 1992
			Vanuatu 1992
Noumea	Issues in the convention in	Every Party is required	Cook Islands 1987
Convention	relation to MSR are:	report to the Secretariat,	Fiji 1989
	Art 14: Specially	highlighting measures	RMI 1987
	protected areas and protection of wild flora	to comply with the	FSM 1988
	and fauna	treaty obligations and other issues that require	Nauru 1995
	Art 16: Environmental impact assessment	assessment, six weeks	Palau 1986
	Art 17: Scientific and	meeting.	PNG 1989
	technical cooperation		Samoa 1990
			Solomon Islands 1989
			Tuvalu 1987

5 Importance of establishing national regulatory regimes

For a State to meet its duty to have effective control over DSM prospecting and exploration activities within national jurisdiction, it will be important that it has rules in place stating who can do what and under what conditions. Preferably, these rules should be set out and published in national policies and laws (SPC 2012). The rules should address the components in Table 5 and Table 6.

Templates for a permit application form (Appendix 1), a MSR/prospecting permit (Appendix 2) and an exploration licence (Appendix 3) are also provided, which PICs can use to develop national templates. Where appropriate, these templates take into consideration the components from Table 5 and Table 6.

National research committees can provide a valuable function in the regulation of DSM scientific research. Although, to date only two committees of this kind have been established in the Pacific (Palau – Research Centre Advisory Group, and Samoa – Scientific Research Organisation of Samoa), it is anticipated that such structures could efficiently contribute to the development of sound and effective regulatory frameworks by: carrying out research that will inform the decision-making process; educate the public and relevant stakeholders on the risks that may be caused to the local environment; and provide expertise in identifying the best options regarding the distribution of revenues, resulting from research projects (particularly in the case of bioprospecting research). The establishment of such committees for MSR is often hampered by the lack of political will and awareness, financial and human resources, and institutional arrangement. A way to address this is to incorporate the establishment of such committees in national legislation during its development⁴².

WHAT?WHY?Specify that no DSM scientific research activities can be conducted without first obtaining a permit for those activities, and explain the application process for how such a permit can be obtained.It will be important for government to: obtain information about the person applying for a permit, an activities they wish to carry out, in order to decide whether or issue a permit; and	d the
Specify that no DSM scientific research activities can be conducted without first obtaining a permit for those activities, and explain the application process for how such a permit can be obtained. It will be important for government to: (1) obtain information about the person applying for a permit, an activities they wish to carry out, in order to decide whether or n issue a permit; and	d the
	not to
 (11) enable monitoring and ongoing coordination and correspond if the permit is issued and the activities proceed. A list of inform that should be required at application stage is provided, in A 1: Application Form for DSM Scientific Research Permit to guidelines. 	ence, nation Annex these
Explain what the rights and obligations of a permit-holder are, set out what pre- conditions, performance standards and other requirements a permit-holder must adhere to, and explain the government's role as the permitting authority. Failure by the government to protect and preserve the marine environ through the adoption, implementation and enforcement of appro- rules for DSM scientific research activities within its national jurisd could lead to environmental damage, and possible State liability to parties for that damage, or for clean-up costs. The rules should, there is the permitting authority.	iment oriate iction third efore, older,
Identify to what extent a permit-holder will be permitted to extract mineral and/ or biological samples, and how those samples must be handled. Government is effectively the owner of any resources contained on used. At the DSM scientific research stage, the permit-holder should be using any resources extracted for profit, as there are no mechaniss place for the State to share in profits (such as royalties, which would be triggered at a later mining phase). If DSM scientific research and does not lead to mining, government may wish to retain the samples subset of each sample for its own study or use. Controls can be p on the number and size of samples taken, and their removal from national jurisdiction.	within es are d not ms in d only ctivity s or a laced n the
Indicate the likely and/or maximum This may vary for different activity types; for example an explor duration of a permit. This may vary for different activity types; for example an explor data for an Environmental Impact Assessment (EIA) (see Part 2 of guidelines).	ration seline these
In establishing the terms of DSM scientific research permits (and these may be renewed or terminated), government should seek to a balance between:	how strike
 (i) providing a predictable and secure operating environment for permit-holder, which will incentivise DSM scientific research; and 	n the d
 (ii) not giving a third party too much freedom to operate withi national jurisdiction without regular checks and approvals to ma effective control and regulation. 	n the intain
Specify what reports and data (type, format and national agency to submit the data to) the permit-holder must provide to government, when, and also describe how government may use this data. How government may use this data.	ment orts ⁴³ ogical and data, alysis ent to iction nnical ata ⁴⁴ .
For an exploration permit, give: An applicant for an exploration permit would usually require that the p give exclusivity and proformatial mining rights to protoct their future in	ermit
(t) exclusive rights to the specific area of the seabed. This means that hopes to recoup by future mining of the same site.	olorer
Before issuing an exploration permit, with exclusive rights, govern marine users will be permitted rights over the same seabed area; and alternative uses or environmental/biological values of that area.	ment ortant
 (n)a presumption of 'first refusal', in relation to future mining rights for the same site. 	

⁴³ Assistance with interpretation and review of submitted data and reports is available to Pacific Island States through regional agencies such as SPC. The Geoscience Division of SPC currently provides this service regarding DSM activities.

⁴⁴ Reporting that also follows the methodologies, standards, and regulations from ISA will be beneficial for ensuring data are comparable. Receipt of data in consistent formats supports easy storage and analysis.

Table 6. Additional DSM scientific research components that States MAY include in national policy and law.	
WHAT?	WHY?
Have specific provisions for MSR (as opposed to prospecting or exploration), that aim for a streamlined process, with a presumption that a permit will be issued, save for express limited circumstances (e.g. the use of explosives).	States have an obligation under international law to facilitate MSR. Once an application is approved, a permit can be issued. The permit should set out the rights, restrictions and other conditions, pertaining to the DSM scientific research activities. The terms of a permit may be less stringent for MSR and prospecting (likely to be shorter-term research with lower-impact) than for exploration (likely to be more site-concentrated and relatively higher-impact activities, and may lead to future mining by the same applicant). Examples of template permits are provided in Annex 2 (Template Permit for DSM Marine Scientific Research or Prospecting) and Annex 3 (Template Permit for Exploration) to these guidelines.
Support government action that is targeted and proportionate to the scale, significance and likelihood of harm of the proposed activities.	government has an interest to minimise its own administrative cost and burden where possible.
Highlight areas where no DSM scientific research activities will be permitted.	To maintain the integrity of marine protected areas, shipping routes, or sites that are already used for other purposes e.g. fisheries, or a pre-existing DSM permit issued to another person. Where mining is planned, marine protected areas will be an important mechanism for maintaining marine biodiversity – and are a requirement of the 1992 Convention on Biological Diversity (CBD) ⁴⁵ . Government may also choose not to permit DSM scientific research activities in areas at the edge of national jurisdiction, to avoid risk of trans-boundary impacts, or international dispute over jurisdiction (e.g. if the boundary has not been formally agreed on with the neighbouring country).
Specify criteria against which a DSM scientific research application will be assessed by government.	This would usually include an examination of the applicant's financial and technical capacity to perform the proposed DSM scientific research (and also its capabilities and financial resources or insurance coverage in case of accidents or damages). The extent to which the DSM scientific research will bring benefit to the country and fit with national policy priorities, is another important criterion. An applicant's track record, particularly in relation to past DSM scientific research and environmental management history may be considered in assessing an application. Some categories of applicants may be prohibited from holding a permit e.g. persons who are insolvent or with an unspent conviction for a serious crime or dishonesty offence.
Set specific timescales and deadlines for actions by the permit applicant and government in the application and permitting process; and set out the criteria against which the application will be assessed by government.	To facilitate efficient, effective, transparent and timely processes, which will incentivise creditable applicants, and assist all parties with following appropriate procedures and adhering to the rules.
Require an application fee, and/or an annual permit fee.	 To cover costs of administering the application and of monitoring the permitted activities (if the application is successful). A higher fee may be considered appropriate for DSM exploration, given: the exclusive rights granted by the permit, and the likelihood of more intense sampling activities, which require a higher level of government regulation and monitoring.

Require or otherwise prioritise the involvement by the permit-holder of national personnel in the DSM scientific research, or the provision of other related training or capacity-building opportunities.	Capacity gaps exist within developing countries, in relation to the technical expertise and know-how required for DSM operations and regulation. International law requires capacity- building initiatives in this area for developing State nationals. National permitting rules can, therefore, require training or secondment opportunities for local personnel. Unduly onerous capacity-building requirements may not be feasible, given the significant forward-planning and cost attached to DSM scientific research, and the limited capacity on board research vessels.
 Have specific rules for exploration (as opposed to MSR or prospecting), to: (1) require more information at the application stage, and establish a more stringent reporting and monitoring regime, and rights to terminate the Permit; 	(i) Exploration may have more impact upon the environment than other DSM scientific research activities, may take some time, and may be the start of a longer State/permit-holder relationship, as exploration is undertaken with the view to a future mining project at the same site (with the same applicant). For that particular reason, a proportionately higher level of scrutiny is recommended. Government may also wish to require an exploration permit-holder to have a locally- registered body corporate (and assets in-country).
(11) provide the permit-holder with security of tenure, i.e. provided the permit- holder abides by the terms and conditions of the permit, their permit continues to run to its end date; and	Government may also wish to retain a right to terminate the permit, in certain circumstances, e.g. if the holder does not undertake the exploration activities (but the exclusive nature of the permit means others are blocked from the site during this time), or acts in contravention to the rules or government's instructions.
(111) set a maximum size for exploration permit areas, require regular relinquishment of a portion of the total area under exploration, and/or require a minimum annual expenditure amount.	(ii) Exploration cruises are costly for the operator, as they do not generate income. The permit-holder company will be looking to reduce their risk and costs in their choice of jurisdiction. Having some predictability and certainty that the permit will run uninterrupted, without the rules changing for a lengthy enough time to complete its plan of work, will be important for exploration companies.
	(iii) Limiting the size of one exploration permit avoids too much of the seabed being under exclusive use and active exploration at any one time. Giving out several smaller size permits rather than one larger permit, may also enable better State control of the activities (and yield higher fees).
	Relinquishment and minimum expenditure requirements aim to ensure that the permit-holder diligently performs the agreed plan of work. The aim is to avoid a permit-holder retaining a portion of seabed under exclusive permit for a lengthy period, with no exploration activity occurring – as this will not yield the anticipated benefit to the country (of increased geological and biological knowledge, and progress toward future mining and associated revenue).

6 Scientific research installations and equipment

MSR can be carried out not only on ships but also on installations or equipment (including floating buoys) (Treves 2012) deployed in the marine environment. Such installations and equipment do not possess the statute of islands, thus they have no territorial sea and their presence does not affect the delimitation of any maritime zones⁴⁶.

The deployment of a scientific-data acquisition buoy within the coastal State's jurisdiction requires the State's consent, while no consent is needed when deployment occurs on the high seas. Nevertheless, due regard for the exercise of other freedoms of the high seas is required.

Safety zones of a reasonable breadth (not exceeding 500 metres) may be created around scientific research installations in accordance with UNCLOS, and all States shall ensure that such safety zones are respected by the vessels which fly their flag⁴⁷, and that the deployment does not constitute an obstacle to established international shipping routes⁴⁸.

⁴⁶ UNCLOS, art. 259.

⁴⁷ UNCLOS, art. 260.

⁴⁸ UNCLOS, art. 261

Installations and equipment used for MSR activities shall bear identification markings indicating the State of registry or the international organisation to which they belong, and have adequate internationally agreed warning signals to ensure safety at sea and the safety of air navigation⁴⁹.

The regulatory regime that applies for the deployment of DSM scientific research installations and equipment, including floating buoys is the same as for MSR. However, the coastal State will be entitled to add specific requirements through its national legislation.

7 **Protection and preservation of the marine environment**

7.1 Marine scientific research

MSR must be conducted in compliance with relevant regulations on the protection and preservation of the marine environment⁵⁰. Accordingly, all provisions of UNCLOS that address the protection and the preservation of the marine environment⁵¹ apply. The below are of particular relevance.

- The obligation for States to take all 'necessary measures' to prevent, reduce and control pollution from any source, including installations and devices operating in the marine environment⁵², or resulting from the use of technologies under their jurisdiction or control⁵³.
- The obligation for States when they have reasonable grounds for believing that planned activities under their jurisdiction or control may cause substantial pollution or significant and harmful changes to the marine environment – to assess the potential effects of such activities on the marine environment and communicate reports of the results of such assessments⁵⁴.
- The obligation for States to cooperate, directly or through competent international organizations for the purpose of promoting studies, undertaking scientific research programmes, and encouraging the exchange of information and data about pollution of the marine environment⁵⁵.
- The obligation for States to provide other States with a reasonable opportunity to obtain from them, or with their cooperation, information necessary to prevent and control damage to the marine environment⁵⁶.

As a general principle in international law, vessels or aircraft owned or operated by a State and used only on government non-commercial service are excluded from the application of the provisions of UNCLOS, regarding the protection and preservation of the marine environment⁵⁷. However, they must "act in a manner consistent, so far as is reasonable and practicable" with UNCLOS⁵⁸.

Specific obligations assumed by States under special conventions with respect to the protection and preservation of the marine environment should be carried out in a manner consistent with the general principles and objectives of UNCLOS⁵⁹. As a result, MSR activities

- ⁵⁷ UNCLOS, art. 236.
- ⁵⁸ UNCLOS, art. 236.
- ⁵⁹ UNCLOS, art. 237.

⁴⁹ UNCLOS, art. 262.

⁵⁰ UNCLOS, art. 240.

⁵¹ UNCLOS, Part. XII.

⁵² UNCLOS, art. 194.

⁵³ UNCLOS, art. 196.

⁵⁴ UNCLOS, art. 204 to 206.

⁵⁵ UNCLOS, art. 200.

⁵⁶ UNCLOS, art. 242.

should be conducted in conformity with the measures and regulations adopted, provided they are consistent with the general principles and objectives of UNCLOS (Caflisch and Picard 1976).

7.2 Prospecting and exploration

In addition to general requirements that apply to MSR (see above), DSM prospecting and exploration activities should be regulated by the coastal State's national legislation, particularly with the view of protecting and preserving the marine environment.

For instance, section 47(e) of the Tonga Seabed Minerals Act 2014 states that "prospecting":

"(e) does not entail any right to drill into the Continental Shelf, use explosives, or introduce harmful substances into the Marine Environment".

PIC governments should have in place a permitting regime for all DSM-related activities, with a specified government agency allocated responsibility for that function. It is recommended that a prospecting or exploration permit only be issued by the relevant government agency after consideration of an application, covering the description of all the proposed research events and activities and the preliminary assessment of likely impact on the marine environment. Annex 1 to these guidelines contains a template application form that PIC governments can adopt in their national regime, and can require DSM scientific research applicants to complete and submit to government, to be considered for a MSR prospecting or exploration permit.

Such applications should be reviewed and considered by government, bringing in relevant officials and/or experts, in order to arrive at a decision whether or not to grant the permit. If a decision is taken to grant a permit, a written document setting out the rights and responsibilities of the permit-holder should be issued by government. Annex 2 and Annex 3 provide template permits that PIC governments can adopt and use in their national regime. It is recommended that the prospecting permit (Annex 2) or exploration permit (Annex 3) expressly states the obligation for the permit-holder to:

- apply the precautionary approach and best environmental practice;
- take appropriate steps to prevent pollution and other hazards to the environment, and comply with national environmental and dumping-at-sea laws;
- only use vessels operated in compliance with international agreed standards and norms;
- comply with the laws of the vessel's flag state, relating to safety of life at sea, prevention
 of pollution from ships and other international agreed standards;
- not proceed with the DSM scientific research activities if there is evidence indicating that to proceed is likely to cause harm to the environment of a nature that is not detailed in the application submitted in the permitting process; and
- keep the coastal State indemnified against any action or claim for damages, which may be made by any third party in relation to the performance of the permitted activities or the actions of the permit-holder.

Monitoring and evaluation of any DSM scientific research activities permitted under national licencing regimes need to be given due consideration. Specific reporting provisions should be incorporated in the terms of the permit. To this end, the non-binding 'Code for Environmental Management of Marine Mining' ('the IMMS Code')⁶⁰ developed by the International Marine Minerals Society (IMMS) could be of great interest (Box 6).

⁶⁰ International Marine Minerals Society, Code for the Environmental Management of Marine Mining, 2011.

Box 6.The IMMS Code

The IMMS voluntary code of conduct consists of a statement of management principles for marine minerals activities, including marine prospecting and exploration. The Code takes into account and endeavours to comply with and implement international legal obligations, relating to the protection and preservation of the marine environment, regarding DSM activities.

The Code provides a general framework and benchmarks for the development and implementation of environmental programmes for marine minerals research, exploration and exploitation by marine mining companies.

The IMMS Code is voluntary (non-binding) and any company or stakeholder can strive towards, adopt or use it. If so, companies which want to conduct DSM scientific research activities commit themselves to the following principles.

- Observe the laws and policies and respect the aspirations of sovereign States and their regional subdivisions, and of international law, as appropriate to underwater mineral developments.
- Apply best practical and fit-for-purpose procedures for environmental and resource protection, considering future activities and developments within the area that might be affected.
- Consider environmental implications and observe the precautionary approach, from initiating a project through all stages from exploration through development and operations, including waste disposal, to eventual closure, and post-closure monitoring.
- Consult with stakeholders and facilitate community partnerships on environmental matters throughout the project's life cycle.
- Maintain an environmental quality review programme and deliver on commitments.
- Report publicly on environmental performance and implementation of the IMMS Code.

The IMMS Code also recommends companies use appropriate risk management strategies and the precautionary approach to guide exploration.

To date, there has been no reporting on implementation of the IMMS Code, thus compliance to it cannot be determined.

8 International and Regional Cooperation

Cooperation between States and with competent international organizations in MSR is encouraged by UNCLOS (Tanaka 2005). In accordance with article 247 of UNCLOS, the coastal State's consent is presumed if the research project the international organisation intends to carry out has been approved by the State and no objection has been made within four months⁶¹.

As acknowledged during the Third UN Conference on Small Island Developing States (SIDS) held in Samoa in September 2014 (Box 7), MSR plays a critical role in sustainable development of the oceans and their resources, including by supporting informed decisions on the conservation and sustainable use of the marine environment. MSR is also at the core of the '2030 Agenda for Sustainable Development' and the Sustainable Development Goal 14a, officially adopted by the UN General Assembly in September 2015.

Box 7. The S.A.M.O.A Pathway explicitly mentions MSR

"To undertake marine scientific research and develop the associated technological capacity of small island developing States, including through the establishment of dedicated regional oceanographic centres and the provision of technical assistance, for the delimitation of their maritime areas and the preparation of submissions to the Commission on the Limits of the Continental Shelf."⁶²

Through establishing national research committees, the exchange of experiences and knowledge can be streamlined and coordinated. Regional agencies such as SPC and its Geoscience Division can assist with this cooperation. At the request of member countries, SPC can coordinate collaboration, mobilise resources, provide training and conduct research. Refer also to Part 2 section 7 on cooperative research.

⁶¹ A detailed procedure for the application of the article 247 of UNCLOS has been adopted in June 2005 by Resolution XXIII-8 of the IOC of the UNESCO.

⁶² UNGA, SIDS Accelerated Modalities of Action (S.A.M.O.A) Pathway, A/RES/69/15, 15 December 2014, p.14.

With regards to prospecting and exploration, although international cooperation is seen as beneficial, it is also important to ensure that confidential proprietary information be protected. However, it is recommended for national legislation to provide for specific requirements, ensuring that such confidential information be protected – and not publicly available – but only for a limited amount of time; for instance, three years. Non-proprietary results arising from the research (e.g. environmental and biological information,) should be made publically available, which may be of particular significance to key stakeholders, including the coastal communities.

9 Responsibility and Liability

9.1 Marine scientific research

UNCLOS requires States to fulfil in good faith the obligations they assume under it and to exercise the rights, jurisdiction and freedoms recognised therein in a manner which would not constitute an abuse of right⁶³.

States and competent international organisations involved in MSR, whether undertaken by them or on their behalf, are⁶⁴:

- responsible for ensuring that is conducted in accordance with UNCLOS;
- responsible and liable for the measures they take in contravention of UNCLOS, and shall provide compensation for damage resulting from such measures; and
- responsible and liable for damage caused by pollution of the marine environment, arising out of MSR undertaken by them or on their behalf.

9.2 Prospecting and exploration

Generally, prospecting permits and exploration licences require that all the requirements set out by national legislation already in force (e.g. environmental, maritime boundaries, fisheries, etc.) and regulations be met. As such, appropriate insurance policies, providing adequate cover for identified risks and costs of damages that may be caused by prospecting and exploration activities may be listed as one of the company's obligations.

Relevant examples of the obligations of prospectors are to be found in the Tonga Seabed Minerals Act 2014 (s.48) and in the Tuvalu Seabed Minerals Act 2014 (s.54):

"Prospectors shall-

- (a) adhere to the terms and conditions of the Prospecting Permit, this Act, the EIA Act, requirements prescribed by Regulations made under this Act, and any rules or procedures relating to Prospecting issued by the Authority; and
- (b) not proceed with Prospecting if there is evidence indicating that to proceed is likely to cause Serious Harm to the Marine Environment or human life".

Regarding exploration licences, these respective Acts state that, as part of a Licensee's duties and liability:

- "(1) Licensees shall comply with the terms of the Licence, this Act, and any Regulations made under this Act.
- (2) The Licensee is responsible for the Seabed Mineral Activities and Ancillary Operations carried out within its Licence Area, and their compliance with this Act, Regulations made under this Act, and the Licence.
- (3) The Licensee shall at all times keep the [country] indemnified against all actions,

⁶³ In accordance with UNCLOS, an 'abuse of right' could be derived for instance from a situation constituting a non-peaceful threat or the use of force prohibited under article 301.

⁶⁴ UNCLOS, art.263.

proceedings, costs, charges, claims and demands which may be made or brought by any third party in relation to its Seabed Mineral Activities, and will be liable for the actual amount of any compensation or damage arising out of its failure to comply with this Act, Regulations made under this Act, or the Licence, and any wrongful acts or omissions and those of its employees, officers, subcontractors, and agents in the conduct of the Seabed Mineral Activities or Ancillary Operations under Licence, including but not limited to that arising from injury to coastal or marine users, damage to the Marine Environment, and any related economic loss or compensation.

- (4) Any obligations which are to be observed and performed by the Licensee shall at any time at which the Licensee is more than one person be joint and several obligations.
- (5) The Licensee shall remain liable for damage resulting from its Seabed Minerals Activities notwithstanding that its Title may have been terminated or suspended"⁶⁵.

10 Settlement of Disputes

10.1 Marine scientific research

All disputes concerning the interpretation or application of UNCLOS regarding MSR shall be settled in accordance with UNCLOS⁶⁶ (Treves 2012). Compulsory procedures entailing binding decisions from the International Tribunal for the Law of the Sea, the International Court of Justice, an arbitral tribunal constituted in accordance with UNCLOS, or a special tribunal constituted in accordance with UNCLOS⁶⁷ are provided for.

UNCLOS also outlines specific limitations and exceptions for MSR disputes arising out of:

- the exercise by the coastal State of a right or discretion with regards to its right to regulate, authorise and conduct MSR in its EEZ and on its continental shelf⁶⁸; and
- a coastal State's decision to order suspension or cessation of a research project in progress within its EEZ or on its continental shelf⁶⁹.

The dispute could be submitted to conciliation⁷⁰ if the case is not related to the ability of the coastal State to exercise its discretionary power to designate specific areas located on the extended continental shelf where exploitation activities can be effectively authorised to start within 'a reasonable period of time⁷¹' from the moment when a title has been granted⁷².

It is worth mentioning that when States use the compulsory procedure of a special tribunal⁷³, the Intergovernmental Oceanographic Commission (IOC) of UNESCO maintains a list of experts in MSR. As of January 2014, 13 States have submitted names for the list of experts⁷⁴, none of whom are from a Pacific Island country.

- ⁶⁵ Tonga Seabed Minerals Act 2014, s.70.
- ⁶⁶ UNCLOS, art. 286 to 299.
- 67 UNCLOS, art. 287 and 296.
- ⁶⁸ In accordance with art. 246 of UNCLOS.
- ⁶⁹ In accordance with art. 253 of UNCLOS.
- ⁷⁰ UNCLOS, Annex X, sect.2.
- ⁷¹ UNCLOS, art. 246(6).
- ⁷² Similar limitation to the conciliation commission's powers is detailed in UNCLOS with regard to the discretionary right of the coastal State to withhold its consent for MSR (UNCLOS, art. 245(5)).
- ⁷³ In accordance with Annex III, art. 2 of UNCLOS.
- ⁷⁴ The list of experts can be accessed via the hyperlink below: http://www.un.org/depts/los/settlement_of_disputes/expertsunclosVIII_iocunesco.pdf

10.2 Prospecting and exploration

Any dispute arising between the permit-holder and the coastal State, concerning the interpretation of the permit and/or the right and abilities of either party will generally be settled in accordance with the laws of the coastal State. However, where there is no national legislation, other arrangements will prevail. It is, therefore, of critical importance for Pacific Island States to ensure that relevant laws provide for such situations. Alternative dispute resolution mechanisms (i.e. arbitration) when agreed by both parties, can also be activated.

Box 8. The Intergovernmental Oceanographic Commission (IOC)

The IOC-UNESCO was established in 1960 as a body with functional autonomy within UNESCO. The IOC is the only competent organization for marine science within the UN system.

The purpose of the IOC is to promote international cooperation and to coordinate programmes in research, services and capacity-building, in order to learn more about the nature and resources of the ocean and coastal areas. Its purpose is also to apply that knowledge for the improvement of management, sustainable development, the protection of the marine environment and the decision-making processes of its Member States. In addition, IOC is recognized through UNCLOS as the competent international organization in the fields of MSR (Part XIII) and Transfer of Marine Technology (Part XIV).

A key aspect of the work undertaken by the IOC is to work towards the development of research capabilities in developing countries and to promote international cooperation in scientific research.
PART 2: - SCIENCE CONSIDERATIONS

1 Introduction

A major challenge for government management agencies is how to facilitate development of mineral resources while ensuring environmental sustainability is not compromised. Maintaining the 'health' of ecosystems is typically a key goal of most governments, management agencies and international bodies. This is made possible by legislation and regulations which should require, for example, an assessment of the impacts of the mining operation on the environment. This is where the role of science becomes critical, as it underpins the ability to measure and understand the environmental effects of mining, and informs the development of effective mitigation and environmental management plans (Figure 3).



Figure 3. Science and data gathering is an underpinning component for environmental management.

While it is easy to say that scientific research is needed to describe and predict environmental impacts of human activities, it can be difficult to determine: what type of studies are needed, what sort of sampling gear should be used, what type of survey methodology should be applied, what parameters to what degree of precision and how often should be measured, etc. The role of science in supporting ecological and environmental investigations can be divided into three main components.

1) General information/specific baseline information:

- Topography and seafloor morphology
- Sampling design
- Physio-chemical characteristics of the seabed and sub-seafloor
- Physical and chemical oceanographic characteristics
- Identification of key habitats, including spawning and nursery grounds
- Composition and distribution of the biota
- Population connectivity
- Chemical characterisation of tissue and whole-organism concentrations of metals
- Food chain structure and dynamics
- Assessment of important ecosystem functions
- Community vulnerability and recovery rates
- Predictions of response to anthropogenic pressures

2) Monitoring:

- Sampling strategies based on baseline survey results to determine the key components to measure
- Definition of appropriate spatial and temporal scales of monitoring (linked to 1)
- Appropriate indicators of environmental status and change
- Repeatable surveys to separate natural variability from human-induced changes
- Database management to ensure data storage and availability
- Quality control procedures for sampling and analytical methods (e.g. using standard procedures, chain of custody for site identification and sample tracking, suitable analytical detection limits)
- Transparent reporting and validation

3) Conservation:

- Species and habitat distributions (observations and models)
- Identification of endemic and vulnerable species
- Population connectivity
- Determination of appropriate spatial units for different species, communities and ecosystems
- Principles for design of conservation areas
- Methods for effective mitigation and restoration.

The types of studies to support these activities may differ, in that some research objectives may focus more on functional processes, whereas monitoring has more of a repetitive structure. However, many activities will be similar and overlap, and elements of research required for baseline information and monitoring need to be integrated with those to support conservation objectives. Hence, there is a high degree of integration and sequential planning of science involved in any environment programme.

Each resource and individual site may have different environmental conditions, and so the nature and extent of scientific research needs to be tailored to the specific set of circumstances at the potential area of interest.

2 Preliminary environmental assessment

Scientific research itself may have a significant environmental impact, hence limits may need to be imposed on certain research activities. A preliminary environmental risk assessment (ERA) is needed to accompany an application for DSM MSR, prospecting or exploration, so the impact of activities can be evaluated, and to ensure that approvals are granted with full disclosure of risks.

A realistic approach is to conduct a preliminary qualitative assessment in line with accepted Australian and New Zealand risk assessment standards (AS/NZS 2004). This desktop-style assessment is based on knowledge of all activities likely to occur, their nature and extent, and temporal duration. Likely environmental threats arising from these activities to the local habitats can be identified, and then evaluated for the likely level of risk. Additionally, activities for which there is insufficient scientific knowledge to evaluate the risks involved should also be noted and addressed.

There are many ERA approaches and methods, but a suitable first-cut can be made using the 'likelihood – consequence risk assessment method' (Fletcher 2005). This involves convening a group of experts with data and knowledge of a range of environmental aspects, who then progress through three main steps:

- 1) examination of sources of risk, their magnitudes, scales, frequencies and intensities;
- 2) assessment of the potential consequences of those risks; and
- 3) likelihood of a particular level of consequence occurring from the various activities.

Scores are given to the potential consequence of each identified activity, resulting in an assessment of the relative significance of the likely impact. Likelihood is often expressed on a scale of 1-6 levels (Table 7).

Table 7. The levels of likelihood	of an impact occurring.		
Remote (1):	Highly unlikely but theoretically possible		
Rare (2):	May occur in exceptional circumstances		
Unlikely (3):	Uncommon, but has been known to occur elsewhere		
Possible (4):	Some evidence to suggest this is possible		
Occasional (5):	May occur occasionally		
Likely (6):	It is expected to occur (includes "certainty" class)		

The more important component is the consequence level, for which an example is given below in Table 8. The likelihood and consequence scores for each activity can be multiplied together to give a relative ranking of the significance of likely impacts. This can be used to guide the key environmental elements to be covered in the MSR plan during exploration.

A likelihood-consequence analysis was carried out by MacDiarmid et al. (2012) to give managers an indication of what sort of activities were likely to cause the most impact across a range of resource and mining operations in the New Zealand marine environment. Where the nature of the resource, site, and technology-specific characteristics are known, an exposure-effects approach may be more appropriate. The "likelihood" component of an assessment is then less relevant than assessing the nature and extent of impacts that will definitely occur.

The ERA should be transparent and rank activities in such a way as to highlight those that have a high risk of causing an impact. The results of a preliminary qualitative risk assessment should guide regulators to determine if specific permit conditions will be required for the activity. Factors/effects that are identified as high risk should be considered carefully to ensure impacts are limited.

As an example, the preliminary environmental assessment should identify if the proposed research activities have a risk of potential impacts to marine mammals. Such an analysis should be taken into consideration when determining if a qualified Marine Mammal Observer (MMO) will be required on board. It is recommended that qualified MMOs be required where acoustic/seismic technologies will be used.

Additionally, a preliminary environmental assessment also provides information on knowledge gaps, allowing both researchers and regulators to know where there may be a need to focus specific research in the future.

Table 8: The Conse	equence Scale and descr	iptions of the resultant in	npacts.		
Consequence level	Recovery period	Key species	Protected species	Ecosystem functional impact	Proportion of habitat affected
0 - Negligible	No recovery time needed	Undetectable for populations of these species	Almost none are impacted	Interactions may be occurring but it is unlikely that there would be any change outside of natural variation.	Affecting <1% of area of original habitat area
1 - Minor	Rapid recovery would occur if stopped – measured in weeks to months	Possibly detectable but little impact on population size and none on their dynamics	Some individuals impacted but no impact on population.	Affected species do not play a keystone role - only minor changes in relative abundance of other constituents.	Measurable but localized; affects <1-5% of total habitat area
2 - Moderate	Recovery probably measured in months - years if activity stopped	Affected but long-term recruitment/ dynamics not adversely impacted	Level of interaction/ impact moderately affects population	Measurable changes to the ecosystem components without there being a major change in function (i.e. no loss of components).	Impacts more widespread; 5-20% of habitat area is affected
3 - Severe	Recovery measured in years if stopped	Affecting recruitment levels of populations or their capacity to increase	Level of impact severely affects population levels	Ecosystem function altered measurably and some function or components are missing/ declining/increasing well outside historical acceptable range and/or allowed/ facilitated new species to appear.	Impacts very widespread; 20-60% of habitat is affected/removed
4 - Major	Recovery period measured in years to decades if stopped	Likely to cause local extinctions if continues	Likely to cause local extinctions if continues	A major change to ecosystem structure and function. Different dynamics now occur with different species or groups now affected.	Activity may result in major changes to ecosystem; 60-90% affected
5 - Catastrophic	Long-term recovery to former levels will be greater than decades or never, even if stopped	Local extinctions are imminent/immediate	Local extinctions are imminent/immediate	Total collapse of ecosystem processes. The diversity of most groups is drastically reduced and most ecological functional groups (primary producers, grazers, etc.) have disappeared. Most ecosystem functions such as carbon cycling, nutrient cycling, flushing and uptake have declined to very low levels.	Entire habitat in region is in danger of being affected; >90% affected/ removed

2.1 Known low-impact activities

Several workshops have been hosted by the ISA where scientists and managers have determined that a variety of technologies currently used in scientific research, prospecting and exploration are considered to have no potential for causing serious impacts to the marine environment, and do not require an in-depth environmental impact assessment. These include (after LTC 2013⁷⁵):

- gravity and magnetic data acquisition;
- multibeam echosounder surveys;
- bottom and sub-bottom acoustic profiling at frequencies not known to significantly affect marine life;
- seafloor photographic imagery surveys;
- water, biotic, sediment and rock sampling for environmental baseline studies, including:
 - o sampling of small quantities of water, sediment and biota (e.g. from remotely operated vehicles);
 - o mineral and rock sampling of a limited nature, such as that using small grab or bucket samplers; and
 - sediment sampling by box corer and small diameter corer, such as a multicorer (note that in some national regulations, this is a discretionary activity, depending on the number of samples);
- meteorological observations and measurements, including the setting of instruments (e.g. moorings);
- oceanographic, including hydrographic, observations and measurements, including the setting of instruments (e.g. moorings);
- video/film and still photographic observations and measurements;
- shipboard mineral assaying and analysis;
- positioning systems, including bottom transponders and surface and subsurface buoys filed in notices to mariners;
- towed plume-sensor measurements (chemical analysis, nephelometers, fluorometers, etc.);
- in situ faunal metabolic measurements (e.g. sediment oxygen consumption);
- DNA screening and chemical analysis of biological samples; and
- dye release or tracer studies, unless required under national or international laws governing the activities of flagged vessels.

Even when using the equipment above, however, there should be consideration of impacts based on the amount and nature of the sampling to be done. There is increasing evidence in deep-sea environments that the effects of scientific sampling can be greater than expected (e.g. Nakajima et al. 2015) and even small disturbances can be long-lasting (e.g. Miljutin et al. 2011). The use of other sampling equipment (e.g. epibenthic sleds/trawls) is generally discretionary, and will need to be included in the preliminary environmental assessment.

⁷⁵ ISA Legal and Technical Commission (2013). 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. 32 p. https://www. isa.org.jm/sites/default/files/files/documents/isba-19ltc-8_0.pdf

3 Best research practices

InterRidge⁷⁶ has developed six recommendations for responsible research practices (Devey et al. 2007). These were developed for research at hydrothermal vent (SMS) sites; however, they are also applicable to research conducted at CRC and MN sites, and provide overarching principles of best practice.

- Avoid activities that will have deleterious impacts on the sustainability of populations of organisms.
- Avoid activities that lead to long-lasting and significant alteration and/or visual degradation of sites.
- Avoid collections that are not essential to the conduct of research.
- Avoid transplanting biota or geological material between sites.
- Familiarise yourself with the status of current and planned research in an area and avoid activities that will compromise experiments or observations of other researchers. Assure that your own research activities and plans are known to the rest of the international research community.
- Facilitate the fullest possible use of all biological, chemical and geological samples collected through collaborations and cooperation amongst the global community of scientists.

OSPAR⁷⁷ Code of Conduct (2008) provides some guidance in addition to the above including:

- when working in areas of particular ecological vulnerability, utmost care should be taken to not disturb or damage the features. A risk assessment should be completed before equipment that may have adverse effects is deployed and, where appropriate, a preassessment of the site should be conducted to determine possible impacts and suitable mitigation measures.
- When working in Management areas/marine protected areas, ensure that activities are in compliance with regulations for the area.
- Use the most environmentally-friendly and appropriate study methods which are reasonably available.
- Practice international sharing of data, samples and results in order to minimize the amount of unnecessary sampling, and to further a global understanding of the marine environment.

Such practices could be included or referred to in the development of policy and regulations.

4 **DSM environmental studies**

Each voyage to a DSM site may have different objectives and perform different scientific studies. The number, nature and extent of the studies will vary with research and management objectives, site characteristics, the size of the proposed area of interest, the techniques to be used, and available equipment and resources (including financial and human). Nevertheless, there are three broad categories of environmental studies that are likely to be requested in DSM MSR, prospecting and exploration applications (Figure 4).

⁷⁶ InterRidge is a community of researchers for ocean ridge science. https://www.interridge.org/

⁷⁷ So named because of the original Oslo and Paris Conventions ("OS" for Oslo and "PAR" for Paris), is now a stand-alone commission based on its own convention: The Convention for the Protection of the marine Environment of the North-East Atlantic. Although this code of conduct has been developed for OSPAR members (made up of European countries), it is relevant in the Pacific context.

Physico-chemical assessment	Oceanographic assessment	Biological assessment
Geology	Physical oceanography	Seafloor community
 Topography Map generation Sub-seafloor Petrology, Mineralogy and geochemistry 	 Currents lincluding flow dispersall Hydrodynamic modelling Water quality Visual characteristics 	Megafauna Macrofauna Meiofauna Microbiota/ microbes Resource-specific fauna
 Sediment characteristics Sediment properties and composition Bioturbation rates Sedimentation rates 	Chemical oceanography Bottom water chemistry Water column chemistry 	Demersal scavengers/ fish Pelagic community Surface plankton Deepwater plankton Marine mammals

Figure 4. Key studies performed at DSM sites.

Physio-chemical studies focus on the seafloor and immediate sub-seafloor structures (Annex 4 s1.4), topography (Annex 4 s1.2) and sedimentological characteristics (Annex 4 s1.6). Knowledge of the seafloor morphology and the development of maps (Annex 4 s1.3) is essential for optimal survey design (Part 2 s5.2), including transects and placement of suitable sampling stations, as is information on the type of substrate at the seafloor.

The determination of a site's commercial viability is dependent on the site's rock type and properties (petrology), its mineral components (mineralogy) and its chemical composition (geochemistry) (Annex 4 s 1.5). The collection of sediment data and information on sedimentation rates (Annex 4 s 1.6.3) as well as physical oceanic data (Annex 4 s 2.1) helps, through numerical modelling (Annex 4 s 2.1.3) and the evaluation and prediction the effects and behaviour of potential plumes.

Knowledge of chemical oceanography (Annex 4 s2.2.1) is important for assessing the possible influence of mining on the composition of the water and where changes could affect biological activity and ecosystem processes. Measurements of currents (Annex 4 s 2.1.1) can also aid predictions of the potential downstream spread of any mining impact, as well as the distribution of species and biological communities.

The key goal of biological assessment (Annex 4 s3) is to collect data, such as species diversity and abundance, genetic information, food-web structure and species relationships, etc. on existing communities, including their natural spatial and temporal variability. This information can be used to provide the basis for an evaluation of the potential effects of anthropogenic activities on the benthic and pelagic fauna.

Data from scientific studies at DSM sites will feed into the identification of the key aspects that need to be monitored during and post-decommissioning of mining projects. Monitoring should be well thought out and justified on the basis of baseline data collected (Clark et al. 2014). The studies undertaken during monitoring should employ the same techniques and analysis used for collection of the baseline information to ensure data comparability and accurate identification of the impacts' extent and duration. It may need to be carried out well after activities have finished in order to record slow or long-term changes in the deep-sea environment and communities.

Current best practices for these studies are given in ANNEX 4: BEST PRACTICE SAMPLING METHODOLOGY FOR DSM SCIENTIFIC RESEARCH, which describes what factors need to be considered for each aspect listed in figure 4, including how and with what they should be measured. Key information from Annex 4 has been summarised into Table 9, which lists potential aspects of a DSM scientific research voyage, together with the main parameters and sampling methods that could be employed. Note that this is an indicative summary list, to be modified as appropriate for the specific resource, location and environments being studied.

Annex 4 is not prescriptive in detail, nor does it necessarily include all methods that may be suitable, but provides sufficient guidance to enable contractors, scientists, and regulators to formulate and understand a scientific work plan appropriate to the particular DSM site. It is also scientifically sound in a broader regional context.

Having consistent methodology in data collection across academic researchers and commercial entities enables regulators to effectively manage the data and combine it to gain a 'big picture' understanding of DSM resources (see also Part 2 Section 6). It is recommended that regulators refer researchers to Annex 4 so that their applications for MSR, prospecting or exploration can be suitably informed. Acknowledging that techniques and technology develop over time, regulators should require additional justification and clarification from researchers who wish to use different or novel methodology.

Table	le 9. Summary of recommended scientific methodologies.					
	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)		
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)		
nent c	Bioturbation rates	Natural mixing of sediments	Bioturbation depth, faunal zonation, Pb210 activity	Sediment cores (box corer or mulitcorer)		
Sedir	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		

ommunity	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
oor co	Microfauna	Impacts on benthic communities	Biodiversity, distribution, abundance	Sediment cores (box corer or mulitcorer)
Seaflo	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)
ceanography	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
Chemical o	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
Ū	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)

5 Understanding research programmes

The most critical aspect of any scientific research occurs right at the start. Hypotheses and operational objectives must be clearly defined. These dictate the necessary survey area, targeted ecosystem(s), survey sampling gear, and the survey design. Objectives will largely be driven by the requirements of the minerals regulations and permit conditions, and by existing knowledge of the studied ecosystems.

Evaluating survey design options is an iterative process: ship-time, gear type and sampling protocols limit the scope of work; hence, hypotheses and survey objectives may need to be recast.

A number of questions⁷⁸ will need to be considered before launching into any science programme.

- Spatial Scale over what area is it intended/possible to generalise results?
- Heterogeneity what are the known sources and scales of habitat heterogeneity in the study area?
- Spatial arrangement how shall sample units be dispersed and arranged to capture spatial heterogeneity?
- Size what size should/can sample units be?
- Number how many samples should be collected to achieve desired statistical precision?
- Time how many surveys and sampling intervals are needed to characterise the likely temporal variability?

These are discussed further below.

5.1 Sampling scale

Deep-sea science can span a broad range of scales from single-organism size studies to basin-wide or global investigations. Needless to say, the objectives of a study are the prime criteria to determine the appropriate scale of sampling and data collection. For example, in areas of hydrothermal vents, habitat features and heterogeneity of benthic structures may vary over scales of 1-10 metres, so the survey area required to characterize this variability may be comparatively small (e.g. Cuvelier et al. 2001). Similarly, seeps, pockmarks, vents and whale falls (dead whale carcasses that have sunk to the seafloor) represent distinct hotspots of biological activity over relatively small spatial scales (typical 1-100 m). However, although sampling at individual sites may be on a very small scale, it is important that any study of a specific mineral resource (1) characterizes variability across habitats with the area of mining interest (e.g. active vents, inactive vents, background hard and soft substrates, etc.) and (2) extends beyond the boundaries of the area of mining interest. Hence, surveys of SMS, for example, must evaluate active vents, inactive vents, and background hard and soft substrates for comparison, including adjacent habitats that may be appropriate "reference or control sites" or "downstream" impacted areas that could be affected by any mining activity (Van Dover et al. 2011). For MN, oceanographic and ecological patterns and gradients over scales of 100s–1000s km must also be considered (Wedding et al. 2013). Similarly, CRC-seamount scale biodiversity should consider a variety of physical and productivity characteristics (Clark et al. 2011). Ultimately, monitoring sites will need to be established in similar habitats at various distances away from the mining area in order to establish the extent of impacts.

At regional scales, the interest is often to identify environmental drivers and habitat attributes that influence biological community metrics (e.g. biomass, abundance, diversity, currents, seabed composition and structure), on scales of hundreds to thousands of kilometres (e.g. Vanreusel et al. 2010, Wedding et al. 2013). Studies will need to encompass replicate sites

⁸ These are mainly related to biological studies, although general concepts apply to other physical and oceanic studies as well.

that are thought to represent a cross-section of regional environmental heterogeneity (e.g. Narayanaswamy et al. 2010).

At the largest scales (ocean-basins to global), nearly all studies will have to draw on compiling data from multiple sources, or using models to predict occurrences of biota for areas not physically sampled (such as predictive habitat suitability modelling, e.g. Tittensor et al. 2009). At larger scales, investigators often have little choice over the spatial distribution of compiled data, with main challenges of quality control of records, matching spatial scales of environmental predictors to the fauna, obtaining accurate taxonomy, and accounting for possible confounding factors.

5.2 Spatial arrangement of sampling

There are a number of generic sampling designs (Figure 5) that can be appropriate for point sampling (e.g. coring) or continuous survey distributions (e.g. ROV transects), depending upon the scientific objectives (e.g. Green 1979, Sissenwine et al., 1983, Etter 2002). The main consideration at the outset is whether to design a survey where sampling sites are based on a regular grid (also known as systematic design), or to position sites in a random manner.





For abyssal MN fields, the seafloor is often flat, or nearly so; therefore, either a random stratified or regular grid design can be used to place the transects. With SMS and CRC resources on seamount or ridge structures, the transect pattern needs to be different. It is recommended on a conical seamount-type structure to run at least four photographic transects across the entire seamount, arranged in a regular 'starburst' pattern centred on the seamount peak and extending to the base. If the feature is more elongated (e.g. a ridge), then a parallel transect design will be more appropriate, with the spacing between transects being either constant (for mapping) or semi-random with a maximum spacing between transects (for more quantitative analysis). The survey must cover the full depth range encountered in the area, and the spectrum of seafloor topographic types.

In the past, exploratory surveys have often occurred when little is known about the environment of an area, and systematic surveys have been an appropriate design to obtain a "first-cut" of habitat and faunal distributions. It is now rare, however, for sampling to be carried out before a detailed multibeam survey has been undertaken, yielding information on topography and coarse bottom substrate type. This enables stratification to be done, and planning for a random sampling design that is more statistically valid by avoiding biases of arbitrarily spaced samples. For areas with known spatial partitioning of habitat types (e.g. from a desk-top study or pilot survey), stratified random sampling, with sampling locations randomly distributed within each habitat type or stratum, can be more appropriate. Therefore, in SMS habitats, there would be stratification of active vent and inactive background areas; in MN regions, dense nodule areas would be stratified separately from low-density nodule areas, and separate from abyssal hill habitats. In CRC seamounts, the summit, flanks and base might be stratified where faunal types differ.

Many deep-sea ecological studies seek to relate biological patterns to environmental drivers, postulated to structure assemblages through a variety of processes (e.g. effects on recruitment, reproduction, food supply, metabolism, dispersal). Some fundamental considerations at the spatial design stage include the following:

- spatial density and scale of sampling the fauna should match that of environmental variables; ideally, measurements of environmental conditions co-occur with faunal collections over the same geographic area;
- environmental variables that have a known and strong influence on the fauna are factored into the sampling design, including coverage of different habitat types; and
- faunal and environmental metrics are estimated at a precision capable of capturing biologically relevant scales of variability.

Many studies end up being unable to separate the primary hypothesis test from other environmental effects that confuse the results. An effective remedy to guard against this at the design stage may be to locate samples, where possible, in similar conditions for all potentially confounding variables. This is usually handled by stratification of the area, whereby similar habitats are treated as separate units for sampling and analysis. For example, depth can often be correlated with confounding environmental factors, so any mining control site will need to be located, at the least, on similar substrate at similar depths to enable a robust evaluation of faunal community structure, or mining impacts. The survey design may break the area up into depth bins where different communities are expected. Howell et al. (2010) provide an example of a well-executed study where confounding by depth, sediment type and seabed topography was carefully controlled at the design stage, through some sample culling and through statistical techniques.

There are no hard and fast rules about separation distance between sampling sites. This depends on the intended sampling density, as well as size of the sampling gear and the nature of the habitat. Fisheries surveys using large trawl nets typically have tows that are several km apart, while fisheries surveys on small seamount features will almost always have sampling sites that are close together. Researchers need to ensure that, as much as possible, sampling sites are separated by an appropriate distance (larger for larger gear and animals), or clear environmental differences.

5.3 Sampling unit size

The size of a sampling unit should match the spatial scale of variation in faunal communities. Most ecological processes vary with area, especially as environmental drivers that structure communities operate at different scales (Levin et al. 2001), and habitat heterogeneity can be scale-dependent (e.g. Williams et al. 2010). It is not often the case that knowledge of the distribution patterns of communities is available prior to an environmental survey being carried out for mining-related purposes. In this typical situation, the sampling unit size can be selected based upon expectations from previous studies of similar types of environment (depth, substratum type, region, etc.).

5.4 Number of samples

Replicate samples are required to estimate variability (variance between samples both within and between habitat types or strata), and to increase the precision of an estimate (e.g. mean, median). Underwood & Chapman (2005) state very simply that "spatial replication is

a mandatory component of any benthic study". The more variable the environment or the fauna, the more replicates will be needed to estimate statistics at a given precision, which will affect the power of statistical tests. Replicate samples need to be taken for any combination of space, time, habitat, or human impact gradient. Given prior knowledge of variability with the study system, analyses should be undertaken to determine the likely number of samples required to achieve a certain level of statistical power.

Replicates should be independent samples of the studied population or spatial scale. Independence between samples is a fundamental principle for most studies since it enables a statistically valid analysis and assessment of results. In deep-sea benthic ecological studies generalized over much larger scales than a square meter, sub-samples from corers and grabs and different tubes from a single multicorer deployment are sometimes used as replicate samples. However, these units are unlikely to represent independent samples of populations or habitats extending over larger spatial scales than the corer or grab. A key argument is the spatial scales over which environmental or biotic parameters are correlated. Feeding or reproductive patterns of animals (e.g. predators or phytodetritus grazers), and patchiness in environmental parameters (e.g. influence of hydrothermal fluids or nodule patches) can cause faunal or environmental variables in nearby samples to be correlated, i.e. non-independent. For example, multicorers have multiple tube-like cores, which are only 20-30 cm apart. These are unlikely to be independent unless key environmental or biotic parameters are highly variable on such small scales.

The variety of animals (i.e. number and types of species) typically continues to accumulate with the number of samples collected (including replicate samples) until the species richness is fully sampled and an asymptote is reached (Magurran 2004). Because of high species richness and a long list of relatively rare species in deep-sea environments, full species inventories have rarely been attained for deep-sea systems, even for large mega-fauna at intensively sampled sites (e.g. seamounts, Figure 6).



Species accumulation curve by number of samples

Figure 6. Species accumulation curves for three seamounts off New Zealand (NIWA, unpublished data).

This makes estimates of the numbers and distribution of rare species, and the level of true endemism very difficult. In the above case, if sampling had stopped on Rumble V seamount at 10 samples, 20% of the species eventually sampled would have been unobserved. Even after 13 samples, at least five new species were recorded with each additional sample.

There are three main ways to handle this in the final data analysis:

- Compare the same number of samples (i.e. similar area sampled): the least maximum number of samples taken at sites is used to compare the relative number of species. However, if biotic abundances between sampling sites are very different, areas with higher abundance are likely to be better sampled (species accumulation curves may be closer to an asymptote simply because more individuals have been collected (Magurran 2004).
- 2) Compare species richness between samples or areas at the same number of individuals, using rarefaction statistics (Magurran 2004) This is an approach widely used in deep-sea studies (Levin et al. 2001; Snelgrove and Smith 2002).
- 3) Compare the estimated total number of species in the system, using statistical estimators: there are several statistical methods to estimate the asymptotic value of the species accumulation curve (Magurran 2004). This enables the estimated absolute number of species to be compared.

The key issue here is to have an understanding of how complete sampling is, the level of uncertainty in results, and whether it is adequate to describe differences or changes in faunal composition. An important general recommendation is that all analyses should have a measure of statistical confidence associated with them, which is recommended by the ISA and was also highlighted in decisions of the New Zealand Environmental Protection Authority in rejecting applications for offshore mining of ironsands and phosphorate nodules.

5.5 Time-temporal aspects

One-off surveys are inadequate to collect data on temporal variability. Information from multiple surveys will need to be combined. Typically, the first survey will be undertaken to provide some baseline data, and then subsequent surveys are required to measure changes over time (seasonal, annual) that can be related to natural variability or mining activity. In addition, sampling gear bias means that many measurements are relative rather than absolute, and so trends over time are important. The number of surveys and their frequency depend on environmental variability, and productivity time scales. Obviously the longer the period of data collection, the more confidence can be had.

5.6 Sampling gear

A wide range of equipment is available for commercial or scientific sampling (see Eleftheriou & McIntyre 2005, Eleftheriou 2013, Clark et al. 2016). All have their advantages and disadvantages. To determine which are appropriate will depend upon the objectives of the survey, the physical and oceanographic setting, the target type of biological fauna (e.g. infauna/epifauna, size, population densities), and the type and nature of the seafloor (substrate, shape, etc.). Technology, and the types of equipment available to researchers are constantly developing and changing, but there is a suite of general gear types that have been, and are, currently in routine use for biodiversity studies, and refinements do not alter the core function or type of equipment. An example of some of the key issues for biodiversity survey gear are summarised for sampling of animals in Table 10.

types (adapted from C	ted from Clark et al. 2016).		
Gear type	Targets	Habitats/substrate type	
Trawls/dredges (fish, beam (Fig. 2-3 I),	Fish, large invertebrates (especially sessile), macro- and megafauna	Mainly soft or smooth bottom for animal sampling	
Agassiz-type)	Epifauna	Hard substrate for geological sampling	
	Large rock samples (but gear damage likely)	Qualitative to semi-quantitative (can be internally consistent for addressing trends)	
ROVs (Fig 2-3 C),	Imaging and collections of Epifauna	All habitats and substrate types Qualitative	
cameras (Fig 2-3 G)	Small-scale sampling of sediment biota		
	Small rock samples		
	Small core or grab samples		
	Seafloor characterisation		
Epibenthic sledges (Fig 2-3 H)	Small epibenthic macro- and megafauna	Suitable for most habitats	
	Rock samples	internally consistent)	
Grabs	Macro- and meiofauna	Soft bottoms only	
	Epifauna and infauna	Semi-quantitative	
	Small surface rocks/nodules	Smaller areas (decimetres) per sample	
	Sediments		
Corers (Fig 2-3 E)	Macro- and meiofauna	Soft bottoms only	
	Infauna, small epifauna	Quantitative to semi-quantitative	
	Small surface rocks/nodules	Smaller areas (decimetres) per sample	
	Sediments		

Table 10. Summary of general sampling gear type, and suitable target organisms and habitat/substrate types (adapted from Clark et al. 2016).

The type of gear used and how it is deployed can make a large difference in the types of animals captured, and their abundance, as well as its impact to the environment. For example, taking core samples is a routine survey activity in many programmes investigating abyssal plain fauna, especially in areas of MN interest. However, all corers can introduce sampling bias, especially if core designs and sampling protocols differ, and if the quality of core samples is not carefully controlled (e.g. eliminating core samples with evidence of surface disturbance). For example, Gage & Bett (2005) examined data from a box-corer and a multicorer, and found a strong under-sampling bias of the box-corer relative to the multicorer. This was attributed to a bow wave from the larger and bulkier box-corer as it approached the seabed, blowing away the smaller and lighter animals. However, the creation of bow waves and sampling biases in box coring can depend on the box-core design, deployment protocol and weather conditions. For example, Glover et al. (2008), found no significant differences between macrofaunal abundances sampled by box corers versus multicorers; they did find differences in taxonomic composition attributed to the different sampling scales of the two devices (a typical box core samples an area 0.25 m2, whereas the individual tubes of multicorers typically sample 0.005 to 0.008 m2).

The nature and extent of impact caused by scientific sampling should be considered when selecting the gear used. The "footprint" of the different gear types differs: the area sampled by each deployment typically increases, going from multicores to box-corers, to grabs to epibenthic sleds or dredges, and up to potentially much larger areas covered by beam trawls or fish trawls. Even less direct sampling equipment like submersibles can drop ballast weights on the seafloor. Together with ROVs, they require settling on the seafloor to take samples; towed

cameras often inadvertently contact the seafloor in poor weather conditions. The number of deployments and their density are determined by the survey design needed to achieve the research objectives with a suitable level of precision. However, care should be taken to keep effort to a minimum when sampling in sensitive habitats (especially where there are dense biogenic habitat-forming taxa like corals and sponges on seamounts). The larger impact-gear, such as trawls should be avoided where possible.

Standardisation of gear type within and between surveys is critical. Most research requires sampling gear and its operation to be standardised. While this is widely recognised, details are not often documented sufficiently to enable someone else to reproduce the same sampling performance, or to reset equipment in exactly the same way after it has been changed or damaged (differing box-core designs and sampling protocols may explain the different findings concerning box-core sampling efficiency by Gage & Bett. (2005) and Glover et al. (2008)). Full details of the sampling gear (including manufacturer and model), and their set up and deployment protocols should always be available in a voyage plan and publications/reports of results, especially for seafloor sampling gear (including trawls, dredges, sleds, and coring devices) where size and construction can vary considerably. Similarly, deployment procedures should be standardised, such as the amount of wire payed out, towing speed, duration and height above seafloor for towed gear, and rate of lowering into, and pulling out of, the seafloor for coring gear (see chapters in Clark et al. 2016).

The combination of gear types required will include plankton nets, imaging platforms, direct sampling trawls, sleds, sediment corers, and water sampling CTD equipment (Figure 7).



Figure 7.Examples of types of sampling gear required during minerals research (clockwise from top left): (A) CTD, (B) bongo nets, (C) ROV, (D) box corer, (E) Autonomous underwater vehicles (AUV), (F) multicorer, (G) towed camera frame, (H) epibenthic sled, (I) beam trawl.

5.7 Sampling protocols

How the catch or content of each gear sample is handled varies with gear type, the nature of the sample and the research institute, and introduces variable sampling efficiency or biases. It is important to ensure that the samples are handled and treated in a consistent way. This may not be an issue within individual research programmes, or the work carried out by an individual mining company. However, when attempts are made to compare across studies, and draw inferences well beyond a single study (such as global analyses), comparability between sample data can be very important. In recent years the Census of Marine Life, the ISA and other major international programmes have made attempts to improve consistency with regards to what gets sampled and how, as well as ensuring that physical, oceanographic and biological samples are treated in a similar way. This is a major field in its own right and beyond the scope

of these guidelines, but some excellent general texts are available (e.g. Eleftheriou & McIntyre 2005, Danavaro 2010, and a new book based on the Census of Marine Life experience by Clark et al. 2016).

Sampling protocols for the main types of scientific studies are covered in more detail in Annex 4.

6 Data reporting, sharing and archiving

Marine scientific research, environmental baseline studies and monitoring programmes of DSM represent a significant source of data and knowledge. Considering the cost of collecting these data, they represent considerable value to the State who should prioritise its receipt and storage to ensure its use is maximised. Good data management practices are becoming increasingly important in ocean research and allow more effective integration and reuse of data (see Stocks et al. 2016).

Developing States have faced difficulties obtaining maximum benefit from their data due to: lack of clear process for data reporting and submission requirements, receiving data in multiple formats, and having no systemic cataloguing of available data.

To address this, States must firstly ensure that researchers are aware of what information needs to be submitted to the appropriate regulatory authority.e easy way to achieve this is by including it in clear permit/licence conditions. MSR is conducted for the purpose of increasing knowledge for the benefit of all and conditions should stipulate that the researchers must publish their findings in peer-reviewed journals, global databases, etc. In addition to this, the State should request that after publication, the data also be submitted to the State for its own archiving. For prospecting and exploration, submission of data should occur in conjunction with the required annual reports. Some data may be considered commercially sensitive (mainly the geological data) and, therefore, the data will not be able to be shared by the State until particular conditions are met (i.e. relinquishment of licence, publication of EIA, a certain time period having passed, etc.).

In just the same way as with survey design, gear and sampling, there is a strong need to standardise as many aspects of data management as possible between researchers, contractors and agencies. Specifying up front what formats are required will make receipt and processing of data submissions efficient. Data submitted to regulators should include metadata⁷⁹, such as sampling information (e.g. time, date, location, depth, gear) and circumstances (e.g. weather, temperature), as well as who conducted the analysis and how the data was analysed.

States should establish a data archival and retrieval scheme which should have implicit flexibility (a relational database enables all data to be linked, and extractions made more easily), and be centralised to ensure it is maintained⁸⁰. Increased data accessibility provides higher levels of information that can be used to inform decisions and, ultimately, allow higher confidence in those decisions. Data may have more than one application and regulators should consider DSM data, not only for potential mine development but also for future users who might be unfamiliar with, or have different purposes for the data.

7 Cooperative research

Pacific States acknowledge the necessity for regional cooperation⁸¹. This should also apply to DSM scientific research. Cooperative research, as part of a regional marine science plan, would not only help to rapidly close gaps in knowledge but, more particularly, provide ongoing and updated resources for PICs to make informed decisions in relation to DSM developments.

⁷⁹ Metadata is additional information about the data.

⁸⁰ Regional agencies, such as the Geoscience Division of SPC can assist in the development of data and information systems.

⁸¹ See The Framework for Pacific Regionalism (http://www.forumsec.org.fj/pages.cfm/strategic-partnerships-coordination/ framework-for-pacific-regionalism/)

A range of studies required during prospecting/exploration will need specialised scientific equipment or expertise – whether technical sampling gear, taxonomic skills for faunal identification, or complex oceanographic modelling. Hence, it is likely, if not essential, that contractual relationships or partnerships are formed between commercial companies and scientific organisations. A number of national research institutions around the world are active in the Pacific Islands region, and have considerable biological and scientific expertise. As already demonstrated in Papua New Guinea and New Zealand with collaborative or contracted research associations with Nautilus Minerals-Duke University and Neptune Minerals-NIWA, combined resources can be more effective than a single programme. There remains considerable scope to develop cooperation arrangements between Pacific institutions, such as the University of the South Pacific (USP) and national research institutes with international researchers and DSM companies.

Cooperative research can facilitate the establishment of regional baselines of natural variability that build on geological, biological and other environmental records acquired in selected areas. The basic scientific information acquired in partnership should result in the cost-effective acquisition of information that will assist in development planning and decision-making on a regional scale that can integrate multiple uses, multiple sites, and manage impacts that could cross national boundaries.

Modelling studies should be undertaken collaboratively and linked closely to field studies at several sites to help assess risks under various management strategies, including various options for the design of protected areas.

GLOSSARY

Abyssal plain	An extensive, flat region of the ocean bottom from 3,500 m to 6,000 m, comprising fine sediments or oozes.
Applicant	A person who is applying for permission to conduct DSM scientific research.
The Area	The seabed and ocean floor and subsoil thereof beyond the limits of national jurisdiction. It is managed by the International Seabed Authority ('ISA'), as prescribed by the 1982 United Nations Convention on the Law of the Sea ('UNCLOS').
Benthic	Living on or pertaining to the seafloor.
Benthos	Organisms living on or in the seafloor.
Community	An assemblage of organisms that occurs together at a location at the same time.
Corers	Gear designed to take a sample of sediment containing infauna from the seafloor.
CTD	An oceanographic instrument that measures conductivity, temperature and depth.
Continental Shelf	Seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines. The Continental Shelf is from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.
Deep-sea minerals (DSM)	Hard mineral resources of the seabed which contain metals, including those in crust, nodule or hydrothermal sulphide deposit form.
Demersal species	An animal (typically a fish) that lives on or near the bottom of the sea and feeds on benthic organisms.
Diversity	The number of species found in a specific habitat or community (see biodiversity).
Dredge	A fishing and research tool used to collect animals from the seafloor – usually a rigid box-like structure.
DSM Project	A collaboration between the Pacific Community and the European Union that is helping Pacific Island countries to improve the governance and management of their DSM resources.
DSM scientific research	For the purpose of these guidelines, all scientific research and investigations conducted at deep sea mineral sites during MSR, prospecting or exploration.
Epifauna	Organisms living on or just above a surface, such as the seabed. May be attached or mobile.
Exploration	The search for, sampling, studying and analysis of DSM deposits for the purpose of investigating whether those minerals can be commercially exploited. Exploration may lead to mining (if viable deposits are found).
High sea	All parts of the sea that are not included in the territorial sea or in the internal waters of a State.

Grab	A type of sampling gear designed to collect sediment and infauna, using a scoop mechanism.
Habitat	The place where an organism lives, providing it with its requirements to live, grow, and reproduce.
Habitat mapping	The representation of habitats delineated by distinct combinations of physical, chemical, oceanographic and biological conditions.
Infauna	A diverse group of aquatic animals that live within marine and fresh water sediments.
Lander	An autonomous frame that is usually not tethered, and can be left on the seafloor for a period completely separate from the movements of the ship.
Macrofauna	Small benthic animals that live in or are associated with sediments and are retained by 0.25 mm mesh sieves.
Marine Protected Area	Any area of the coastal zone or open ocean/deep seabed, which has been accorded a level of protection for the purpose of managing or protecting vulnerable or threatened habitats and species.
Marine Scientific Research (MSR)	Although this term is not defined by UNCLOS, it is commonly agreed that two main categories of MSR coexist, namely: fundamental and/or resource-related research. For the purpose of these guidelines, MSR means any study, research or other related scientific activity, intended to increase knowledge about the environment for the benefit of mankind. Marine scientific research is usually carried out by academic institutions or State-owned enterprises and leads to published works. It does not include research directly for commercial or economic purposes.
Megafauna	Large animals visible to the naked eye and discernible on photographs or video imagery (generally large than 2 cm).
Meiofauna	That part of the microfauna which inhabits superficial layers of the muddy sea bottom and passes through a 0.3 mm sieve.
Mesopelagic	The pelagic zone below the euphotic zone, in the mid-depths of ocean waters, generally 200-1000 m.
Multibeam echosounder	An echosounder that transmits many beams and rapidly enables a 3-dimensional picture of the seafloor to be determined over a wide area under the ship or towed instrument.
National jurisdiction	The marine area (both the ocean and seabed areas) that falls under the control and management of the country. Government has sovereign rights over the living and non-living resources found within national jurisdiction, including any DSM. UNCLOS sets some rules for measuring the extent of the national jurisdiction. Generally, it runs up to 200 nautical miles from the coastal country's shoreline (but may be larger or smaller in some cases, depending on geological features or nearness to neighbouring nations).
Pelagic	Referring to organisms that live in the in the water column and not in association with the seafloor or coastlines. Can include the larval stages of benthic species.

Permit	A legal document issued by a government, giving written permission to conduct DSM scientific research within a country's national jurisdiction. From country to country, this may be called by a different name (e.g. 'consent', 'licence', 'contract', 'title', 'agreement') and may be issued by a different ministry or government agency, depending on national rules and laws.
Person	Any legal entity. This may include an individual person, or a company, institution, partnership, cooperative, or association.
Precautionary approach	Defined by the Principle 15 of the 1991 Rio Declaration on Environment and Development and requires that 'where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation'.
Prospecting	The first stage of the geological analysis, seeking potential mineral deposits. It is usually performed over a wide area, with no exclusive rights to the minerals found.
Remotely Operated Vehicle	A tatharad under water rebat an arated from a viscosi
(ROV)	A tethered underwater robot operated from a vessel.
Seamount	An underwater mountain. In ecological terms, they have an elevation above the seabed of 100 m or greater. Geologically, they are divided into seamounts (1000 m or greater elevation), knolls (500–1000 m) and hills (100–500 m).
Sediment	Small mineral particles, such as sand, mud or carbonate ooze, that cover most of the seafloor.
Species distribution	The geographical distribution of species, usually dictated by latitude, depth, temperature, proximity to required habitats.
Stratification	A means of subdividing an area for sampling, or for analysis, to reduce the variability in results.
Taxonomy	The classification of life in to categories, according to evolutionary relationships.
Towed camera frame	A camera system contained within a frame that is towed behind a ship.
Trawl	A net that is towed by a vessel across or through the water column.
Zooplankton	Floating and drifting small animals that have little power of independent horizontal movement. Some spend only some time as plankton as they pass through a larval or reproductive stage (Meroplankton), and others spend their entire lives as plankton (Holoplankton).

ANNEX 1:

APPLICATION FOR DEEP-SEA MINERALS SCIENTIFIC RESEARCH PERMIT

This Annex provides guidance to the content required in DSM scientific research applications. It can be used by States to develop or review application forms/criteria for DSM scientific research, or be referenced until such time that the State enacts appropriate legislation/regulations.

This Annex is divided into three sections. A) information which must be supplied in an application for all types of DSM scientific research (MSR, Prospecting and Exploration); B) additional information the State may wish to also request; and C) additional information that must be provided in an Exploration application.

A: An application for DSM scientific research activities must contain the following information:

1. Information about the applicant:

- a. Name.
- b. Nationality and (where relevant) evidence of incorporation or registration as a body corporate.
- c. Registered address, street and postal address of the principal place of business (if different).
- d. Telephone number, facsimile number, and email address.
- e. Nature of business.
- f. Details of directors and ownership.
- g. Details of any other collaborators and participants in the proposed research activities.
- h. The key positions in charge of the proposed DSM scientific research activities, and the name, nationality, contact details and brief curriculum vitae details of the personnel who will fill each key position, where known.
- i. Brief particulars of the previous experience of the applicant in DSM activities.
- j. The credit rating of the applicant (and any principal financial backer).
- 2. Details of the area in which the research activities will be conducted ('permit area') that:
 - a. adheres to any prescribed requirements or guidance issued by government with regards to size, location and shape⁸²;
 - b. includes the coordinates (in accordance with the World Geodetic System WGS 84);
 - c. includes an explanation and appropriately scaled chart of the location and boundaries of the permit area, with reference to government's cadastral map and system of blocks, where relevant; and
 - d. specifies the total size of the permit area.
- 3. A description of the type(s) of minerals with which the research activities are associated.
- 4. The proposed start and end date of the research activities.

⁸² For example, government may specify marine protected areas where DSM scientific research is not permitted, or may have restrictions on the size of exploration permit areas (to avoid too much of the seafloor being under exclusive use and active exploration at one time).

- 5. A general description of the nature and objectives of the proposed activities, and the proposed use of the data collected, including any plans to make raw and processed data available to the host country, as well as research results to be made internationally available.
- 6. A plan of work, covering the life of the proposed research activities, including:
 - a. vessel name(s) and number(s);
 - b. the proposed dates and ports of embarkation and disembarkation of vessels, and dates of planned entries to and departures from the permit area;
 - c. the details of any intended ports of call, any special logistical requirements at ports of call, and the details of the relevant shipping agent, if available;
 - d. particulars of the vessel(s) and any underwater vehicles/craft to be used, including type/class, details of owner and operator, nationality (flag state), identification number, particulars of the crew, and evidence as to their certification against international standards⁸³;
 - e. a description of the proposed research events and activities, including:
 - (i) sampling of rocks, sediments, seabed mineral deposits or ore including the type(s), proposed extraction methods, and estimated volumes to be extracted;
 - (ii) drilling into the seafloor or substrate including the type of drilling, and the number, size and depths of drill holes;
 - (iii) release of substances into the marine environment;
 - (iv) removal and/or export of (living or dead) biological specimens, or water samples, including details of methods of extraction and available details as to type and quantity;
 - (v) details of the methods and technology to be used (excluding confidential proprietary information, as appropriate), including locations, depths and duration of deployment of any scientific instruments or other equipment;
 - (vi) any planned decommissioning and rehabilitation activities; and
 - (vii)studies to be undertaken in respect of environmental, technical, economic or other factors.
 - f. A time-event chart to summarise proposed work plan.
- 7. A general description of the current state of knowledge about the environment and biological communities, and current or historic uses (e.g. local or international fishing, mammal migration route, existing oil or mineral extraction, dumping area listing known data and information sources).
- 8. A "Gap Analysis" should be undertaken, which identifies the information needs and basis for that need (i.e. what is needed for what reason).
- 9. A preliminary assessment of likely impact on the marine environment or other sea users of the proposed activities, consistent with Part 2 of these guidelines, including indication of the nature and quantity of any substance(s) to be released into the marine environment.
- 10.Details of the environmental management plan (of the vessel and/or institution) and track record.

⁸³ Such as those included in the International Maritime Organization Conventions, listed here: http://www.imo.org/About/ Conventions/ListOfConventions/Pages/Default.aspx

- 11. The expected dates and method of submission to the government of any preliminary or interim reports, the final report, and assessment of data, samples and research results.
- 12. The proposed means for the government to access data, samples and research results, and any proposed means to provide assistance in data assessment or interpretation.
- 13.Details and evidence where available of the applicant's technical/financial capacity to carry out the proposed work-plan and to respond to accidents, emergencies or serious incidents⁸⁴, and details of any relevant insurance.
- 14.Details of the applicant's occupational health and safety policies and track record.
- 15.Details of any other permits required (whether received or pending) for the proposed activities (e.g. under the country's foreign investment or environmental laws).
- 16. The application fee (or proof of payment of the application fee), where required.
- 17.Any other relevant information or supporting documentation that will assist the government with reaching a decision whether or not to issue a permit for the proposed DSM scientific research.
- B: An application for DSM scientific research activities may also contain the following -
 - 18.Details as to the participation of a national of the host country in the research activities, or other local capacity-building initiative, where relevant.
 - 19.A report of any goods, services or employees anticipated to be procured locally for the research activities.
 - 20.Details of any public engagement and information-sharing planned about the research activities and arising results.
- C: An application for DSM exploration must also contain the following -

21.A financing plan, including insofar as possible:

- a. a forecast of: capital investment, operating costs, and annual expenditure;
- b. the anticipated type and source of financing; and
- c. copies of the applicant's financial statements for the preceding three financial years, audited in conformity with internationally accepted accounting principles and certified by a duly qualified firm of public accountants; or if the applicant is a newly organised entity, a pro forma balance sheet certified by the Chair of the Board of the applicant.
- 22.A summary of any feasibility or other studies previously conducted by the applicant, or other party, upon which the applicant is relying in relation to the potential of the proposed permit area.
- 23.Details of planned environmental and oceanographic studies and baseline data collection, consistent with Part 2 of these Guidelines.
- 24.Plan for minimum expenditure and permit area relinquishment requirements.

⁸⁴ Such as collision or capsizing of a vessel, serious injury occurring in the course of the research work at-sea, or spillage of toxic substance into the ocean, etc.

ANNEX 2:

TEMPLATE FOR DEEP-SEA MINERALS MARINE SCIENTIFIC RESEARCH OR PROSPECTING PERMIT

[Name of responsible Government Department] hereby consents to the [marine scientific research / prospecting] activities of [name] in [location] on [dates] ('the Activities'), subject to –

- A) the strict adherence of the project and its proponents to the description of the Activities contained in the application form of [date] ('the Application'); and
- B) the following terms and conditions:

1. This permit -

- (a) does not entail any exclusive rights of access to the seabed or water column;
- (b) does not permit extraction of seabed mineral deposits or biological specimens except in small-scale samples and only insofar as has been detailed in the Application form, or as may otherwise subsequently be agreed during the term of this permit in writing by [Government Department] prior to any such extraction;
- (c) does not constitute the legal basis for any claim to any part of the marine environment or its resources; and
- (d) shall cease entirely or within a particular area upon written notice being given by [Government Department] to that effect, and in accordance with the timescale provided in that notice.
- 2. It is a condition of this permit that the persons conducting the Activities at all times shall:
 - apply the precautionary approach and best environmental practice;
 - take appropriate steps to prevent pollution and other hazards to the environment, and comply with national environmental and dumping-at-sea laws;
 - comply with the laws of the vessel's flag state relating to safety of life at sea, prevention
 of pollution from ships and other international agreed standards;
 - not proceed with the Activities if there is evidence indicating that to proceed is likely to cause harm to the environment of a nature that is not detailed in the Application;
 - conduct the activities exclusively for peaceful purposes, [if permit is for MSR, add: and for the purpose of increasing scientific knowledge for the benefit of all mankind];
 - not interfere with other legitimate uses of the sea, except where to do so is considered necessary [for example to prevent harm to human life and safety];
 - keep [Country] indemnified against any action, proceeding, cost, charge, claim or demand, which may be made, brought, or levied by any third party in relation to the performance of the Activities, and will be liable for the actual amount of any compensation or damage arising out of the permit-holder's failure to comply with the permit or the laws of [Country], and any wrongful acts or omissions and those of its employees, officers, subcontractors, and agents in the performance of the Activities; and
 - [optional] make every reasonable endeavour to facilitate and support the meaningful participation of [insert name and details of representative(s) of [Country]) in the Activities.]

3. This permit is further conditional upon:

 (a) transmission to [details of appropriate channels] of: all entries and departures into and out of [Country's] national jurisdiction, any port arrivals and departures, and daily position reports;

- (b) removal of installations or equipment once the at-sea research activities are completed;
- (c) submission to [Government Department] and the Geoscience Division of the Pacific Community of preliminary and final reports when and as detailed in the Application, which:
 - (i) include:
 - A) details as to the Activities performed, against the plan of work, and other plans and commitments set out in the Application;
 - B) results obtained from the Activities, including a statement of the quantity of seabed minerals recovered as samples, and any estimates of the economically recoverable quantities of seabed minerals within the research location;
 - C) a list of maps, reports and other geological, geophysical, and environmental data prepared by or for the holder in relation to the Activities; and
 - D) raw data with detailed acquisition parameters, and copies of assessment of data, samples and research results.
 - (ii) are provided in formats that are user-friendly and comprehensive, consistent with the guidance for research given in Part 2 of these Guidelines, and
 - (iii) identify and justify any material that cannot be published;
- (d) retention and secure storage of all data and samples derived from the Activities;
- (e) prompt response to any reasonable [Government Department] requests for information relating to the Activities, and related data or samples, and cooperation with any reasonable inspection and monitoring activities undertaken by the Government of [Country] in relation to the Activities;
- (f) any deviation in the Activities from the information provided in the application being notified promptly (and where possible – in advance) to [insert name of Ministerial focal point], and following any instructions received in response;
- (g) provision of immediate notice to [insert name of Ministerial focal point] in the event of any unexpected emergency situation or serious incident⁸⁵, occurring during the course of the Activities.

4. This permit may be:

- (a) surrendered by the holder with one month's prior notice in writing, without penalty; and
- (b) wholly or partially revoked by [Government Department] upon written notice being given to the holder by the [Government Department], in particular where:
 - (i) a right to explore or mine, or a declaration of a marine protected area, has been or is about to be issued for that area, or
 - (ii) the holder breaches any material undertaking or requirement of the permit and fails to remedy the breach within one calendar month of being required to do so by [Government Department];
 - and shall otherwise terminate upon [either insert date or the wording 'completion of the Activities'].
- 5. Upon surrender, revocation or termination of this permit, all rights granted shall cease; but, the holder shall remain subject to any ongoing obligations or liabilities imposed on the holder by the permit.

⁵ Such as collision or capsizing of a vessel, serious injury occurring in the course of the research work at-sea, or spillage of toxic substance into the ocean, etc.

ANNEX 3:

TEMPLATE FOR DEEP-SEA MINERALS EXPLORATION LICENSE

[Name of responsible Government Department], and address/contact details] hereby consents to the [exploration of deep-sea minerals – or insert more detailed description of the activities and the minerals] of [name and registered address of company and contact details] ('the Company'), represented by [name and contact details of managing officer] in [location] on [dates of commencement and conclusion] ('the Activities'), subject to –

- A) the strict adherence of the project and its proponents to the plan of work, time schedule, financing plan, environmental management plan, employment strategy, capacitybuilding programme and any other aspects of the description of the Activities, derived from the application form of [date], and included as Schedule 2 to this license; and
- B) the following terms and conditions:
 - 1. This permit enters into force on [insert date/'upon inclusion in the register held by [Government Department]'] and shall remain in force until surrendered, revoked or terminated in accordance with clause 8 of this permit.
 - 2. This licence -
 - (a) gives the Company exclusive rights of access to the area(s) of the seabed delineated in Schedule 1 to this permit, for the purpose of exploration for seabed minerals, as reduced from time-to-time in accordance with clause 5(a) of this license ('Licensed Area');
 - (b) permits extraction of seabed mineral deposits from the License Area for the purpose of sampling, only insofar as is detailed in Schedule 2 to this permit, or as may otherwise be agreed by [Government Department] in writing prior to any such extraction;
 - (c) does not give ownership or property rights to the Company over any cores, mineral samples or biological samples acquired in the course of the Activities. Such samples remain the property of the [Crown/State] and shall not be disposed of or removed from the territory of [Country], except with the consent of the [Government Department]. [Government Department] shall not withhold such consent save with good reason, where the purpose of the disposal or removal is the assay, identification, analysis or storage of the cores or samples;
 - (d) gives the Company:
 - i. preferential rights to apply for the right to mine within the License Area up to and including the year following the expiry of this permit; and
 - ii. the right to apply for the exclusive retention of nominated blocks within the License Area, which shall reserve those areas exclusively for a future mining application by the holder for a period and fee to be agreed by [Government Department]; and
 - (e) [Subject to advice of Government lawyers/finance officers that this is compatible with national law and policy] acknowledges that the Company may freely import into [Country] and remit outside of [Country] funds and equipment as is necessary for the performance of the Activities.

3. The [Government Department] hereby -

- (a) guarantees the Company security of tenure for the continuing duration of the permit, and will not suspend, revoke or vary the license before its end-date, except in accordance with the terms of this permit; and
- (b) undertakes not to permit any other entity to undertake deep-sea mineral research in the License Area, or otherwise take action in the License Area that might cause unreasonable interference with the Activities.

4. It is a condition of this license that the persons conducting the Activities at all material times shall:

- (a) undertake the Activities diligently and responsibly and in accordance with the terms of this license and [insert reference to relevant national rules/laws];
- (b) apply the precautionary approach and best environmental practice;
- (c) take appropriate steps to prevent pollution and other hazards to the environment, and comply with national environmental and dumping-at-sea laws;
- (d) comply with the laws of the vessel flag State, relating to safety of life at sea, prevention of pollution from ships and other international agreed standards;
- (e) only release into the environment substances of a biodegradable nature, except and only insofar as is detailed in Schedule 2 to this permit;
- (f) not proceed with the Activities if there is evidence indicating that to proceed is likely to cause harm to the environment of a nature that is not foreseen in Schedule 2;
- (g) conduct the Activities exclusively for peaceful purposes;
- (h) not interfere with other legitimate uses of the sea, except where to do so is considered necessary [for example, to prevent harm to human life and safety];
- (i) make every reasonable endeavour to facilitate and support the meaningful participation of representative(s) of [Country] in the Activities;
- (j) maintain at its expense comprehensive insurance with respect to its property and the Activities with a creditable provider, and provide copies of the certificates and policies upon [Government Department's] request;
- (k) keep [Country] indemnified against any action, proceeding, cost, charge, claim or demand which may be made, brought, or levied by any third party in relation to the performance of the Activities, and will be liable for the actual amount of any compensation or damage, arising out of the Company's failure to comply with the license or the laws of [Country], and any wrongful acts or omissions and those of its employees, officers, subcontractors, and agents in the performance of the Activities; and
- make the following payments to the [Treasury? Insert back account and bank name] in [local currency] in respect of the Permit:

Fee description	Due date	Amount	Conditions of Payment
Annual License Fee			Non-returnable
Performance Bond			Returnable upon successful completion of the Activities, including any rehabilitation activities detailed in Schedule 2 to this permit.

5. It is further a condition of this License that the Company will be required to:

- (a) [Insert relinquishment requirements in accordance with national policy/DSM type, e.g. for nodules: 'relinquish 50% of the License Area (leaving the remaining License Area in a contiguous block) 5 years from the date of commencement of this permit, and 10% of the remaining License Area every 2 years thereafter, until 25% of the original License Area remains (in a contiguous block), at which point no further relinquishment is required']; and
- (b) meet or exceed the minimum expenditure commitments specified in Schedule 3 to this permit. In the event that those commitments are not met, the Performance Bond required under clause 4(l) of this license may be used to pay to [Government Department] the full amount of the shortfall.

6. This license is further conditional upon the Company's:

- (a) transmission to [details of appropriate channels] of: all entries and departures into and out of [Country's] national jurisdiction, any port arrivals and departures, and daily position reports;
- (b) removal of installations or equipment once the Activities are completed;
- (c) submission to [Government Department] and the Geoscience Division of SPC of preliminary and final reports, as and when detailed in the Application, which:
 - (i) include:
 - A) details as to the Activities performed, against the plan of work, and other plans and commitments set out in the Application;
 - B) results obtained from the Activities, including a statement of the quantity of seabed minerals collected as samples, and any estimates of the economically recoverable quantities of seabed minerals;
 - C) a list of maps, reports and other geological, geophysical, and environmental data prepared by or for the holder in relation to the Activities;
 - D) raw data including all oceanographic and environmental baseline data acquired – with detailed acquisition parameters, and copies of analysis and assessment of data, samples and research results;
 - E) a summary of any engagements with the public about the Activities; and
 - F) financial statements showing the expenditure incurred in carrying out the Activities;
 - (ii) are provided in formats that are user-friendly and comprehensive, consistent with the guidance for research given in Part 2 of these Guidelines; and
 - (iii) identify and justify any material that cannot be published;
- (d) retention and secure storage of all data and samples derived from the Activities;
- (e) acceptance of the regulatory control of [Government Department] over the Activities and, in this regard, its:
 - (i) prompt response to any reasonable [Government Department] requests for information relating to the Activities, and related data or samples;
 - (ii) cooperation with any reasonable inspection and monitoring activities undertaken by the Government of [Country] in relation to the Activities; and
 - (iii) compliance with any directions or orders lawfully made by [Government Department] or the Court of [Country], including those relating to the protection of the marine environment, safeguarding human life and safety at sea, or any other matter of public interest;
- (f) prompt (and where possible, in advance) notification to [insert name of Ministerial focal point] of any deviation in the Activities from the work plan and other details contained in Schedule 2 to this permit, and adherence to any instructions received in response;
- (g) provision of immediate notice to [insert name of Ministerial focal point] in the event of any unexpected emergency situation or serious incident⁸⁶ occurring during the course of the Activities.
- 7. This license may not be assigned, transferred, leased, sub-let or mortgaged without [Government Department]'s prior written consent, and the Company must notify [Government Department] of any significant change in the constitution, ownership, control or corporate organisation of the Company.

⁸⁶ Such as collision or capsizing of a vessel, serious injury occurring in the course of the research work at-sea, or spillage of toxic substance into the ocean, etc.

8. This license may be:

- (a) surrendered by the Company with [three] months' prior notice in writing, without penalty; and
- (b) wholly or partially varied or revoked by [Government Department] upon written notice being given to the Company by the [Government Department] only where:
 - (i) the Company breaches any material undertaking or requirement of the license or the [insert reference to relevant national rules/laws] and fails to remedy the breach within one month of being required to do so by [Government Department];
 - (ii) no material efforts have been made by the Company to undertake the Activities for a period exceeding [three years] and that inactivity is not due to conditions of force majeure;
 - (iii) any payment or deposit owing to [Government Department] by the Company is in arrears or unpaid for [six months], following the day on which it ought to have been paid; and
 - (iv) the variation or revocation is, in the reasonable opinion of [Government Department], necessary to avoid: serious risk to the safety, health or welfare of any person, or the marine environment; conflict with any obligation of [Country], arising out of any international instrument in force for [Country]; or any situation which may reasonably be expected to lead to a breach of international or domestic peace and security;
- (c) renewed for successive periods of up to [five] years, upon approval by [Government Department], having received written application and payment of any prescribed renewal fee [or state here the required amount and method of payment of application fee] from the Company before the expiry of this permit;
- (d) reviewed to adapt conditions imposed for environmental management if monitoring indicates that this is required; and shall otherwise terminate upon [insert date, e.g. 5 years after the start date].
- Upon surrender, revocation or termination of this permit, all rights granted shall cease, but, the Company shall remain subject to any ongoing obligations or liabilities imposed on the Company by the license and [insert reference to relevant national rules / laws].
- 10.The Company may at any time seek prior written agreement from [Government Department] to make such changes in the work plan, and other details contained in the license and its Schedules, as may be necessary and prudent in accordance with best industry and environmental practice, and relevant global economic conditions. [Government Department's] agreement to such changes shall not be unreasonably withheld and decisions shall be taken in a timely manner.
- 11.No oral understanding nor prior written agreement affects the terms of this permit, and any modification to the terms set out must be evidenced in writing and signed by both parties.
- 12.Any dispute arising between the Company and the Government of [Country], touching or concerning the interpretation of this license and the rights and liabilities of either of the parties shall be settled in accordance with the laws of [Country] or, by alternative, dispute resolution mechanisms where this and the terms of those mechanisms is agreed to by the Company and the Government.

13.Any application, request, notice, warning, report, or direction made or given under this permit, or service of process or notification in any proceeding of any court or tribunal having jurisdiction, shall be made by the [Government Department] or the Company to the address specified in this license in writing, and shall be deemed served the day after delivery, if delivered by hand, facsimile or email.

[Insert signature clauses]

[Insert as Schedules to the permit:

- 1. A chart of the License Area.
- 2. The work plan, financial plan, exploration environmental management plan, employment strategy, capacity-building programme, and any other material details from the application documents.
- 3. A table showing annual minimum expenditure requirements (may differ from year to year, or allow 'carry-over' across to two years, and may also specify minimum expenditure that must occur in [Country].

ANNEX 4:

BEST PRACTICE SAMPLING METHODOLOGY FOR DSM SCIENTIFIC RESEARCH

This Annex provides recommendations and describes procedures to collect baseline data and monitoring operations that should be performed during prospecting and exploration activities, which can then underpin the preparation of an Environmental Impact Assessment, prior to any application for a full mining permit.

These guidelines are not prescriptive in their detail, but provide sufficient guidance to enable contractors, scientists, and managers to formulate a scientific work plan for deep sea minerals scientific research that will be appropriate to the particular site, and which is also scientifically sound in a broader regional context.

The research plan will need to be devised, taking into account the particular site characteristics, and appropriate research and management objectives. The intention is that the advice below is a reasonably comprehensive starting point, from which a practical and appropriate research plan can be developed.

1 Physical assessment

1.1 Geology

Geological research addresses a large variety topics of interest to deep sea mining, but particular focus is usually on the seafloor and immediate sub-seafloor structures, geomorphology and sedimentological properties. The scale of sub-seafloor investigation varies, depending on the specificity of the research and the resolution needed, and can be up to a few hundred meters. Likewise, marine geological survey design varies according to the aim and scale of the research programme and the equipment and tools used.

Knowledge of the seafloor morphology is essential for optimal survey design, including geometry of survey transects for geophysical data acquisition and placement of suitable sampling stations. Geological information can provide proxies to help derive semi-quantitative data on resources, benthic habitat, hazards, and infrastructure installations, to name but a few. Physical assessments of the benthic environment include bathymetry and bathymetric-derived data, substrate composition and structure and the relationship with benthic faunal communities. Such information and assessments require acquisition, processing and interpretation of both remotely sensed-data and physical sampling.

1.2 Seafloor topography

Information on the shape and structure of the seafloor is generally derived from remote-sensing data sources, such as from satellites, sea-surface vessels and deep-sea equipment — either towed (e.g. side scan) or autonomous (e.g. AUV, ROV).

There are three main issues that need to be considered for building baselines or for monitoring purposes from a geophysical data point of view, and which will influence the choice of methodology used.

- 1. Scale and extent of the survey: whether to use satellite derived data, ship-borne multibeam echosounders, or deep-sea equipment (e.g. ROV, AUV, deep-towed sonar).
- 2. Surrogate variables: these are the biophysical variables that can be mapped with a quantifiable correspondence to the occurrence of substrate, benthic species or communities. Acoustically derived data (most generally bathymetry and backscatter) have been successfully used as surrogates to predict physical properties of the seabed.

3. Required resolution: whether working at a regional scale (e.g. basin-wide), local scale (e.g. seamount) or organism scale, the density of data acquired across the mapped area will impact the interpretation of the final habitat map.

The most widely used method for gathering information on shape and structure of the seafloor are the ship-borne multibeam echo-sounders (MBES), which collect bathymetric and backscatter data, and are the focus of the text below. Other methods, not discussed in detail, which may also be considered include: seismic reflection, magnetic and gravity data.

The design of a mapping survey will aim to optimise ship time, data coverage and data quality. Such a survey should follow a systematic and purposeful approach to data acquisition. A number of documents have been written to help with designing MBES mapping surveys, such as Boyd et al. (2006), Anderson et al. (2008), and Lamarche et al. (2016).

Using acoustic technology, MBESs collect information on the depth of the seafloor by transmitting acoustic signals (sound waves) into the water column and measuring the time the signal takes to reflect off the seafloor and return to the receiver. This bathymetry data should be collected over the total area expected to be significantly affected by the dispersal of mining by-products. The likely affected area can be estimated from prior oceanographic studies. The mapping survey should cover multiple seamounts in areas of interest for CRC or SMS (if a ridge or back-arc system), and at least double the area of potential minerals interest in abyssal plain or deep-slope environments for nodules to determine how consistent the seafloor topography is relative to the surrounding region.

Echosounder data rely primarily on sound velocity in sea water, which depends on water salinity and temperature. Knowledge of the sound velocity variations with depth, time and space is essential for the accuracy of MBES data, and must be monitored during the survey through, for example, regular sound-velocity profiles (SVP). Vessel motion also directly affects the geometry, quality and accuracy of the outgoing and incoming sound signals of the MBES. Most modern vessels have the ability to accurately measure the vessel movement and position (attitude) in real time, and modern software usually apply the appropriate corrections to the incoming sound data.

Full processing of MBES data post-survey is time consuming and relies on ancillary data (e.g. sound velocity) and technical expertise. Hence, both the unprocessed (raw) data recorded by the echosounder and the fully processed data — corrected for vessel motion — compensated for sound propagation and cleaned of erroneous data, should be provided to the coastal state. The fully processed data are usually provided as a grid, or Digital Terrain Model (DTM) of interpolated depths from the cleaned and processed soundings at a user-selected resolution. All echosounder data need to be accompanied by sound velocity data through the water column and other correction information.

As well as measuring the time the acoustic signal takes to return to the receiver, the intensity of the returning signal is also recorded by the echosounder. This is called "backscatter" (or seafloor acoustic reflectivity). The backscatter provides information on the substrate (Lurton and Lamarche 2015), as it relates to seafloor micro-topography (or roughness), and sediment grain-size (or volume heterogeneity) and, therefore, has direct links with sediment composition. Importantly, the backscatter signal provides direct qualitative and quantitative information of the nature of the substrate and micro-topography.

Backscatter data require processing procedures, separate from those of the more routine derivation of bathymetry. The backscatter signal needs to be retrieved and decoded from the echo level at the receiving array onboard, and includes system-specific corrections. Post-processing can involve highly complex analyses, depending upon the nature of the substrate and topography, and the need for quantitative or qualitative outputs. Processed backscatter maps are traditionally presented as black and white images (also called seafloor imagery). Such maps emphasise topographic and geological features not necessarily recognised with conventional surveying. Data can yield fine detail, in particular, sediment composition, but also

information on the origin, nature, and structure of bedforms. The combined use of backscatter and micro-topographic processing enhances the interpretation of fine-scale geological and topographical features visible in multibeam data. For example, strong reflectivity on canyon floors may suggest gravel deposits, indicating active sediment delivery of coarse-grained bedload, strong up- or down-canyon bottom currents that have winnowed away fine-grained sediment, or intra-canyon debris flows.

Weather and the resulting sea state may impact on both bathymetry and backscatter data quality (Lurton and Lamarche 2015). The survey plan should be adaptable, so that if the wind and sea direction is causing poor data (usually bubbles being drawn down along the ship's hull and under the transducers — so called "bubble sheeting"), the transit line direction can be altered to minimise the issue. Transiting with the weather (downwind and parallel to the swell) can be effective, whereas transiting into the weather generally results in poor data recovery. Transiting across the weather can achieve variable results, depending on vessel size, hull design and the wave/swell height.

During surveying, bubble sheeting and turbidity caused by rough seas can have a negative impact on backscatter data. Furthermore, since the intensity of the seafloor backscatter is dependent on the incident angle of the acoustic wave on the seafloor, overlap between adjacent swathes and direction of steaming are of great importance, as redundancy may provide further information for downstream users interested in examining any angular response of the seafloor.

1.3 Map generation

The choice of a map scale is highly dependent on equipment resolution, i.e. the density of data acquired across the mapped area. This, in turn, will impact upon subsequent interpretation. Maps should provide the optimal balance between regional scale that provide information on the heterogeneity of the environment, such as major geological and geomorphological features, and outcrop scale that display the substrate variability, and provide an appropriate context for the sites of interest. A wrong scale can yield either too simplistic or too complex maps. This is particularly true where point data, such as sample stations, do not align closely with the level of spatial heterogeneity revealed by the continuous mapping of the physical environment. Also important to consider is the impact of temporally separated data used to generate a map, and whether different equipment was used to generate contiguous maps.

The choice of projection for generating a map is not trivial and may result in undetected errors or inaccuracies in positioning and estimates of areas. Even though most GIS systems seem to manage the projection issues seamlessly, a good understanding of the pros and cons of the most popular projection is required when generating the map and when using it (Maling 1992).

Bathymetric maps are the primary tool for any resource-based investigations on MN, SMS or CRC. They provide essential information on water-depth and first-order seafloor morphology. Such maps show the seafloor as contour lines or a colour-coded digital elevation model. Bathymetry maps together with backscatter maps will help identify the likely extent and morphology of the resource deposit and the distribution of broad habitat types (e.g. flat areas of soft sediment, knoll or hill features, steep ridges of hard substrate). This can be further enhanced in a second stage by generating derivatives of the bathymetry (e.g. slope, slope change, bathymetric position index, easting, northing) and once seafloor photographic surveys are undertaken as part of the biological survey programme. Video imagery, in particular, can give fine-scale information on changes in the substrate type.

In sites of SMS potential, maps need to include the distribution of active venting sites, in order to highlight areas of interest, such as those with potential biodiversity and resource. Backscatter and geomorphology maps are well suited for SMS mapping as the low reflectivity of hydrothermal vents and smooth surface of sulphide mounds strongly contrast with the surrounding high reflectivity and roughed nature of volcanic material. This depends, however,

not only on the geological setting, but also on the resolution of the original datasets. Geological studies (in concert with chemical analyses) should classify areas that are still under the potential influence of a heat source (even if there is no current venting of hydrothermal fluids evident at the time), or extinct sites (e.g. inactive chimney fields) which are at sites remote from presentday heat sources. From an ecological point of view, because faunal communities will vary with venting activity and chemical composition, it is important to know, as far as possible, whether the proposed mining site has active hydrothermal vents and/or inactive vents that may restart, owing to mining activity, and/or inactive vents that will remain hydrothermally inactive even when disturbed by mining.

1.4 Sub-seafloor data

Sub-seafloor investigation will usually be required for DSM exploration or pre-mining investigations, especially for SMS and CRC. The depth of penetration will range from a few meters (e.g. for information on sediment bioturbation rates) to tens of meters for quantitative estimates of resource extent or investigation of physical processes of formation or deposition.

Sub-seafloor investigation during the exploration phase most usually requires acoustic technology (e.g. seismic reflection) and physical sampling (e.g. coring, drilling). Much heavier seafloor and surface equipment not detailed here will be required at the feasibility phase or pre-mining testing.

Seismic reflection data are of particular importance for assessing the physical environment as they provide a means to image the architecture of the geological layers at depth, and to relate seafloor physical characteristics to fundamental geological processes (tectonics, volcanism, sedimentology). In the case of SMS, seismic reflection data will provide an efficient means to estimate the size of the orebody and, therefore, quantify the resource. Seismic data can be derived from sea-surface (ship-borne) or deep-towed systems. Sea-surface technology is well tested and reasonably affordable compared with deep-water high-resolution seismic data which, although state-of-the art, remains complex in deployment and processing. Deep-towed seismic equipment can be deployed from either vessels or AUVs, and provides sub-metre resolution of sub-seafloor structures (Marsset et al. 2014), whilst surface-towed equipment provides a means to obtain deeper penetration at the cost of coarser resolution.

There is a wide range of equipment available for collecting sub-seafloor geological and biological samples, the choice of which is dependent on the nature and the depth below seafloor of the targeted material (Narayanaswamy et al. 2016).

The targeted depth range of interest rarely exceeds one metre below seafloor for CRC and MN; however, depths of ~ 30 meters may potentially be required for SMS. The competence (the ability to withstand stress) of the targeted material can vary considerably, from very low for unconsolidated soft sediments (for which the use of various coring systems will be suitable), to very high for e.g. indurated volcanic rocks, for which drilling may be required.

For SMS and CRC investigations, coring will rarely be feasible for collecting mineralised consolidated rock materials, but may provide valuable information on any unconsolidated material and/or barren rock overlaying the mineral deposit. Seafloor grabs, dredging and drilling will likely be the most useful gear to retrieve samples from the mineral deposit. It is probable that dredging and coring will be sufficient for MN in the first stage of exploration.

Superficial bulk rock sampling for either SMS, CRC or MN can be conducted using a seafloor grab or rock dredge, of which many designs exist. These methods, however, will not collect material more than a few tens of centimetres (grab) to a meter or so (dredge) below the seafloor and may, therefore, be of limited use for quantitative SMS investigations. Seafloor grabs have limited use on hard substrates but, for samples in sediment, such as MN, a grab (and in some cases, box-corers) remains an acceptable method as it provides sediment and rock material.

Similar to a dredge, an epibenthic sled/sledge can be used for MN and possibly for CRC,

with the added benefit of being able to return biological specimens. Sledges, however, are not suitable for extracting bedrock samples from hard substrates, such as found in volcanic environments.

Targeted sampling can also be conducted with the use of ROVs or manned submersibles (Human Operated Vehicles). These allow accurate sampling of rock types of interest but are significantly more expensive and, hence, their use is likely to be later in the exploration phase when areas of particular interest have been defined.

Whether for drilling or coring, a well-developed sampling strategy will need to account for a variety of issues, including:

- the objectives of the survey: coring and drilling surveys usually aim at collecting geological samples for assessing mineral grades and resources estimation. However, other objectives, such as calibration of high resolution seismic data and backscatter, geotechnical testing of substrate or overlaying unconsolidated material, and in-fauna assessment will be required during the early stages of DSM exploration. Drill cores, particularly of SMS deposits, though expensive to obtain, are invaluable for ground-truthing of geophysical and geochemical anomalies, and enabling geochemical analyses from which precise mineral grades and critical geological information at depth are obtained. Whether the retrieval of undisturbed material is required will also have implications on the choice of sampling gear. Dredging and coring are likely to be chosen at the early stage of investigation, for their affordability, but will be limited for SMS and CRC, where the use of ROVs may be required.
- sampling scale is always an important issue. For SMS, the sample collection will most often be site specific and limited in space; whereas, for CRC and MN, the extent of the survey may be substantially larger. For the latter, the sampling stations must provide a good representation of the area, but also give detailed data at small spatial scales. The use of video-guided equipment will considerably enhance the precision of the sampling and help optimise sampling. To balance the need for 'always more' samples with funding/ time constraints, the sample sites must be appropriately distributed over the area. A strategy must be in place for rejecting/accepting a sample before moving to the next station. Criteria for acceptance of samples include: reaching of target, size of sample (e.g. minimum acceptable core length), mixed/disturbed material within the sample gear, position of the gear during sampling (e.g. tilted corer), state of gear on retrieval (e.g. bent corer), etc.

The storage of samples onboard the vessel and post-survey is important. Samples for geological study will usually be sealed and safely stored in a dry, possibly cool (to conserve organic matter) place. Particular attention must be paid to label the top/bottom of the sample, in particular for cores.

As in all scientific operations, it is extremely important to keep comprehensive notes on all aspects of sampling operations, and to ensure that all relevant metadata can be uniquely linked to the resultant samples.

1.5 Petrology, Mineralogy and Geochemistry

The determination of a site's commercial viability is dependent on the site's rock type and properties (petrology), its mineral components (mineralogy) and its chemical composition (geochemistry). MSR, prospecting and exploration may include sampling of the surface rocks, and, at SMS and CRC sites, may also include drilling (see above).

Samples acquired onboard need to be cleaned of biological material and dried. They may also be cut open with a rock saw to view their interior. Typically, each sample is then given a sample number and photographed, with both their outside and interior exposed (if cut by saw), next to a sample label. They are described for their physical, petrological, and mineralogical properties (Potts 1987). This can include the sample size, weight, colour, angularity, extent of alteration and thickness of any manganese coating, as well as a more detailed petrographic description
of the sample, such as rock classification, texture, minerals present and their abundance, vesicularity and any glass rim present. The sample is then placed together with the label into a plastic bag that is labelled twice with a permanent marker and stored in an air tight container, together with other samples. As the sample label needs to be kept dry so that it remains legible, it is usually placed in its own small plastic bag. For large sample sizes (e.g. over 100 kg of material), a detailed sample description is usually too time consuming to conduct onboard, so the entire sample is photographed together with the station label, dried and stored in lidded containers. Full descriptions of any samples analysed can be conducted onshore prior to analysis. This routine assumes analysis of individual samples but, where bulk samples will be analysed (e.g. in the case of multiple phosphate or polymetallic nodules), they can be treated together as for individual samples.

The methods used for chemical analysis of rock and mineral samples are dependent on the type of sample (its matrix) and the concentration of the elements of interest that are present. In particular, analyses of silicate and non-silicate (including ore material) can differ. The techniques described below are preferred techniques, but a full range of techniques used can be found in Potts (1987).

Petrographic descriptions of rock samples and mineral phases are conducted on polished sections of samples under a microscope. In the case of silicate samples, this requires making a 30 micron thick polished thin section of the sample, which is then described, using plane and polarised light under a petrographic microscope. As mineralised samples contain isotropic minerals that do not transmit light, the sample is embedded in a 25 mm round epoxy mount with a polished surface, and observed under a reflected light microscope. Chemical analysis of mineral phases is conducted by electron probe microanalyses (EPMA - an electron microprobe). This can include precise analysis, using a wavelength dispersive spectrometer (WDS) attached to the microprobe, or simply by using an energy dispersive microanalyser (EDS), which is less precise but considerably faster and less expensive. WDS analyses are typically used where precision and accuracy of mineral chemistry is needed, whereas EDS is best used as a mineral identification technique and to scan a large number of minerals quickly. Analysis of elements present in trace amounts (< 0.1 wt. %) can then be conducted by a laser ablation (LA) system attached to an inductively coupled plasma (ICP) mass spectrometer (MS) (known as LA-ICPMS) if required. These techniques in combination will allow geochemical analysis of all elements in a given mineral phase.

Geochemical analysis of major elements in bulk rock samples, including ores, can be conducted, using an X-ray fluorescence (XRF) spectrometer. This technique is relatively quick and inexpensive, and can measure elements present in minor (> 0.1 wt. %) concentrations. For elements present in lower concentrations, conventional ICP analysis, requiring dissolution of the sample in acid, will provide a range of analyses for all trace elements. However, for more precise analysis, such as for grading precious metals to calculate ore reserves, this method is not suitable. Instead, assay analysis is necessary. This process includes melting of the samples so that all phases present are fully melted and fused. Analysis is then conducted by equipment best suited to the element of interest, typically ICP analysis. Due to the longer preparation time and the possible need for different analytical techniques, assay analyses are usually more expensive than conventional geochemical analysis.

In addition to analysis of samples in a laboratory, ship board geochemical analysis is becoming easier and more commonplace. Hand-held XRFs can analyse any sample for minor and major elements in a few minutes. Although less precise than a conventional XRF, this technique has the advantage of being able to quickly scan samples as they are collected, allowing samples of interest to be identified for collection and other samples discarded.

1.6 Sediment characteristics

1.6.1 Sediment properties and composition

The collection of data on sediment properties (including pore water and/or elutriation chemistry) is targeted at describing physical and chemical characteristics of the substrate and, ultimately, helping predict the behaviour of the discharge plume and the effect of mining activity on sediment composition. The basic properties of the sediment, including measurement of particle mechanics and composition, need to be described to adequately characterise the surficial sediment deposits, taking into account the variability of the seabed. A photographic record of the sediment depth profile should be taken to document structure, such as bioturbation, redox discontinuities and general uniformity of sediment structure. Scanned colour images of core profiles can be used to provide semi-quantitative determination of the strong metal-binding phases of hydrous ferric oxides and acid-volatile sulfides (e.g. Bull & Williamson, 2001). More detailed investigations could include the technique of diffusive gradients in thin films (DGT), which can better measure in situ dissolved metal concentrations in pore waters and associated bioavailability (e.g. Simpson et al. 2012).

The geochemistry of the pore water (or elutriates) and whole sediments needs to be determined to describe the natural level of dissolved contaminants for evaluation of future levels with mining disturbance. Measurements should be made as far down as 20 cm. A set of six core-depth intervals was recommended by the ISA (2002): 0-1, 1-3, 3-5, 5-8, 8-12, and 12-20 cm. This number constitutes a detailed assessment, and it might be adequate to analyse more amalgamated intervals (e.g. 0-2, 2-5, 5-10, 10-20 cm), and examine further samples in greater detail if warranted. The pore water (or elutriate fractions) would normally be determined on dissolved fractions (<0.45 μ m) to high analytical sensitivity appropriate to biological effect thresholds. Blanks would need to be collected to ensure that adequate quality control procedures for sample-handling were in place.

Sediment elutriates for dredge spoil evaluation generally follow the US Environmental Protection Agency procedures (US EPA 1991). The procedure is undertaken by combining the sediment material with clean oceanic water in a sediment-to-water ratio of 1:4 on a volume basis. This elutriate preparation standardly includes a short-term elutriation – while a long-term elutriation should be considered to better simulate recovery processes: (i) the standard elutriate preparation period of 30-minute agitation – which simulates mixing during the dredging process; and (ii) a 24-hour elutriate preparation – which provides a longer period for sediment re-equilibration. The short elutriation period is appropriate for assessing potential near-field mixing effects, while the longer elutriation period would be considered to better indicate equilibration conditions, which might occur after resettling of the sediments. The 24-hour elutriation data provides values suitable for use in assessment of potential bioaccumulation uptake of contaminants. The elutriation procedure involves tumbling the sediment/water mixture, which largely maintains the integrity of large particulates, such as phosphorite granules.

The elutriate samples may be used for chemical analyses and for toxicity testing, using a suitably sensitive suite of species (e.g. invertebrates, algae, juvenile fish) (US EPA 1991). Any toxicity testing will probably have to use surrogate test species, since deep-sea species are generally not available, and will probably have to be undertaken at shore-based facilities.

The assessment of the potential effects on fauna should compare measured elutriate concentrations with marine water quality guidelines after allowing for some initial dilution with the plume mixing zone (e.g. 10-50x initial mixing). The ANZECC (2000) water quality guidelines for 99% species protection would provide an initial comparison for the dissolved metal, ammonia and sulphide concentrations. Predicted far-field concentration elevations could be used for tissue bioaccumulation prediction for potential food-chain effects on metals accumulation in key species groups (e.g. crustaceans, fish, marine mammals) — see section 3.3.

Information is also needed on the composition and concentrations of heavy metals and trace elements that may be harmful in some forms, as these could be released into the water column during mining operations (e.g. iron, manganese, zinc, cadmium, lead, copper, cobalt, nickel, cobalt, vanadium, thallium, uranium and mercury). The concentrations of these elements in minerals would usually be normalised to average earth crust concentrations to provide a normalised measure of the hazard potential.

Other sediment parameters of relevance include specific gravity, bulk density, and grain size, as well as the sediment depth of change from oxic to suboxic, or suboxic to oxic, conditions. Measurements should include organic and inorganic carbon in the sediment, nutrients (phosphate, nitrate, nitrite and silicate), carbonate (alkalinity), and the redox in pore waters (identifies oxic/suboxic boundaries – complemented by colour transitions on cores).

Sediment grain size can be determined in a number of ways, and there is no standard protocol that approximates in situ sediment properties that are, perhaps, the most important aspect for plume generation. It is important to specify how sediment particle size was determined, and processing aspects, such as whether distilled water or seawater was used to sieve the material. Smith (2002) noted that if sediments recovered from box or multicorers were immediately washed in a cold room on nested sieves, fractionated and weighed, it could give a picture of the natural sediment composition, rather than processing samples back on land after weeks or months of preservation or freezing.

Recommended protocols are listed below for sediment samples (Table 2-5), and samples of sediment pore water (Table 2-6) from the ISA's report on standardisation of environmental data (ISA 2002). The latter methods apply equally to elutriate samples. Elutriation techniques are practical for ship-board and laboratory application, and provide larger liquid volumes. It is also relevant to the type of disturbed sediment contaminants that would be produced during mining operations, primarily for manganese nodules, but are also relevant to dissolved material, arising from disturbance of SMS and CRC. Representative cores and sediment samples should be collected and archived.

Table 2-5: Key parameters to be measured from sediment samples (updated from ISA 2002).			
Parameter	Purpose	Methodologies	Recommendation
Specific gravity	Geotechnical properties	Wet weight and volume	No common standard
Bulk density	Geotechnical properties	Gamma ray attenuation: volume and dry weight	No common standard
Water content	Geotechnical properties	Wet and dry weight	Dry at 105°C for 24 hrs
Porosity	Geotechnical properties, environmental risk	Calculated from other measured parameters	Calculated from other measured parameters
Shear strength	Geotechnical properties	Vane shear	In situ if possible
Grain size	Geotechnical properties, benthic communities	Sediment balance, sedigraph, wet sieve, pipette analysis	Various good methods; Use seawater
Oxidation reduction potential	Impact assessment	Eh/ORP electrode	Eh/ORP electrode
Organic carbon	Habitat	CHN analyzer	CHN analyzer
Inorganic carbon	Impact assessment	CHN analyser, acid dissolution-CO ₂	Best available method
Chemical composition	Impact assessment	X-ray fluorescence, atomic absorption spectroscopy (AAS), Inductively coupled plasma spectroscopy(ICP)	ICP method
Bioturbation depth	Benthic mixing depth	Pb-210, Th-234, Th-239, Pu-240	Most appropriate isotope decay series

Table 2-6: Key parameters to be measured from sediment pore water or elutriate samples (updated from ISA 2002).				
Parameter	Purpose	Methodologies	Recommendation	
Phosphate	Habitat description	Spectrophotometric; ion exchange chromatography (IEC); flow injection analysis (FIA)	Best available method	
Nitrate	Habitat description	Spectrophotometric; IEC; FIA	Best available method	
Silicate	Habitat description	Spectrophotometric; IEC; FIA	Best available method	
Nitrite	Habitat description	Spectrophotometric; IEC; FIA	Best available method	
Carbonate alkalinity	Habitat and impact assessment	Titration; spectrophotometric	Titration; spectrophotometric	
Eh	Impact assessment	Electrode	Electrode	
рН	Impact assessment	Electrode	Electrode	
Fe	Impact assessment	AAS; ICP-MS (inductively-coupled plasma methodology- mass spectrometry); spectrophotometric	AAS; ICP-MS; spectrophotometric	
Mn	Impact assessment	AAS; ICP; spectrophotometric	AAS; ICP-MS; spectrophotometric	
Zn, Cd, Pb, Cu, Cr, Cd, Hg, Co, V, U, Ni, Tl, As, Ag, Sb, Te,	Impact assessment	AAS; ICP	AAS; ICP	

The elements listed in Table 2-6 relate primarily to MN environments, with some common SMS toxic elements. However, with SMS, other toxic elements may be enriched, and so further analyses specific to the mineral composition at a particular site might be required. ICP methods also include a variety of other techniques, such as mass spectrometry and sector field types of analyses, that would be used for certain elements.

Processing onboard is ideal, although it presents logistical difficulties. Handling speed and the need for centrifugation and filtration often greatly reduce the speed of processing. If samples must be transported to shore-based facilities, they should be maintained on ice. If a long transport period is required, then the sediment samples could be frozen – but should not be dried prior to undertaking chemical or toxicity analyses.

Whole sediment chemistry should be undertaken on representative samples. The chemical analyses need to consider the particle size fraction (recommended grain size classes of: >2 mm; 2mm - 0.063; <0.063 mm). The latter correspond to the silt fraction, which can be highly dispersive. The chemical analyses would generally follow the chemical measures undertaken for the pore water or elutriate samples.

1.6.2 Bioturbation rates

Bioturbation is the mixing of sediments by organisms. This is a particularly important aspect in MN environments, and of potentially less importance with CRC and SMS resources. Data on rates of bioturbation are necessary to describe the background "natural" rates of biological activity and sedimentary processes, including spatial and temporal variability, prior to a mining disturbance.

Bioturbation rates can be evaluated from profiles of excess Pb-210 activity from cores (ISA 2002), taking into account the variability in the sediment. This involves the measurement of other radiogenic products, including Ra-226 and Po-210. Various radiogenic decay series and isotopes are also used, such as excess Th-234, Th-239, and Pu-240. The selection of

isotopes will depend upon the time scales that need to be investigated, and the expected sedimentation rates in the environment. Pd-210 is a relatively short time-span indicator.

The isotope activity should be evaluated on at least five levels per core (suggested depths are 0-0.5, 0.5-1.0, 1-1.5, 1.5-2.5 and 2.5-5 cm). Rates and depth of bioturbation are to be evaluated by standard advection or direct diffusion models.

1.6.3 Sedimentation rates

Sedimentation is a critical aspect of the potential impact from mining activities, and data collection is required to gather time series data on the flux and composition of materials from the upper water column into the deep sea, and evaluate the effects of potential plumes.

Sediment traps need to be used, and generally should be set below 1000 m to reduce particle flux identified by radiogenic trapping efficiency. In abyssal MN environments, ISA (2002) it is recommended that deployment of moorings with sediment traps on a mooring line be undertaken, with one trap below 2,000 m to characterize the particulate flux from the euphotic zone (and clear of higher variability in upper current-influenced layers). A second trap should be approximately 500 m above the sea floor to characterize the flux of materials reaching the sea floor (and high enough so as not to be influenced by sediment re-suspension. A third trap should be placed close to the seafloor to help understand the resuspension process caused by a sediment plume. Ideally, two traps should be deployed at each depth horizon, as sediment trap data can be highly variable in the deep sea, because as depth increases, the transport area gets larger and potentially more variable. However, this is logistically very difficult with the present types of particle flux traps, and unless two mooring lines are deployed close to one another, this might be an aspect of uncertainty that needs to be considered with data from a single series.

In SMS and CRC environments on seamounts, traps should be deployed on the summit area, as well as on the abyssal seafloor beyond the base. This enables an evaluation of background rates free of the seamount influence (the deep traps), as well as gaining an idea of seamount-induced variability from the summit traps.

Sediment traps should be installed for a suitable period of time, ideally at least over a 1- to 2-year period, with samples collected at least quarterly to examine seasonal changes in flux. Inter-annual variability could be important, especially in the western South Pacific where major climatic events occur over years/decades (e.g. El Niño, La Niña). This may be impractical, but should be considered if exploration work takes place over several years.

The trap installation should share the same mooring as the current meters described in section 2.1.1, depending on mooring design. It is important to know how the trap is performing on the mooring in relation to current flow effects. Traps have a lot of drag, so in high flow regions, there can be "mooring blow down" (NIWA has experienced over 100 m in moorings at 3000 m depth). Hence, too much drag on the mooring may compromise the current meter data.

Given that the flux of materials from the upper water column into the deep sea is ecologically significant in the food cycle of bottom-dwelling organisms, an adequate characterization of the material flux in mid-water and flux to the sea floor is necessary for a comparison with the effect of tailings or return water discharge. In situ studies on settling velocities of discharge particles, both in mid-water and near the sea floor, will help to verify and improve the capacity of mathematical models for predicting the dispersion of the mid-water and benthic plumes. This information is relevant to the effects of the discharge plume and operation plume on the benthic biota and benthic boundary layer pelagic organisms. With two or more traps on a single mooring string, particle sinking rates can be inferred, or direct measurements can be made using cameras and laser methods (Laser in Situ Scattering and Transmissometry (LISST) settling tubes), or particles can be collected, taken to a laboratory, and measured in settling tubes.

The temporal resolution of the particle-flux measurement must be one month or greater. Typically, a time-incremental deep ocean trap will have 21 bottles, hence sample 21 time periods. Over a one-year period, this will typically be a sample every 2.5 weeks. A "suspended solids time series" should be recorded in conjunction with the sediment traps, which can be measured with a variety of different instruments, including nephelometers or transmissiometers. These need to be calibrated with data from suspended solid measurements from selected depths in the water column.

There are various types of sediment traps available. The Joint Global Ocean Flux Study (JGOFS) recommended cylindrical traps for free-floating upper ocean use, and conical traps for moored situations (refer to http://usjgofs.whoi.edu/protocols.html). Most designs are similar in their construction and operation. Selection will depend, to an extent, on the analyses to be carried out on the samples. For example, if trace metal studies are intended, then an all-plastic trap may be needed, rather than one with metal components.

2. Oceanographic assessment

2.1 Physical oceanography

Physical oceanographic data are required to estimate the potential influence of the operational and discharge plumes. Together with information on the geomorphology (see sections 1.1 and 1.6) of the seafloor, these data can also aid predictions of the potential distribution of species.

A general scheme for physical and chemical oceanographic baselines includes:

- collection of water column hydrographic and light-transmission data of sufficient resolution to characterize the dominant current parameter patterns, taking into account the characteristics of geomorphology and topography of the seabed at the exploration site, where appropriate;
- collection of data appropriate for assessing the horizontal and vertical advective and eddy-diffusive dispersal potential of dissolved and particulate matter on relevant time and space scales; and
- set-up and validation of a numerical circulation model that covers the temporal and spatial scales important for dispersal, and the carrying out of experiments to test the model, e.g. to investigate the potential impact of accidental spills.

2.1.1 Currents

Oceanographic water masses and flows are dynamic, hence data on temporal variation in the physical structure of the water column are required. This is especially the case for surface waters, but also near the seafloor with CRC and SMS deposits, as these are located in areas of more complex topography (seamounts and ridges), are often relatively close to land, and may be subject to tidal currents.

Measurements of currents and particulate matter loading are particularly important for predicting the behaviour of sediment plumes. These will be generated by physical disturbance during the collection stage of mining, and again by the discharge of processing waters. Hence research needs to concentrate on gaining an understanding of dynamics close to and at the seafloor, and at the depths where the processing wastes will be discharged. The latter may vary; for example, Nautilus, with their Solwara 1 SMS operation are planning to return discharges back to the seafloor (Coffey-Nautilus 2008); whereas, various MN contractors have referred in the past to possible discharges at the surface, or in the upper part of the water column.

The Acoustic Doppler Current Profiler (ADCP) is a sonar device that measures water current velocities over a range of depths based on the Doppler Effect, using fixed transducers that are directed into the water column. ADCPs are typically used in three different operational modes: (1) VM-ADCP (vessel mounted system for underway and on-station sampling), (2) L-ADCP

(lowered system for obtaining vertical current profiles at single stations and times) and (3) M-ADCP (moored system to be left in situ at a single location for long periods of time) (Collins et al. 2012).

The number and location of moorings need to be appropriate for the size of the area and the complexity of the underlying current and property fields to adequately characterise the current regime, in particular in areas of complex geomorphology. Based on World Ocean Circulation Experiment and Climate Variability and Predictability Research standards (refer to http://www. nodc.noaa.gov/woce/), the recommended sampling resolution given by the ISA for nodule resource areas is a maximum of 50 km between stations. In regions of large lateral gradients (e.g. in boundary currents and near major geomorphologic structures, such as possible with SMS and CRC seamounts and ridges), the horizontal sampling spacing should be decreased to 5 km or less, in order to allow resolution of the gradients. The number of current meters on a mooring is dependent upon the characteristic vertical scales of topography of the area studied (difference in heights from the bottom) and stratification in the water column. The suggested location of the lowest current meter should be as close as possible to the seafloor, normally 1 m to 3 m. Thereafter, the basic levels of the current meters should be 10 m, 20 m, 50 m, 100 m and 200 m above the seabed. The location of the upper current meter should exceed the highest point of adjacent topography.

A satellite-data analysis is recommended for understanding synoptic-scale surface activity in the area and for larger-scale events. The relevant satellite products available are:

- sea surface temperature (SST), which can be used to infer surface flows and variability, as well as information about stratification and seasonal changes;
- ocean colour, which indicates local primary productivity, suspended sediments and water clarity; and
- sea surface height (SSH), which gives information about integrated density (mean temperature and salinity) and surface currents.

2.1.2 Current-flow dispersal dynamics

Regardless of the mining techniques to be employed, it is expected that some particulate and/ or dissolved mining by-products will be released into the water column in the vicinity of the mined deposits, the transport conduits and processing at the sea surface.

For each mining by-product, the timescale over which it causes significant environmental impact must be modelled. If these timescales depend on dilution, determination of vertical and horizontal mixing rates near the target site must be included in the dispersal assessment. Dispersal potential must be assessed over timescales that range from the tidal frequencies to the largest relevant environmental-impact timescales. El Niño–Southern Oscillation (ENSO) or Interdecadal Pacific Oscillation (IPO) variations occur over multi-year or decadal time scales and, although it would not be expected for prospecting-exploratory studies to last this long, the baseline measurements should be in place for ongoing monitoring. A thorough assessment of the dispersal potential in the deep ocean generally requires long-term monitoring, and even the determination of mean-flow directions and speeds at depth can require several years of current-meter data. However, practicality suggests that if there was one year's data, and supporting information to ensure that year was representative (and not anomalous), it should be adequate as long as there is ongoing monitoring as mining activity develops.

Assessing eddy-diffusive dispersal is difficult and generally requires the application of Lagrangian techniques, such as neutrally buoyant floats or dye-release experiments. For these reasons, it is recommended that an assessment of the regional dispersal potential at several levels in the water column begin early during exploration. It may be possible to assess dispersal near the surface and near 1,000 m from available data (from surface drifters and Argo floats). The dispersal potential must be assessed at all levels where harmful by-products may be released into the water column and where accidental spills may occur. The required vertical resolution

will depend on the regional dynamical regime (vertical shear of the horizontal currents), but it is anticipated that data will be needed from at least three levels (near-surface, mid-depth and near-bottom). Measurements of the hydrodynamic regime and particulate matter sinking rates are important to enable this assessment.

Near active hydrothermal vent fields, it is often possible to gain useful first-order dispersal information at the level of neutrally buoyant plumes from hydrographical, chemical and optical observations. Interpreting plume-dispersal observations in terms of dispersal potential for mining by-products is complicated by a variety of factors, including poor knowledge of the temporal and spatial characteristics of hydrothermal sources. Hydrothermal plumes disperse at their equilibrium level, which depends both on the source and environmental background characteristics; therefore, the particle composition (and, thus, the settling velocity) of hydrothermal plumes cannot be controlled. Nevertheless, when such plumes occur in the vicinity of a mineral resource, it is expected that hydrothermal-plume dispersal observations will be useful, in particular for designing controlled follow-up dispersal studies.

2.1.3 Hydrodynamic modelling

To complete an assessment of the dispersal potential, a three-dimensional hydrodynamic numerical model that covers the temporal and spatial scales important for dispersal must be constructed. Numerical modelling is required, both to describe the present-day character of the oceanic system and to explore scenarios in which mining is likely to occur, hence quantifying likely downstream impacts. These impacts will be both at the seafloor (generated by digging up the resource), as well as at the point of discharge of processing wastes.

The model used should be one that is accepted by the ocean modelling community as suitable for dispersal studies near the seabed; simple box models or z-coordinate models with coarse vertical resolution at depth are not expected to be adequate. The details of the model will be dependent on the topographic and oceanographic settings of the target site. Resolution should be in accordance with the scales described above (i.e. gradients should be resolved by several points) and the model needs to be validated by comparison with the observational data. After validation, the numerical model should be used to investigate potential scenarios, such as to estimate the potential impact of accidental spills or for certain extreme cases (e.g. atmospheric storms).

The lack of observational data in deep-sea near-bottom environments is a major challenge for both regional and site-specific assessments. The mining operations will typically take place within the oceanic bottom boundary layer, the structure of which will depend on the tide and wind, any mean currents, etc., and the local topography. Combined, the spatial and temporal scales of these features will stretch the ability of a numerical model to resolve them locally at the seafloor, and also to resolve the wider flows in which potential material dispersal can occur.

There are three key types of information required to support hydrodynamic modelling:

- basic water column properties (temperature, salinity, current flow direction, speed) as per section 2.1.1;
- turbulence, which covers vertical mixing processes throughout the water column, generally a result of temperature gradients. This can be measured by electronic profilers, deployed from a vessel. It can also be modelled by software, such as GOTM (General Ocean Turbulence Model); and
- Turbidity (see section2.1.4).

A critical factor is the methodology of the mining operation itself. In the early stages of exploration, there may be limited technical details regarding the extraction tools, and the discharge of return water and other processed material to the receiving environment. The initial conditions are an important part of the scenario phase of the modelling, and uncertainty in those conditions adds another layer of complexity to an already difficult numerical process.

Recent advances in operational ocean forecasting (e.g. the provision of daily mean threedimensional oceanic fields, resulting from larger scale models, such as Hybrid Coordinate Ocean Model (HYCOM) mean that modellers can now more readily generate a reasonably high resolution ocean (regional) model over the site of interest at kilometre horizontal spatial scales. This regional ocean model can be verified with any observational data to set limits on its likely applicability. Improved nesting techniques then allow for an even higher-resolution (inner) model to be embedded within the regional system to try to get to the scales of relevance around the mining operation itself. A model used commonly in New Zealand and Australian regions is ROMS (Shchepetkin & McWilliams 2005) that can be developed for smaller regions and incorporate finer-scale topography. Tidal and wind forcing can be applied to the inner model. However, the inner model may have issues given the uncertainties of the turbulent dispersal and mining operation itself; it is in light of the latter uncertainties in which in situ measurements should be made in order to give confidence that the scenario modelling is representative of what may actually occur.

Discharge modelling may differ from that used to evaluate the sediment plume generated at the seafloor. There are a number of mathematical models used to provide predictions of the mixing of discharges from the end of a pipe. A commonly used model is CORMIX, developed by the US EPA for discharge simulations (Jirka et al. 1996), though more sophisticated models are available that provide predictions of concentrations in the near-field and far-field areas of the plume. The key information required from such models includes the size of the plume and concentrations of contaminants with distance away from the discharge point. Such assessments will be made using concentration data from sediment elutriate tests (see 1.6.1) and comparisons with water quality guidelines.

2.1.4 Water quality

Changes in water chemistry and assessment of potential ecotoxicity effects associated with mining activity and potential discharges from support vessels or operational processes (e.g. drilling muds, antifouling release from structures) requires provision of data on background physico-chemical conditions and seasonal variability of these parameters.

Water quality measurements typically include turbidity (optical clarity), suspended sediment concentrations, dissolved oxygen levels, pH and chemical composition (e.g. nutrients, particles, trace elements). These analyses are broadly similar to a number of those described above in 1.6 for sediment and pore water, and below in section 2.2 on water chemistry.

The oceanographic structure of the water column is typically measured by conductivitytemperature-depth (CTD) systems. The traditional CTD sensor package comprises a temperature sensor (fast response thermistor), conductivity cell and pressure sensor. These may be extended by additional biological and chemical sensors, such as fluorescence, turbidity, oxygen, and dissolved oxygen, etc.

CTD profiles and sections should be performed from the sea surface to the seafloor in order to characterise the stratification of the entire water column. A CTD system measures both physical and chemical properties of water masses and can be used in a variety of configurations for deep-sea operation (White et al. 2016).

A CTD may be used from a winch on board a vessel in real time, when connected to a conducting cable, or as an internally-recording instrument. CTD type instruments can also be fixed on trawls, mooring lines, ROVs or seabed lander systems. The most frequently used set up is as a vertical profiler attached to a sampling frame bearing a rosette of water sampling bottles. This configuration has the advantage of being able to take additional water samples at discrete depths for later calibration of the sensor package and for determining independent physical and chemical water characteristics.

Samples of water properties in the vertical plane should, in general, be no more than 100 m apart, although more frequent sampling is required in the upper and lower 200 m of the

water column, and less frequent sampling may occur where there is little change in water characteristics. The resolution should be greater in high-gradient regions (e.g. to locate and quantify the boundaries of oxygen minimum zones). For parameters without significant horizontal gradients, the determination of base-line ranges (e.g. means and standard deviations) is adequate.

2.1.5 Visual characteristics

'Optical water quality' is a broad term used to encapsulate how changes in the colour and clarity of water are related to its environmental 'quality' (Davies-Colley et al. 2003). Optical water quality is influenced by concentrations of the light attenuating components (suspended sediment, phytoplankton and coloured dissolved organic matter (CDOM), and their absorption and scattering (forward and backscattering) characteristics. Of particular relevance to proposed mining activities is how changes in suspended sediments may influence environmental conditions. Visibility aspects are most relevant in the upper water column, and will be of little value below about 400 m.

Measurements of water clarity at a range of depths (e.g. on a mooring line) can be made with several types of instruments, principally nephelometers, transmissiometers and turbidity (optical backscatter (OBS)) sensors. Transmissiometers are more commonly used now than nephelometers and provide a better proxy for optical clarity. However, the instruments measure slightly different things: OBS and nephelometers measure the "mass effect", while transmissiometers measure the "optical effect".

OBS is often used in sediment transport research to capture temporal changes due to their operational sensitivity over large scales of sediment concentration, compactness, ruggedness and ability to be easily kept clean (Downing 2006). These sensors measure relative scattering, or 'turbidity' (cloudiness), which is not an absolute scientific quantity and requires careful, location and sensor-specific calibration to parameters of interest.

The vertical distribution of light directly affects primary productivity in the euphotic zone (see section 2.1.4). If there is surface discharge, vertical light-intensity profiles will show the effect of discharged particles on light attenuation and spectral bands over time, depth and distance from the mining ship. Those values can be used to detect any accumulation of the suspended particles at the pycnocline. In addition, this can be used to assess potential effects on visual predators, such as pelagic fish and certain marine mammals.

Turbidity and turbidity reduction rate is often an important parameter for the elutriate tests relative to an effects assessment. This would need to be translated to a water clarity (black disc) distance to predict fish visual acuity reduction. Other particle measurements to consider include particulate organic carbon and nitrogen, chlorophyll a, and trace and heavy metals. Dissolved organic carbon measurements can also be made, similar to the parameters suggested for sediment pore water (section 1.6.1). All instrument measurements need to be calibrated with water samples collected at selected depths and processed in the laboratory, including chlorophyll a, total suspended solids, and CDOM.

2.2 Chemical oceanography

Knowledge of chemical oceanography is important for assessing the possible influence of mining on the composition of the water, such as concentrations of metals, and where changes could affect biological activity and ecosystem processes.

The water overlying the mineral deposits and the pore water in the sediments should be characterized chemically, where possible, to evaluate processes of chemical exchange between the sediment and the water column. Chemical oceanography is sometimes separated into bottom and water column chemistry. However, the same methods and analyses are employed for both, and they are combined here.

2.2.1 Water column (including bottom) chemistry

Samples should be collected at the same locations as the physical oceanography measurements, using water bottles deployed in tandem with the CTD. The chemical parameters to be measured and the suggested protocols for sediment and sediment pore waters are listed in the two tables in section 1.6.1.

A range of nutrient concentrations are routinely measured from water samples, including nitrate, phosphate, and silicate. Nutrient values can also be obtained from global databases, such as the World Ocean Atlas, but the reliability of such values will depend upon the sampling frequency near the area of interest. In many offshore areas, existing data will not be adequate. Hence, water analyses samples will be required. For measurement of dissolved and particulate trace element concentrations, 'metal-free' sampling systems are required, as well as suitably equipped laboratories on the vessel. Polyethylene or Teflon containers are essential for trace metal studies (Batley 1999), and rigorous container cleaning and handling procedures to avoid contamination are required (Ahlers et al. 1990). To determine the extent of contamination or losses during field sampling, quality assurance (QA) measures should include field blanks, container blanks and trip blanks. We refer the researchers to Batley (1999) for details but, as an example, field blanks are bottles filled with distilled water (or clean seawater) that are taken on the field trip and subjected to all of the operations of a sample container. Appropriate QA procedures should also be applied to filtration procedures to obtain dissolved fractions, including pre-rinsing of the apparatus prior to sample handling.

There are standard protocols adopted by water quality laboratories that should be followed. Table 2 7 lists the minimum requirements of parameters that should be measured from the water column, which includes major nutrients, metals that are released in reducing conditions (Fe, Mn), essential metals (e.g. Cu, Co, Zn), and non-essential elements (e.g. Cd, Hg, U), which may cause toxic effects to sensitive species. A preliminary screening guidance for the analytical suite of elements for potential release from the minerals to the dissolved in overlying waters can be made by comparing the local mineral composition standardised to the average earth crust composition, and seeing which have elevated compositions. More definitive measures of contaminants released from sediments can be obtained by undertaking elutriate procedures under standardised conditions (e.g. US EPA 1991).

Table 2-7: Chemical parameters to measure in the water column (updated from ISA 2002).			
Parameter	Purpose	Methodologies	Recommendation
Phosphate	Habitat description	Spectrophotometric; IEC; FIA	Best available method
Nitrate	Habitat description	Spectrophotometric; IEC; FIA	Best available method
Nitrite	Habitat description	Spectrophotometric; IEC; FIA	Best available method
Silicate	Habitat description	Spectrophotometric; IEC; FIA	Best available method
Carbonate alkalinity	Habitat and impact assessment	Titration; spectrophotometric	Titration; spectrophotometric
Oxygen	Impact assessment	Electrode	Electrode (needs calibration, e.g. Winkler titration)
Fe	Impact assessment, productivity assessment	AAS; ICP-MS	AAS; ICP-MS
Mn	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Zn	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Cd	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Pb	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Cu	Impact assessment	AAS; ICP-MS	AAS; ICP-MS

Hg	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Со	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
V	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
U	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Ni	Impact assessment	AAS; ICP-MS	AAS; ICP-MS
Organic carbon	Habitat and impact assessment	CHN analyzer	CHN analyzer
рН	Impact assessment	Electrode	Electrode

Once details of the proposed mining techniques are known, the parameter lists should be extended to include any potentially hazardous substances that may be released into the water column during test mining. All measurements must be accurate in conformance with accepted scientific standards (e.g. Climate Variability and Predictability Research and GEOTRACES protocols). To allow for later analysis of additional parameters, water samples suitable for analysis of dissolved and particulate matter should be collected and archived in a repository accessible for future study.

It is particularly important to measure these parameters at several depths close to the seafloor, but extending up to the estimated depths of the sediment plume, or discharge waste depth. Heights of 10, 20, 50, and 200 m are recommended by ISA (2002). If local topographic features are nearby the proposed mining area, then measurements should be made well above the summit of these, by at least 200 m, to account for an upwelling effect of the feature. Surface measurements may also be necessary, depending on discharge depths. Changes in the concentrations of trace nutrients could be significant at the surface as well, and relate to localised phytoplankton blooms and dynamics.

Water chemistry is often evaluated at a series of 'standard depths', and this should be considered in the context of the resource depth and regional circulation. These depths are usually: surface, 25 m, 50 m, 75 m, 100 m, 150 m, 200 m, 300 m, 400 m, 500 m, 750 m, 1000 m, 1500 m, 2000 m, 2500 m, 3000 m, 4000 m, and 10 m above the seafloor. Vertical profiles and temporal variation also need to be addressed in the field measurement programme.

Changes in the pH of oceanic water associated with the mining activity are something which should be considered. Undertaking an elutriate procedure specifically designed for pH change measurement (i.e. without gas head-space) would be required for these measurements. The measurements would also need to include alkalinity measurements on the elutriates. Simple alkalinity-pH calculations would then be used to predict oceanic pH change with mining plume dilution.

3 Biological assessment

The characterisation of pelagic and benthic communities should be carried out within all habitats identified by high-resolution MBES and oceanographic surveys (see section 5-1), covering both the immediate mining site area, and surrounding wider area (determined from topography and oceanography results. Variability in the environment will affect the nature and extent of communities that may be impacted by mining operations. Thus, identifying different habitats (both on the seafloor and potentially in the water column) is useful for determining the regional distribution of communities for the potential creation of conservation areas and for mitigation strategies to promote the natural recolonisation of areas affected by mining activities. The identification of habitats (especially benthic) using data from MBES surveys and associated sampling has developed considerably in recent years (e.g. Brown et al. 2011, Diesing & Stephens 2015), and providing guidelines for habitat classification and mapping is outside the scope of this report. The fundamentals of seabed habitat mapping are outlined in Lamarche et al. (2016), which cites a number studies that provide useful methodological approaches.

Habitat information coupled with information on communities (see below) can be used to identify biotopes, classification units that have proved useful for environmental management purposes in Europe because standards have been developed for their comparable identification and description (Conner et al. 2004, Davies et al. 2004, Parry et al. 2015). Biotopes may also prove a pragmatic level of natural biological organisation to use in spatial management decision-making for seabed mining.

While most existing classifications have a benthic-focus, mining impacts can affect the structure and dynamics of water column communities, as well. However, pelagic habitat classification is not well developed. Broad-scale biogeographic classifications have recently been developed for surface waters (e.g. Spalding et al. 2012) and for mesopelagic depths (Sutton et al. in review), but these are at large spatial scales that are of limited use when assessing individual DSM operations.

3.1 Seafloor community

3.1.1 General sampling stratification

Spatial variation in biological communities can occur at any scale, and in all the mineral resource environments. Biological sampling must, therefore, be stratified by habitat type, which can be defined simply by topography (e.g. summit, slope and base for seamounts), hydrography, current regime, predominant megafauna (e.g. coral mounds), oxygen content of the water (if the oxygen minimum layer intersects the feature) and, potentially, depth (Table 2-8). Habitat strata identified by other means (see above) can also be used to direct sampling, and where there are adequate data may be preferable.

Table 2-8: Examples of the type of environmental factors that can determine the level of stratification required to evaluate variability in faunal communities.			
Stratification factor	MN	SMS	CRC
Depth (if large range)	Y	Y	Y
Topography-large scale (e.g. flat plain, abyssal hills, seamount, ridge)	Υ	Y	Υ
Topography-medium scale (e.g. seamount summit, flanks, base)	Υ	Y	Y
Topography-small scale (e.g. chimney structures, gullies)		Y	Υ
Resource density (e.g. nodule cover)	Y		
Substrate type (backscatter)	Y	Y	Y
Venting characteristics (e.g. diffuse low temperature, black smoker)		Y	
Productivity (flux) gradients	Y		

A minimum number of stations per stratum is three, in order to estimate variance. This will almost certainly be inadequate to fully describe biodiversity, and more should be carried out (see Figure 4-2). Species accumulation curves will be needed to give an idea of how complete/ incomplete sampling is to describe the biodiversity. However, a minimum number of three will enable a first-cut estimate of the likely variability on certain spatial scales, and inform sampling design modification where appropriate to give a more robust result. For example, if sampling indicates patches of cold-water coral reef, then the number and density of photographic transects in those strata can be increased.

Hard substrata (such as at SMS and CRC) are challenging environments to quantitatively sample. Multiple collection techniques may be required, using whatever gear type is likely to be successful at the particular site (see Table 2 0 4). Photographic transects may be the only method suitable for developing a species-abundance matrix in some cases, even though this method will bias against smaller organisms. Methods for collecting baseline biological data must, therefore, be adapted to each specific set of conditions.

The survey must cover the wider surrounding region beyond just the site or sites of interest. An ISA recommendation for SMS is to sample and describe the fauna at three or more mineral deposits (ISA 2007), if present, each separated by a distance greater than the projected deposition of 90 per cent of the particles suspended by the mining operation. This is because it is important to know the degree of isolation of populations occupying the mineral deposits that are to be removed, and whether a given population serves as a critical brood stock for other populations. A useful reference for general connectivity issues is the review by Hilario et al. (2015).

Temporal variation must be evaluated for the potential mining site and any potential preservation reference or control sites prior to any mining activity. This must cover seasonal sampling if there is a likelihood of significant changes in conditions during the year, or at least a time series of annual surveys. There are no hard-and-fast rules about the number of years that is appropriate - it is a balance between what is feasible from a commercial operator's viewpoint (e.g. the ISA stipulate over three years for MN permits in the Area), and potentially much longer time periods that scientists would like to measure changes in the deep sea. This is where the distinction between assessing variability for a baseline description and monitoring conditions over a longer time becomes an important consideration. Monitoring has to be based on a robust baseline set of temporal measurements. Where multiple mining sites are identified, the survey data must inform the degree to which temporal studies at one site are applicable to another. The timing of repeat surveys will depend upon how variable potential environmental drivers of faunal abundance are over time. For MN, it has been suggested that each station should be sampled four times before any mining activities take place, at periods of 4, 2, 1 and 0.5 years before disturbance (ISA 2002). In SMS and CRC environments, seasonal changes may be important, hence four surveys over 2 years would be more appropriate.

3.1.2 Megafauna

Data on megafauna (>2 cm) (Figure 2 0 1) abundance, biomass, species structure and diversity should be based on video and photographic transects. Photographs need to have a sufficient resolution in order to identify organisms greater than 2 cm in their smallest dimension. The width covered by the photographs should be at least 2 m. The pattern of the photographic transects should be defined by stratification, taking into account the different features of the bottom (Table 2 5).



Figure 21. Examples of megafauna. Stone crab (left), corals and feather stars (centre), rattail fish (right). Source: NIWA

Survey design should be similar irrespective of whether towed cameras or ROVs (and potentially AUVs) are used. Straight-line transects are an efficient method of mapping biodiversity on all types of seafloor, and enable comparative density estimates along and between transects and strata (e.g. Bowden & Jones 2016, Smith et al. 2012). It is important to run at a constant speed and at a constant altitude, and not to stop and start (which is common with ROV or submersible operations) because this introduces sampling biases. It is thus advisable to do transects first, and then return to sample or explore interesting features.

For abyssal MN fields, the seafloor may be relatively flat, so transects may be randomized over relatively large strata in a stratified design. With SMS and CRC resources on seamounts

or ridge structures, the transect pattern needs to be different. It is recommended on a conical seamount type structure to run at least four photographic transects across the entire seamount, arranged in a regular "starburst" pattern centred on the seamount peak. If a towed frame system is used, it should be towed downslope, as upslope or along-contour towing often causes the gear to hit the seabed where the flanks of the seamount are steep or boulder strewn (Clark & Rowden 2009). If the feature is more elongated (e.g. a ridge), then a parallel transect design will be more appropriate, with the spacing between transects being either constant (for mapping) or random (for more quantitative analysis).

For any seamount structure, transects should be distributed around all sides of the feature, in order to determine the variability of benthic communities with depth, aspect, substrate type, etc. With SMS deposits in a back-arc volcanic setting, the seamounts are likely to be small enough to be readily and thoroughly surveyed. However, CRC deposits on large guyots may require stratification of the seamount by depth and topographic aspect, and transects allocated to cover each habitat type.

Video sampling should also extend beyond the base of the seamount or ridge system, especially down-current by at least 1 km. It has been recommended for SMS sites that community distribution, in particular, localised chemosynthetic communities, should be mapped and their position relative to potential mining locations assessed to a radius of 10 km from the proposed mine site.

A combination of video and still camera deployment can enable both large-scale habitat mapping and megafaunal distribution to be determined, while the higher resolution still shots enable more detailed identification, as well as guantification of faunal densities (Bowden & Jones 2016). The use of higher taxonomic classification (e.g. order or family) is possible from video images, as is using morphospecies (or "operational taxonomic units") to describe consistent fauna, even if the species is unknown. This is often appropriate for a first-order description of biodiversity, but is an issue of scientific debate. Where possible, species identification should be confirmed by collection of specimens at the site. Where a photographic survey is the main method being applied to describe the megafauna, then direct sampling should be targeted at areas where a short tow can sample a diverse array of animals (hence reducing the impact of sampling), or targeted at animals where specific identification is uncertain. The direct sampling will not need to be used in a quantitative way, but as a support tool for the photographic survey. An additional consideration with photographic data is that from the photographic record, geologists can characterise the substrate at fine spatial scales. Large-scale photomosaics are recommended (and the technology for this is improving) showing the areal extent of the site to be impacted. Especially for SMS, visual coverage of the entire site is recommended to document the habitat variability of the entire site.

Sampling efforts should be used to characterize the less abundant but potentially key megafauna in the system (including fish, crabs and other motile organisms). Representative samples of those organisms should be preserved for taxonomic, molecular and isotopic analyses. Sampling can be carried out by trawl or sled. Few oceanographic vessels can carry out double-wire trawling operations to sample fish, although single-wire beam trawl or epibenthic sled equipment is suitable for benthic invertebrates. Towed gear has the advantage of being able to capture mobile animals (often difficult with the manipulator arms of an ROV), as well as small animals or those that are hidden within a biogenic habitat matrix. A rock dredge may also retain biological specimens but, by its nature, the gear is not designed to move smoothly over the seafloor to sample epibenthos. Scientific institutes around the world have a variety of sled-type gear that may be available for use, and also offer a degree of consistency where similar designs are used. If such equipment is unavailable (but see Clark & Stewart 2016), at the very least the ROV should sample representative megafauna observed in the photographic transects.

Direct sampling will depend upon the type of resource. Sleds and dredges can operate well on MN sites if outfitted with grids to prevent nodules from overloading the gear and grinding

up the megafauna. Trawls are not effective in MN areas for collecting epibenthic megafauna because trawls quickly become laden with nodules, which then grind up the megafauna and can tear the net. For CRC, the seafloor may be too rough for trawls to operate successfully, but epibenthic sleds or dredges should be able to sample effectively. Large grabs may also be suitable. For SMS, if the site is associated with active chimney formations, or even low-temperature venting, direct sampling from a surface vessel may be difficult to position precisely (although dynamic positioning of the ship and tracking gear location with Ultra-Short Baseline (USBL) transponders has improved this in recent years) so as to avoid damage to the sensitive communities. Sampling with an ROV, and using direct collection by the manipulator arm, slurp-suction apparatus, scoops or small nets will likely be necessary.

Where an ROV is used to collect biological samples, each collection needs to be carefully video photographed and recorded, so that samples from different locations can be identified. A 'biobox' system with a closed lid is necessary to avoid loss of samples when the ROV is being recovered. Samples should also be returned to the surface within 12 hours from collection to ensure good quality specimens are obtained.

Large bodied fauna recovered by trawls and sleds are typically sorted to Operational Taxonomic Units (OTUs), i.e. using the approach 'same with same', which doesn't require detailed taxonomic knowledge but reduces the effort involved in sorting samples after the voyage. The level of identification will vary with taxon. Deep-sea benthic invertebrates are often poorly known, and reliable identification can be impossible except by specialist taxonomists. Nevertheless, science staff without taxonomic experience can still use basic keys, regional guides, and separate most groups at the order or family level.

The largest, most fragile and best condition specimens should be immediately placed in seawater before the sample is removed from the deck and transported to the sorting area. This reduces damage and stress and keeps specimens in optimal condition and, therefore, suitable for subsequent photography and preservation for taxonomic study.

The catch is then placed in buckets or bins (each with a label noting the sampling station) and transported to the sorting station. Here, the sample can be sorted in more detail, gently washing it with sea water from hoses if needed. When all specimens of one OTU have been extracted into a container, they are usually treated together as one sample 'lot'. Each sample lot is then labelled, weighed), and recorded on the recording sheet to ensure samples are quickly taken away to be fixed and/or frozen to avoid degradation. Sometimes it is necessary to split the sample lot into multiple sub-lots for separate subsequent treatment (e.g. for genetics, taxonomy, etc.). If samples of particular species or OTUs are to be subsampled, it is important to know in advance in order that they are handled appropriately (e.g. using gloves and tweezers).

All steps of molecular analyses can be performed at sea, if the vessel is equipped with the necessary instruments. However, it is most likely that specimens destined for DNA sequencing are only fixed, leaving DNA extraction, amplification and sequencing to be done in a well-equipped laboratory on land. Samples for molecular studies can generally be frozen or fixed in highly concentrated ethanol (> 80%). Preservation must happen quickly and deep-sea animals must be kept chilled throughout the sample processing (Glover et al. 2016): the longer the delay and exposure to temperatures above in situ habitat conditions, the lower the quality of the DNA and the lower the potential for success in extraction and amplification.

Some additional guidelines for the handling and processing of specimen samples are given in section 5.5, and Glover et al. (2016) also provide information on protocols used in their work on MN fauna in the Clarion-Clipperton Zone (CCZ).

In addition to describing the distribution and abundance of faunal communities, the ISA recommends that for active sulphide deposits, temperature-fauna relationships should be analysed by five or more discrete, video-documented, temperature measures within each sub-habitat. This enables an understanding of how the benthic communities might change if mining affects the active venting processes.

Many animals may be able to swim away from towed gear, and may also avoid ROVs, if scared away by lights or noise. Baited cameras and traps, usually housed on lander-type equipment, can be highly effective at attracting dispersed and often sampling-shy fauna (see section 3.1.7). They also can be readily deployed at great depths, and can be effective in MN habitats, as well as SMS and CRC. Landers are valuable tools for studies of temporal variation at the seabed, as they can readily be fitted with time-lapse cameras. Ideally, such sampling should cover an annual cycle to determine the physical dynamics of surface sediment as it is deposited on the seafloor, document the activity level of megafauna on the surface of the seafloor, and the frequency of Particulate Organic Carbon (POC) flux deposition and resuspension events. Deployment periods will be governed by image storage capacity and battery life for camera lights. This in turn will dictate how often the equipment needs to be retrieved, and reset (a potentially expensive exercise if offshore vessels are needed). With long-term deployments, photographic images may be taken at 3–12 hourly intervals.

3.1.3 Macrofauna

Data on macrofauna (>250 µm) species (Figure 2 2) structure, diversity, density and biomass need to be obtained. Some macrofauna may be captured in ROV sampling and towed sampling gears for megafaunal epifauna (see above), but the class of fauna is most important in the sediment. In soft sediments, vertical profiles with a suitable depth distribution (suggested depths: 0-1, 1-5, 5-10, and 10-20 cm) should be obtained from box cores (0.25 m2) or multicorers, as appropriate. A grab or scoop may also be useful, but these devices usually do not collect quantitative samples and do not allow vertical sectioning. Scientific studies tend to favour sampling with a box corer or multicorer, depending on the targeted scale of sampling. However, with multicorers, the size of the tubes is an important consideration. If the tube diameter is relatively small (some can be around 6 cm), then these may be inadequate for macrofaunal sampling. Most multicorers used in the deep sea have larger tubes (about 10 cm diameter), which are sometimes called "megacorers" (Narayanaswamy et al. 2016).



Figure 2 2. Examples of macrofauna. Brittle stars (left), amphipods (centre), gastropod snails (right). Source: NIWA

In MN exploration, a box corer is typically used for macrofauna in preference to a multicorer in order to collect large enough samples with statistically useful numbers of macrofauna, which occur at very low abundance in MN region. If nodules are more than several cm in diameter, they may prevent a multicorer from working, and multicores typically collect only a few macrofaunal animals per tube. Tubes can be manually inserted into the box core material for subsampling, and separate cores processed for different purposes. However, these are not typically considered quantitative subsamples for macrofauna, due to sloshing of topwater inside the box corer during recovery. Multiple core samples can be very useful to assess small spatial scale variability in the infaunal communities at shallower depths where macrofaunal abundances are higher (e.g. in sediments around cold seeps), and can be distributed to specialists that use different techniques for fauna identification and counting. For example, at bathyal depths where the macrofauna are relatively abundant, NIWA protocols for an 8-tube multicorer will typically provide three cores to be used for bacteria and meiofauna (shared), three for macrofauna, and one for sediment grain size/organic matter analysis, with one spare as back-up. It should be stressed that the diameter of the tubes must be appropriate to avoid excessive disturbance of the sediment or obstruction by large particles, such as nodules and rock fragments, and that biological samples must be large enough to generate good sample sizes in terms of abundance and biomass for robust statistical analyses. In addition, macrofaunal densities in the MN nodule regions are typically so low, and diversity so high (Snelgrove and Smith 2002, Smith et al. 2008b), that multicorers cover too small an area to obtain statistically useful samples of macrofauna.

To obtain sufficient numbers of macrofauna, Smith (1999) recommended at least 10 box-core samples per study site (or stratum) in MN areas.

Macrofaunal samples are usually puddle-sieved on a 250–300 µm mesh sieve.

3.1.4 Meiofauna

Data on meiofauna (traditionally defined as organisms which pass through a 0.5-1.0 mm mesh, but are retained on a 32 µm mesh) (Figure 2 0 3) species community structure, diversity, density and biomass also need to be obtained. In soft sediments associated with MN, vertical profiles should be assessed down to 5 cm (suggested depths: 0-1.0, 1-2, 2-3, 3-4, 4-5 cm). At least one, and up-to-three multicorer tubes per station should be allocated to meiofaunal sampling.



Figure 2 3. Examples of meiofauna. Nematodes (I, r), copepod(c). Source: NIWA

Multicorer sampling is a preferred method for meiofauna. The use of box corers is problematic, in that the 'bow-wave' artefact that is associated with this collecting gear means that small meiofauna living in the flocculent or soft surface layers get blown away as the box corer deploys. However in some cases, a box corer might be the only method available when sampling sediments with high densities of nodules.

Meiofauna are commonly found on and in nodules, and different sizes of nodule can have different faunas. Large, complex nodules can have meiofauna within them, as well as encrusting the outer surfaces, while small solid nodules may only have encrusting meiofauna, such as foraminifera. Large complex nodules need to be broken up carefully and the fauna sorted, and encrusting fauna needs to be sampled. The encrusting organisms on MN are often very diverse, cover much of the nodule surface and are dominated by undescribed mat-like, tubular and more complex agglutinated and organic-walled morphotypes that are not represented in the sediment community. Many are foraminifera, which vary in size, and can be macrofaunal tomegafaunal (xenophyophores).

With SMS and CRC, there is much less likelihood of obtaining soft sediment samples. While seamounts and ridges have mixed and varied substrates, the actual resource sites will be dominated by hard substrate. However, plume effects could be transported down slopes to soft-sediment systems. The ISA has recommended that meiofaunal and microbial community structure and biomass associated with both SMS and CRC deposits be examined from rock dredge and rock drill samples, or obtained from ROV/submersible sampling, where possible. The latter is almost certainly necessary, as meiofauna from dredge and drill samples will generally get washed away by the time the gear gets to the surface. At least three samples should be taken from which meiofauna species that live on the rock or in crevices and pits in the deposit can be identified.

Sorting and identifying meiofauna can be a time-consuming and specialised task. For MN environments, a recommendation from the DISCOL experiment (a Disturbance and recolonisation

study in a manganese nodule area of the south-eastern Pacific (Thiel et al. 2001)) was that nematodes and copepods are likely to be the most important faunal groups, and efforts should focus on those (ISA 2002). However, the dominant meiofaunal organisms, in terms of numbers and diversity, in MN areas of the CCZ typically are the foraminifera, and it is important to include this faunal component in baseline and impact studies. A separate core should be used for this purpose. Sorting foraminifera retained on a 32-um mesh is impractical, while analysis of 63-µm fractions (the lower size limit for foraminifera in normal use) is still very laborious. For CCZ samples, sorting 150-µm or preferably 125-µm fractions is more realistic, particularly if larger (10-cm diameter) core tubes are used. Limiting analyses to the upper 1-cm layer, and wet-splitting of samples, also reduces the amount of work necessary. Rose Bengal staining is typically used to distinguish specimens that were alive at the time of sampling from dead tests; this can be done by immersing the sieve residue (while still on the sieve mesh) in the stain solution. Many monothalamid foraminifera are delicate, soft-shelled and prone to fragmentation. Since fragments are sometimes abundant, it is recommended that they be included in analyses, but counts of specimens and species treated separately from those of complete individuals. Hard-shelled foraminifera (mainly multi-chambered taxa) can be stored dry on micro-palaeontological slides, but those with soft shells become unrecognisable when dried and are best stored in glycerol on glass cavity slides.

3.1.5 Microbiota /Microbes

Microbial ecology in the deep sea is much less developed than in shallower coastal environments. However, in recent years, the field has developed considerably, and it is now recognised that the relative abundance of Protists, Bacteria, Archaea and viruses in deep-sea sediments is very high, and that they play an important role in the long-term biogeochemical cycles (Inagaki et al. 2006; Foshtomi et al. 2015). However, a large proportion of this functional and microbial diversity is unknown (e.g. Sogin et al. 2006, Massana et al. 2015). Hence it is an important field for research to further develop scientific knowledge, but also to support understanding of DSM systems. Study of microbial faunas will inform the trophic structure of energy flow to larger animals – especially, deposit feeders that consume bacteria attached to the sediment in MN areas, and on chimneys at SMS deposits. The microbes also play fundamental roles in the geochemistry of seafloor ecosystems, including sediments in MN areas and at vents around SMS deposits.

Microbial metabolic activity (e.g. bacterial production) should be determined, using adenosine triphosphate (ATP) or other standard assay, such as thymidine and leucine incorporation. In soft sediment MN environments, the ISA (2002) includes a recommendation that vertical profiles should be obtained with suggested intervals for sampling of 0-0.5, 0.5-1.0, 1-2, 2-3, 3-4, 4-5 cm. One multicore tube per station could be devoted for this purpose. For bacterial work, surface scrape a sample into a 50 ml sterile Sarstedt falcon tube with an ethanol sterilised spoon (2-3 teaspoons), wearing gloves. Write a label on the outside, and freeze at -80°C. Subsequently, bacterial counts can be made, and diversity assessed by the DNA genotyping method of choice (e.g. DNA metabarcoding analysis), while functional aspects of the community could be explored through RNA sequencing approaches (e.g. MetaTranscriptomics).

The value of this work in the context of EIA is arguably less than characterising the larger faunal communities, hence less effort is necessary unless the sampling reveals it is important. It takes little time to collect the sample (1 tube) and, once frozen, they can be kept indefinitely until subsequent analysis.

Recent technological progress in metagenomics is opening up the scope for less costly processing of samples, and "next-generation" sequencing enables analysis of the composition of microbial assemblages from various habitats, as well as metabolic differences. The

application of metabarcoding techniques to "environmental DNA" (defined as the genetic material obtained directly from samples of water, substrate, etc.) has revolutionized biodiversity assessments, particularly in remote systems like the deep sea where it is very costly and time-consuming to characterise biodiversity adequately. The development of new generation sequencing technology provides massive parallel sequencing capacities that allows community barcoding of entire communities ('metabarcoding'), and makes it a powerful tool to unveil species composition. The 16S/18S rRNA genes are the most common gene markers used to identify and quantify the relative the relative proportions belonging to various taxa — these tend to be higher level groups, as most species patterns are unknown (see Bik et al. 2012, Creer & Sinniger 2012). Such metagenomic analyses are specialised, and results are still open to interpretation difficulties (are identified genotypes all from living organisms, or long-dead?), but can be very informative for how variable community composition might be at larger regional scales. Hence, their application in a DSM context could best be for a rapid comparison of whether patterns from the prospective mining site are similar in other parts of the region, or suggestive of considerable variability.

3.1.6 Resource-specific fauna

Data on fauna abundance, biomass, species structure and diversity specific to MN, SMS or CRC are required. A critical aspect for any EIA is to determine whether there is an endemic fauna (restricted in their distribution to the site, area, or region) or major differences in faunal communities associated with the resource from the 'background' communities. If there are specialised or very localised species associated with the resource (e.g. community of animals restricted to manganese nodules), these will be most affected by mining activity and will need specific management.

Fauna attached to MN should be determined from selected nodules (e.g. 10 randomly selected nodules from 10 box-core samples (Smith 1999) taken from the top of box corers or sampled by a remotely operated vehicle. Nodule-specific fauna include bacteria, foraminifera, polychaetes, corals and sponges, and whole nodules should be kept since the nodule fauna often is delicate and encrusting.

The chemosynthetic megafauna (Figure 2 0 4) of active SMS sites may include tubeworms, mussels, clams, snails, barnacles, and shrimp. In association with these animals may be fishes, crabs, starfish and other predators. The larger clumps of attached fauna (e.g. worms, clams, mussels, barnacles) as well as large-bodied starfish and crabs can be sampled by the ROVs manipulator arm, and suction samplers are generally able to collect smaller, more mobile animals. Sleds and dredges can also sample these animals but, in general, will cause too much damage to be recommended.



Figure 2 4. Examples of chemosynthetic fauna. Source: NIWA

It is uncertain whether there are fauna that are specific to inactive SMS sites, so this fauna should be carefully assessed prior to mining. It is also uncertain whether there are taxa that are specific to CRC. As for inactive SMS sites, species composition and abundance may vary, but this may be driven by particular seamount characteristics rather than by the thickness or grade of CRC. Sampling fauna is best performed by ROV, as CRC seamounts can have high densities of fragile corals and sponges (e.g. Schlacher et al. 2014); however, epibenthic sleds and dredges could also be used.

Particular attention to methodology selection should be paid to potentially 'sensitive' habitats, such as those described by the CBD as being ecologically or biologically significant⁸⁷, or as sensitive habitats under New Zealand mining regulations⁸⁸, such as hydrothermal vents (where SMS deposits occur) and seamounts (where CRC occur).

3.1.7 Demersal scavengers

Scavenging animals can be important components of deep-sea communities, where they feed on available food on the seafloor. These animals are frequently sampled with a combination of landers and traps.

Landers are used for short-term deployment (24–48 hrs) of cameras and baited traps that will capture deep-scavenging fish (e.g. cusk eels, synachobranchid eels, rattails) or crustacean necrophage communities (especially amphipods) at bathyal and abyssal depths. They can be particularly important in MN habitats.

Fish traps require separate deployments from the camera landers, because the conventional metrics to evaluate relative abundance and biodiversity assume that the bait creates a single odour plume in the vicinity and that the animals are free to come and go. Further bait outside of the camera's field of view will be counterproductive to census activities. To prevent interference of trap odour plumes with those of cameras, traps should be deployed at different times or at a reasonable distance away from the cameras if deployed at the same time.

Baited cameras and traps should be deployed at a range of depths (in particular summit, flanks, base) on a seamount/ridge to determine depth-related variability with CRC and SMS fauna, and spread throughout a MN area to measure spatial variability. When landers are deployed for short periods, still camera images can be taken at 1- or 2-minute intervals. Video systems can record 1-2 minutes of footage every 5-10 minutes.

3.1.8 Demersal fish

Surveying fish may be a major challenge for survey operations that are geared for exploration of mineral resources. Fish can be mobile, extend the full range of the water column, and come in all shapes and sizes. Consequently, they can be difficult to sample quantitatively from many research or geological survey vessels. It is likely, however, that information on fish associated with SMS or CRC habitats will be available from commercial fisheries and bycatch records, in areas of similar habitats or nearby regions. For many PICs, these may be from surveys for deepwater snappers, or from more extensive fisheries research surveys designed to assess the size and status of commercial fishery resources in similar environments off New Zealand, New Caledonia, or Australia.

Existing advice on sampling fish in conjunction with minerals exploration is limited. In MN environments, it was recommended that fish be assessed around the depth of the plume, and benthic boundary layer (ISA 1999), which was also advised for SMS and CRC resources (ISA 2007). The ISA (2007) recommended trawling should be carried out to sample fish in CRC and SMS environments. Trawling with specialised otter trawl gear⁸⁹ is desirable in many

⁸⁷ CBD (2009) lists criteria for determining ecological or biological significant areas.

⁸⁸ New Zealand Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012.

⁸⁹ A trawl net that is spread and kept open horizontally by two "otter" boards designed to shear outwards.

situations, but is also a practical limitation given the extreme depths and cobbly nature of MN habitats, and the rough seafloor nature of SMS and some CRC environments. In addition, many research vessels that might be engaged in exploration activities for DSM are unlikely to have twin-wire deep-sea trawl capacity or suitable otter trawl gear. Hence, the information below outlines sampling that is based on the expected capabilities of a non-trawler research or survey vessel. Emphasis is placed on sampling by photographic or single wire sampling equipment, as well as the use of baited traps and cameras.

Demersal fish (including sharks, skates and rays) typically live close to the seafloor, either resting on the seafloor, or living close to the seafloor, but often several metres above it. Populations of demersal species often have a more localised distribution than pelagic species (e.g. tunas) and, being close to the seafloor, they are potentially vulnerable to the immediate effects of the physical mining operation and sediment plume generation.

The key questions to address with demersal fish are (1) what species are present (2) are any very abundant (indicating a site of aggregation for feeding or spawning), and (3) are certain species threatened, rare, endemic (or very localised in their distribution), or particularly vulnerable to disturbance and mining impact?

The use of multiple sampling techniques is required to provide information on the composition and relative abundance of fish species. In the first stages, photographic surveys in combination with baited lander deployments are required. Baited traps and cameras are covered above in Section 5.3.9.7. A towed camera or ROV survey will be carried out in conjunction with that for megafauna (section 5.3.9.2).

There are three concerns with use of photographic techniques for fish surveys.

- Fish will sense the physical presence of a large towed camera system or ROV, as well as the noise and light that are generated. Some species may have an avoidance reaction, others an attraction. This can be tested, to an extent, by trials with holding the equipment stationary, and turning lights on and off. The results when stationary and when lights are first switched on should be compared with what is seen with constant lights, and how density may change with time.
- 2. Fish are difficult to identify when viewed and photographed from above. Typically, a side-on (lateral) aspect is needed to identify the fish to species level and, even then, it may not be possible to take identification to species level. It is important to have forward-facing cameras so that fish can be seen in lateral perspective, and this also helps gauge if the fish are being scared away as the vehicle approaches them.
- 3. Small fish will be difficult to distinguish. These are often fast-moving, or partially hidden in crevices or coral thickets. Such species are important, as they may have a highly localised distribution, compared with larger-bodied fish that are more likely to swim greater distances between sites and habitats. Still cameras fitted in combination with video may help as they enable higher resolution images to be obtained. The frequency of image capture should be as high as possible to increase the chance of a successful shot.

The same sorts of issues arise with baited photographic landers.

In many cases, direct capture is required to confirm species identification, as well as sample small-bodied fish that may escape detection in photographs. Baited fish traps can aid capture of scavenging species (see Section 5.3.9.7), but many species will not be attracted to bait, especially in SMS and CRC environments where food is not as limiting as in abyssal depths with MN.

Fish capture in SMS and CRC environments needs to be evaluated for each site. In some cases, capture of small-bodied and slow moving fish can be done by a ROV, with a scoop net or suction pump ("slurp gun"). Special care is needed in sensitive habitats, such as around active hydrothermal vents, or patches of dense biogenic habitat (e.g. corals, sponges), where destructive sampling must be kept to a minimum and, preferably, only done where direct

sampling is necessary for species identification. In some situations, it can be appropriate or necessary to use a small epibenthic sled (such as described in Section 5.3.9.2), which may catch slow-moving fish. Sleds can be deployed off a single warp, and so many vessels with a stern A-frame or towing block can use this gear if there is sufficient wire strength and length (up to 1.5 times the water depth is required). If the photographic survey shows the seafloor to be relatively flat and smooth, a beam trawl can be used (see Figure 2-4). This gear is also deployed off a single wire, and can be made to suit the capabilities of the vessel (in terms of beam size and weight). However, the net is, like any fish trawl, prone to damage on hard rough seafloor. It will be suitable for a range of CRC and MN habitat, but will not be appropriate in areas of SMS with chimney structures (Table 2-9). Chapters 7 and 8 in Clark et al. (2016) give more detail on these gear types, and their use.

Table 2-9. Suitability of some common sampling gear types in resource habitat (efficiency for sampling fish)			
Trawl type	SMS	CRC	MN
Epibenthic sled	Y (low)	Y (low)	Y (low)
Agassiz trawl	Y (low)	Y (med)	Y (med)
Beam trawl	N	Y (high)	Y (high)
Otter trawl	N	Y (high)	N (too deep)

The catch will be sorted into species, and counted and weighed. The length and weight of individual fish should be measured (an indicator of the life-history stages present), and the body cut open to determine the sex and reproductive state (is it a spawning area?). Stomach contents should also be examined to identify prey, as feeding type can be important for assessing mining impacts (whether fish are general foragers or predators, and whether they feed on benthic or bentho-pelagic prey). Samples should be taken for isotope and genetic studies, whereby individual fish are placed in separate bags, or a small piece of flesh taken form the fish and stored separately in ethanol. Details of processing should be discussed with fisheries experts prior to the voyage.

Consideration may also need to be given to repeating surveys at different times of the year. Fish may migrate to a particular site, or a specific seamount, to aggregate for spawning at a certain time of the year. Hence, information on the reproductive cycle of the species, or similar genera, should be factored into the timing of fish surveys. At least two surveys (likely spawning season – often winter, and the opposite season) should be carried out.

In the same way as for mega-fauna, the number of sampling tows, the length of each tow, and the spacing of events will be dependent on the scale and characteristics of the particular site. The factors considered in Section 3 need to be kept in mind. If there are indications that there could be significant fish biodiversity or densities in an area, and hence potential interactions with any proposed minerals exploitation, consideration may need to be given to a more dedicated fish-sampling programme, using a specialised trawler or commercial line vessel.

3.2 Pelagic community

Most scientific research associated with DSM has been focussed on benthic environments, as that is where the most significant impacts are perceived likely to occur. Hence, ISA recommendations to date have focused on describing benthic community structure and vulnerability to impact as a priority. This may be appropriate in many situations, but all marine ecosystems are three-dimensional, and systems and processes occurring higher in the water column should be included to understand the functional dynamics of seafloor communities, and the nature and extent of potential impacts from a deep-sea mining operation. Hence, pelagic components need to be addressed as part of an integrated exploration science plan.

3.2.1 Surface plankton

The plankton community in the upper 200 m of the water column should be characterised if there is potential for surface discharge that could affect species composition or abundance. Depending on plume modelling studies, it may be necessary to study plankton communities over a wide depth range where they could be impacted by mining operations.

Phytoplankton measurements are made by collecting water samples from a CTD-rosette. Phytoplankton biomass is assessed by fluorometric analysis, measuring chlorophyll a and phaeopigments, and community composition is often assessed in a similar way to bacterial analysis, using liquid chromatography. Phytoplankton productivity is measured by incubation experiments under laboratory conditions. Because the phytoplankton are generally close to the sea surface, remotely sensed data (chlorophyll a and ocean colour) can provide information on levels of surface productivity and, if this is relatively stable in an offshore environment, then such analyses can substitute for specific phytoplankton sampling. However, this will need to be evaluated against the nature and extent of possible surface disturbance by vessel operation or discharges. For example, increased surface turbidity has been shown to alter phytoplankton assemblage structure, favouring flagellated forms (e.g. dinoflagellates) over non-flagellated forms (e.g. diatoms).

Zooplankton sampling is typically carried out with nets, and the techniques and methods are similar for surface and the deep sea. The ICES Zooplankton Methodology Manual (Harris et al. 2000) gives a comprehensive description of zooplankton sampling and analysis methods, and Wiebe & Benfield (2003) give details of nearly all types of plankton nets, as well as acoustic and optical sensors.

ISA publications recommend that oblique tows for zooplankton be carried out from the surface to a depth of 200 m, using a standard 'bongo net', which is standard equipment owned by many scientific institutes. They generally comprise a double net frame, with a 60 cm diameter mouth opening. A 200 micron mesh size net and cod-end is recommended by Koslow et al. (2002). A flow meter should be attached to the frame, so that the amount of water filtered can be determined. Bongo nets are suitable for sampling smaller and less mobile zooplankton, but will not sample mesopelagic fishes well, as mobile swimming animals can avoid the nets. However, although bongo nets will enable plankton composition and relative abundance between sites to be assessed, if surface plankton need to be sampled, it is best done with depth-specific samplers that will include sampling of greater depths (see below). This enables a depth-stratified set of data, which is more useful for assessing likely impacts from mining operations and sediment plumes.

For MN environments, it has been suggested (Smith 2002, Koslow 2002) that at least four stations be sampled, up to 100 km apart, to reflect gradients in oceanographic conditions (hence plankton) through a claim area. This is based on the variability observed in the CCZ but, for most areas, there will need to be an assessment of the site-specific scale of variability. Hence, it is not possible to set a standard number, but a minimum of four will provide initial data to evaluate the required sampling design. For seamount and ridge environments (SMS and CRC), the scale will need to be much smaller (on the order of 1-5 km) to measure the higher variability expected in a more oceanographically-dynamic topographic setting.

Sampling should be replicated at least twice during a 24-hour period, to determine community composition and capture differences due to diel vertical migration (DVM) of zooplankton to and from the surface waters. One possible outcome of DSM is an alteration of behaviour (e.g. DVM), rather than faunal composition per se, which could have ramifications throughout the food web. Assessment of temporal variation of the plankton community on seasonal and interannual scales will likely be needed. This might be impractical to monitor over several years, but remote sensing of phytoplankton productivity could be used to augment field programmes. The use of remotely sensed data needs to be accompanied by calibration and validation. If the discharge of processing waste is not near the surface, but several hundreds of metres depth, then the impacts of mining on plankton are likely to affect principally mesopelagic zooplankton and nekton (fishes, shrimps and squids; see below).

3.2.2 Deepwater plankton (meso-, bathy- and abysso-pelagic)

The pelagic community structure between the depth of the wastewater discharge point and the near-seafloor benthic boundary layer needs to be assessed if there are likely impacts from the discharge plume or its composition. Typically at these greater depths, the density of zooplankton is low, hence the sample volume often needs to be large to collect sufficient plankton to describe its composition and abundance. This requires larger nets than the bongotype, and equipment that can sample discrete depths throughout the water column.

Both vertical and horizontal/oblique tows can be used in quantitative sampling to determine the composition and abundance of zooplankton, and its variability with depth or site. Horizontal tows and gear should be used if narrow depth layers and large volumes need to be sampled, such as close to the seafloor or targeting specific sound-scattering layers — this could apply over deep slope areas, or above abyssal MN regions. However, if small-scale horizontal differences are important, such as around seamounts (SMS, CRC), then vertical hauls are appropriate (Christiansen 2016).

Multiple opening-closing net systems are required for deep-sea plankton sampling. These consist of a series of single nets that can be opened and closed sequentially at a range of depths (under acoustic control, or pre-programmed). The two most common type of sampler are the MOCNESS, and MultiNet, although many pelagic trawls can also be fitted with opening-closing mechanisms.

Koslow (2002) recommended sampling zooplankton at six-depth intervals in MN areas, which are also proposed here.

- 1) Surface to seafloor (vertical net or opening/closing net while being shot away)
- 2) Seafloor (within 25 m of it) to 2000 m
- 3) 2000 m to 1000 m
- 4) 1000 m to 500 m
- 5) 500 m to 200 m
- 6) 200 m to the surface

However, the most potentially important component to measure is the pelagic community in the benthic boundary layer, which is the active interface between pelagic and benthic communities, and where the zooplankton community changes considerably. This occurs within the bottom 5-10 m of the seafloor, and should be a separate stratum.

7) Seafloor to 10 m above the seafloor.

Opening-closing nets also allow more discrete depths to be sampled, and these can be located based on echo-sounder recordings of particular scattering layers, the location of vertical migration limits, thermocline depth, etc. However, plankton sampling at depths below 1500 m is relatively uncommon, and such deep tows are of great scientific interest (Sutton 2013).

The bottom boundary layer can be sampled by plankton nets, but they will require accurate pinger systems, depth meters, or altimeters mounted on the gear to reduce the risk of damage from contact with the seafloor. Plankton nets mounted on sleds that are towed across the seafloor, with a net several metres above the seafloor, can be used to characterise this layer as well. A common type of sled for sampling the hyperbenthos is the "Brenke Sled" (Brenke 2005, Kaiser & Brenke 2016), which is suitable for MN areas, but may not be successful in SMS or CRC habitats due to the rough seafloor. Sampling should occur in the benthic boundary layer, following a similar survey design to that of benthic gear, as this is the component of the zooplankton community that could be most at risk from mining operations.

Guidance on deep zooplankton sampling procedures can be found in Christiansen (2016), complemented by Harris et al. (2000).

Other techniques are available, that can measure properties of zooplankton in deeper waters, but which do not physically capture them. These include using an underwater video profiler/s, which is an optical recorder, and which has proven useful in quantifying fragile gelatinous plankton that are poorly sampled in nets. Video surveys from ROVs can also be useful with high resolution close-up cameras, although these data are rarely quantitative. Acoustics is a further technique to consider. Whereas, the depths of DSM resources and small body size of plankton largely prohibit hull-mounted acoustics near the seafloor, acoustics can be effective when mounted on ROVs or AUVs. High frequency (120-200 kHz) transducers can be useful at ranges of several hundred meters.

Plankton distribution and abundance also needs to be linked to the assessment of water column quality and chemistry (Sections 2.1.5 and 2.2.1). Transmissiometers can help evaluate the relationships between zooplankton abundance and suspended particle load. Some plankton may be attracted to nepheloid layers (with high levels of suspended sediment), whereas most might avoid them. Particulate organic carbon and nitrogen are particularly important (Koslow 2002), and should be assessed using JGOFS procedures. These are based on filtration of water samples onto glass fibre filters, and use of an electronic elemental analyser.

3.2.3 Pelagic nekton (especially fish)

In the same way that sampling deep plankton requires the use of specialised equipment, surveying pelagic nekton will also require sampling gear that may not normally be carried on geological survey vessels, or even many generic fisheries-type research survey ships. In addition, various types of pelagic sampling gear have different selectivity characteristics, and will only sample some components of the nektonic fauna. Hence, several different gear types will need to be applied.

There are several 'types' of nekton that can be associated with mineral habitats, and need to be considered.

- Epipelagic fishes, typically found in the upper 300 m of the water column, often largebodied and fast swimming (e.g. tunas).
- Deep-diving surface fishes, such as devil rays and some shark species.
- Mesopelagic fishes, shrimps and squids that are small-medium sized (i.e. micronekton) and perform synchronous or asynchronous (not all of population) vertical migrations.
- Non-migrating nekton that stay at mesopelagic or bathypelagic depths day and night.
- Bentho-pelagic fishes that can live and migrate several to tens of metres above the seafloor.

These types require different approaches to survey; some are very difficult even with sophisticated fisheries acoustics or trawl sampling equipment. However, direct survey work may not be necessary on all of them. The large surface-pelagic predators are generally commercial species, and taken as target or bycatch in commercial fisheries. In the South Pacific region, the various species of tuna (e.g. skipjack, yellowfin, albacore, and bigeye), as well as billfish (e.g. marlin, sailfish, spearfish, swordfish) and large sharks are reported in commercial fishery returns, and by observers on fishing vessels. Hence, the composition and distribution of these species could be assessed from existing fisheries information held by national fisheries agencies or regionally, for example, at SPC and the Forum Fisheries Agency (FFA). Similarly, large deep-diving species may also be recorded. If the species composition of this component of the pelagic fauna can be adequately described, then it is possible that an assessment can be made from existing records of whether such fish are likely to interact significantly with a deep-sea mining operation. Of particular importance here is whether they aggregate over the summit of seamounts that are of interest for SMS or CRC, and whether the

depth of the minerals will preclude any direct interaction with adults or juveniles, except for the surface vessel. However, new information should be collected from observations of fish or fish schools at the surface, and as towed cameras or ROVs are deployed down through the water column. Cameras should be recording with lights on during descent and ascent.

Mesopelagic nekton (e.g. lantern fishes, hatchet fishes, sergestid shrimps, cranchid squids) are typically small-bodied, and may be collected in larger zooplankton sampling gear. Their catches in vertical nets will be limited but, if larger open-closing nets, such as MOCNESS are used, then smaller species will be retained. Depth distribution can be determined from deployment of nets at different heights through the water column. These should match the ranges advised in section 3.2. However, to sample larger mesopelagic taxa effectively, towed midwater trawls are necessary. Unlike single-wire rigid frame nets, such as MOCNESS that are towed slowly (Christiansen 2016), these are typically twin-wire nets that are towed at 3-6 knots. Depending on the likely mining techniques, mesopelagic nekton (and migrating predators) may not be a concern in MN environments, but can be at SMS and CRC depths where operations can occur well within the depth range of vertical migrations. If enclosed riser pipes/buckets and discharge pipes minimise any material loss through the water column, then such sampling would need to focus primarily upon the depths that would be affected by a sediment plume from the seafloor, and the depth of waste material discharge. The vertical migration dynamics of mesopelagic nekton mean that sampling should be carried out both during the daytime, and at night to determine the variation in vertical distribution.

Tows should be carried out at depths above the likely plume height, as well as at several depths within it, and repeated temporally to account for vertical migrators. This will be siteand resource-specific, but the general depth bins defined above should be a good starting point. At least three tows should be done at each level to give information on faunal variability at depth over the area of interest.

Mesopelagic nekton are larger-bodied than zooplankton, and acoustics is a technique that can be more readily applied. Hull-mounted mid-frequency transducers (38 kHz is common) can effectively measure the sound-scattering density of midwater animals (the micronekton, which include larger zooplankton, mesopelagic fishes, squids, etc.) to depths of 100-1500 m, depending on water column structure, and how "acoustically quiet" the vessel is. These data can give a measure of total acoustic backscatter, which can be used to estimate biomass (e.g. Kloser et al. 2009), but still requires direct observation or sampling to determine species/taxa composition (e.g. Trenkel et al. 2011).

Larger-bodied fishes that live in close proximity to the seafloor will probably be seen in at least some photographic surveys, especially when densities associated with CRC seamounts or near SMS hydrothermal venting areas can be relatively high. Many (but not all) fish tend to dive towards the seafloor when disturbed in midwater, and an oncoming ROV or towed camera frame may herd them down to within sight. This will give information on species composition, but such data are not quantitative.

Vertically migrating fauna can be difficult to determine without either acoustic echosounder surveys, or targeted midwater trawls at different heights in the water column with large fish nets. The use of acoustics for fisheries and pelagic survey studies is rapidly increasing, and multiple frequency echo-sounders can give useful data on species composition, size frequency, and densities (e.g. Demer et al. 2009, Gode et al. 2014). Multibeam echosounder systems can also collect data throughout the water column, and provide insight into diel migrations, and potential interactions between deepwater plankton and fishes, and the seafloor environment. It is recommended that discussions occur with regional acoustic experts who can advise on transect length and spacing, and appropriate echosounder frequencies that could be useful, given the local conditions and plankton/fish composition.

Where direct sampling occurs, the species composition, weight of catch, weight and length of individual fish, and reproductive condition should be measured as for demersal fishes. This will enable an evaluation of whether particular sites are areas of juvenile fish, spawning grounds, or feeding areas (if above a seamount, for example).

3.2.4 Marine mammals

Marine mammal disturbance by acoustic/seismic surveys has become a major issue for oil and gas exploration in the deep sea. It may be less relevant to CRC and MN deposits, where bathymetry data is collected by multibeam echosounder systems. However, seismic surveys may be used to determine the depth extent of SMS deposits. Additionally, there is a clear association of seamounts and ridges (SMS and CRC) with higher densities of marine mammals, turtles, pelagic fish species, and seabirds (see Pitcher et al. 2007).

The ISA recommends that sightings of marine mammals, other near-surface large animals (such as turtles, sharks and fish schools) and bird aggregations, should be recorded and species identified where possible. Details should be recorded in transit to and from areas of exploration and on passage between sampling stations.

Having a qualified Marine Mammal Observer (MMO) onboard, during research activities will depend upon the nature of the operation and national regulations. The Joint Nature Conservation Committee (JNCC) operates a qualification scheme for MMOs, although there are a number of schemes in operation around the world.

If observations are to be useful, they should be carried out in a systematic way, and not just recorded when somebody onboard happens to see a whale or shark. This could be a single person, or two operating as a team, to cover daylight hours when the weather is acceptable. The viewing platform 'eye height' must be specified, as distance and bearing are important. Standard MMO Burris 7 x 50 binoculars are commonly used. By way of an example, the type of information gathered for each sighting under the JNCC scheme (which is commonly used in Australia and New Zealand) is shown below.

- Date and time (specify UTC or local)
- Vessel latitude and longitude at first sighting: degrees and decimal minutes (DDDo MM.MM)
- Vessel latitude and longitude at final sighting: degrees and decimal minutes (DDDo MM.MM)
- Initial method of detection: naked eye, reticle binoculars
- Distance determination method: eye, binocular reticles, measuring stick
- Features of the sighting; size and shape of 'blow', size and colour of the animal, anatomical description, such as prominent dorsal fin or none, notch in tail, etc.
- Species name and estimate of numbers (adults and calves) if possible
- Range from vessel to sighting (kilometers/meters)
- True compass bearing in degrees from vessel to cetaceans
- Direction of travel by the cetacean
- Behaviour of the cetacean: swimming, breaching, feeding, etc.
- Vessel operations at the time: transiting, multi-beaming, SVP deployment, etc.
- Environmental data: visibility, water depth, influences on sightings, Beaufort sea state, sighting conditions, swell height

Wherever possible, records of mammals, sharks, turtles and seabirds should be backed-up by photographs. Direct observations will give an idea of the extent to which marine mammals occur in the area, but these need to be combined with other information on likely behaviour of the animals in the general region. Such information includes known migrations (seasonal patterns are known for many species), tracking data are available in some areas, habitat use (distribution with water masses, topography, etc.).

3.3 Food web and trophic dynamics

Trophic interactions and the linkages of both food energy, and contaminants in the food chain can be important for an EIA. Emphasis might be placed on knowledge of trophic levels, the degree of interaction between benthic and pelagic communities, whether there are specialised predators that could be more vulnerable than generalists, and how complex the food web and species interactions are to give an idea of resilience of the system to disturbances. Scientific interests may also look at going further and developing models to quantify the trophic structure, and energy flows through the ecosystem.

Sampling a range of fauna from plankton, infauna, epifauna, larger invertebrates, and fishes will give a wide array of taxa and ecosystem components on which to base initial food web studies. Species composition is important in order to combine various functional groups, and abundance data are critical to translate into biomass. This underpins the development of quantitative food webs as a step towards investigating ecosystem effects of any mining operation. There are a number of ecosystem models that could be considered, as data are collected during exploration phases. Such data can begin to support a trophic model structure that quantifies the transfer of organic material through a food web, such as that based on the widely used mass-balance identities of the Ecopath trophic model (Christensen and Walters, 2004). It is beyond the scope of this report to describe such models, but the important point is that such modelling is likely to become a more common feature of EIAs, whereby mining-like perturbations to the system can be modelled and assessed (e.g. Chatham Rock Phosphate Ltd, 2014).

Direct observations of feeding behaviour, and examination of stomach contents are often impossible across a wide range of faunal types. Whereas, fish stomachs can readily be cut out and frozen for laboratory study; this is impossible for smaller macrofauna and meiofauna. Hence, stable isotope analysis has developed, whereby isotopes of carbon and nitrogen (and sometimes sulfur), which are not subject to radioactive decay (and hence "stable"), are analysed, using an Isotope Ratio Mass Spectrometer (IRMS). Details of the approach and methods are given in Petersen & Fry (1987) and Post (2002). This technique requires processing of samples at a specialised laboratory, and experts should be consulted prior to data collection. However, it is straight forward to preserve material collected in the array of sampling gear described above, and retain samples for isotope analysis. Some key points are that the catch should be sorted and separated by species (or similar groups) as much as possible, prior to bagging, labelling, and freezing. While community level analyses can be done on lumped samples, this is not recommended. Individual sample data are recommended. Freezing at -20 °C is adequate although, if fatty acid analyses are intended, -80 °C freezing is required. Freezing is preferred, as preservation in ethanol can affect isotope values. For small invertebrates, whole specimens can be retained. For fish, this is not as practical, and so a standard-sized (1-2 cm by 1 cm) cube of flesh should be cut out, from the same part of each fish (e.g. dorsal flank, just behind the head). Rubber gloves should be worn to prevent contamination from bare hands.

3.3.1 Bioaccumulation

Bioaccumulation is the process by which the chemical concentration of elements in an organism exceeds that in the water, as a result of chemical exposure and uptake (e.g. dietary absorption, transport across the respiratory surface). Bioaccumulation is a combination of bioconcentration and biomagnification — the latter is where the concentration of an element progressively increases through the food-chain, primarily as a result of dietary consumption of lower trophic levels. Marine species take up and accumulate trace metals whether essential or not, all with the potential to cause toxic effects. Subsequent tissue and whole-body residues of accumulated trace metals vary enormously across metals and between species (Rainbow 2002). The complexity of chemical and biological components of the bioaccumulation process makes it difficult to establish environmental quality criteria for metals on the basis of total metal exposure concentrations (Adams et al. 2011); therefore, tissue or whole body concentrations of metals can be used to develop adverse effects thresholds (e.g. Meador et al. 2014; Meador 2015).

A range of common trace metals (e.g. arsenic (As), chromium (Cr), Cu, Cd, lead (Pb), Hg, nickel (Ni) and zinc (Zn)) are generally used to provide a baseline suite of potential contaminants of concern (refer to section 1.6.1). Additional elements, such as calcium (Ca) and strontium (Sr) - which are major components of bone and carapace - and iron (Fe) and manganese which are potentially released in high concentrations from disturbed sediments - should also be measured to characterise organisms from reference and impact sites. An extended suite of trace elements may be required for mining-related studies in areas targeting rare earth elements (REEs). The REEs include atomic numbers 57 [lanthanum, La] through 71 [lutetium, Lu]) with two additional elements (yttrium, Y; scandium, Sc) that have similar physicochemical properties (USEPA 2012). For DSM-related studies, the measurement of whole organism concentrations of bioaccumulated contaminants from a species sampled along a gradient from an impacted sites to distant reference sites will provide a robust initial assessment approach. Selection of a few species, which are both common to all sites along this potential exposure gradient, and with differing trophic levels and feeding characteristics, will help identify the more vulnerable species. Sessile filter-feeding species (e.g. sponges, corals) are susceptible to accumulation of both particle-associated and dissolved metals, arthropods (e.g. crustaceans) incorporate metals in both tissue and carapace, while benthic-associated fish with a limited range may also be useful candidate species. If specific concerns are for human health and consumptive exposure, then the studies should target tissue (fillet) concentrations and species, which are commercially caught.

4 **Processing and preservation of biological samples**

Biological sampling and handling techniques can be complex, and this should be considered and planned for in advance. Hence, such voyages should have biological expertise onboard, during their sampling operations. This section highlights some of the key aspects that need to be considered with processing biological samples, and handling the associated data.

Deep-sea animals that live in temperatures of around 5°C can deteriorate rapidly once in warmer surface waters or on deck. Hence, there should be immediate processing and preservation of samples on deck or storage in cold rooms for durations of no more than six hours before preservation (or less where molecular assays are planned).

Standard practices for the preservation of organisms should be followed, which may vary by taxon (see chapters in Eleftheriou 2013, Clark et al. 2016). Multiple preservation methods may need to be used, including preservation in formalin for taxonomic studies; freezing or preservation in 100 per cent ethanol for molecular studies; drying of whole animals and/or selected tissues for stable isotope analyses; and freezing of whole animals and/or selected tissue for trace metal and biochemical analyses.

It is important that preservation techniques are decided prior to the voyage, ideally in agreement with any researchers who will study the material afterwards. This will avoid any misunderstanding and will ensure the samples are appropriately preserved for their intended use post-voyage. The great majority of specimens collected will be preserved in liquid, which usually is ethanol or formalin. The volume of the preservative has to be kept high with respect to that of the sample (a rule of thumb is at least 5 to 1). Species with a large body containing a lot of water and an impermeable integument (e.g. large fishes, crustaceans, holothurians) will have to be injected with preservative to ensure complete penetration into the body cavity. The choice of preservative depends on the later use of the material. Since the decision about what fixative to use for a particular sample has to be made quickly and consistently on board the vessel, it is recommended that a 'guidance sheet' at the sorting station be developed.

Colour photographs of organisms should be obtained whenever possible, both in situ from towed cameras or ROVs, and fresh specimens on deck to document natural colouration. The photographs should be clearly labelled to the actual specimen, and archived.

Specimens must be archived for comparison with taxonomic identifications from other sites and to understand the details of changes in the composition of species over time. If species composition does change, it might be subtle, and reference back to the original animals (where there might only have been a preliminary identification) is essential. It is recommended that samples be archived as part of national or international collections in a recognised museum or scientific agency, where material can be curated and maintained.

All samples and sample derivatives (e.g. photographs, preserved material, gene sequences) should be linked to relevant collection information (the minimum requirement is date, time, method of sampling, latitude, longitude, depth).

Identification and enumeration of samples at sea and in the laboratory should be complemented by molecular and isotopic analyses, as appropriate. This will link with studies that are likely to be required under an EIA on connectivity of species and populations, in order to understand overall distribution of a species, and the likelihood of a site acting as a source or sink of biodiversity.

It is important to standardise taxonomy between mining companies, scientists and agencies within a region wherever possible. As stressed by Glover et al. (2016), it is important to undertake complementary morphological taxonomy and genetic studies. To facilitate identification, there should be an exchange of identification codes, keys, drawings and sequences at major laboratories, and collections that carry out taxonomic studies of marine organisms. Taxonomic expertise is extremely limited, even for major faunal groups, and the idea of the development of cooperative taxonomic centres or groups of experts may need to be considered. Taxonomy by numbers (e.g. species 1, species 2), if consistent rules are used and vouchers maintained, is a good basis for baseline studies, but classical and molecular taxonomy must be supported. either directly by the contractor or as part of cooperative research programmes. Molecular methods continue to advance rapidly, making biotic surveys at all levels, especially the level of microorganisms, much more rapid and economically feasible. Molecular sequences should be deposited in Genbank or equivalent internationally recognized sequence databases. Trace metals and potential toxic elements should be assessed in muscle and target organs of dominant demersal fish and invertebrate species. This should be replicated over time before any-mining operations begin. This will measure natural variability, and provide a baseline of 'background' trace and heavy metal levels. A combination of monitoring and shipboard and laboratory experimentation may be necessary to identify potential ecotoxicological impacts. This work links with chemical analyses of the sediment and water column.

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CONTRIBUTORS TO THE RSRG

In addition to the primary authors feedback and contributions to the document were received from:

Pacific Island Countries	Respondent
Cook Islands	Phillip Strickland - Cook Islands National Environment Service
Fiji	Senivasa Waqairamasi - Department of Environment
Kiribati	Tebete England - Ministry of Fisheries and Marine Resources Development
	Victoria Hnanguie - Ministry of Environment, Lands and Agriculture Development
Nauru	Claudette Wharton - Ministry of Commerce, Industry and Environment
	Tini Duburiya - Department of Foreign Affairs & Trade
Palau	Francesca Sungino - Palau Environmental Quality Protection Board
Papua New Guinea	Winterford Eko - Department of Mineral Policy and Geohazards Management
	Samuel Himata - Department of Mineral Policy and Geohazards Management
Republic of the Marshal Islands	Julius Lucky - RMI Environmental Protection Authority
	Ywao Elanzo - Office of Environmental Planning & Policy Coordination
Samoa	Ferila Brown - Ministry of Natural Resources and Environment
Solomon islands	Brendon Dony Pinau - Ministry of Environment, Climate Change, Disaster Management and Meteorology
Tonga	Siosina Katoa - Department of Energy
Vanuatu	Michael Leodoro - Geology and Mines Unit

Other Contributors	Organisation
Adrian Flynn	Fathom Pacific
Akuila Tawake	Pacific Community (SPC)
Alfred Railfo et al.	World Wide Fund for Nature (WWF) Pacific
Alson Kelen	Waan Aelõñ in Majel Program (Canoes of the Marshall Islands)
Amon Timan	Kiribati Association of Non-Governmental Organisations
Andreas Gurtierrez-Rodriguez	National Institute of Water and Atmospheric Research (NIWA)
Andrew Gooday	National Oceanographic Centre (UK)
Ashley Rowden	National Institute of Water and Atmospheric Research (NIWA)
Charlie Timpoloa Harrison	Vanuatu Association of Non-Governmental Organisations (VANGO)
Craig Smith	University of Hawaii
Daniel Leduc	National Institute of Water and Atmospheric Research (NIWA)
Dheny Raw	Australian Department of Foreign Affairs and Trade. Sea Law, Environment Law and Antarctica Section
Jeff Ardron	Commonwealth Secretariat
Jeff Drazen	University of Hawaii
Jope Davetanivalu	Secretariat of the Pacific Regional Environmental Programme (SPREP)
Kiyoshi Kawasaki	Japan International Cooperation Agency (JICA)
Kristina Gjerde	International Union of the Conservation of Nature (IUCN)
Laisa Vereti	Pacific Disability Forum
Matt Pinkerton	National Institute of Water and Atmospheric Research (NIWA)
Melanie Bradley	Secretariat of the Pacific Regional Environmental Programme (SPREP)
Michael Lodge	International Seabed Authority (ISA)
Pelenatita Kara	Civil Society Forum of Tonga
Rene Grogan	Nautilus Minerals
Richard O'Driscoll	National Institute of Water and Atmospheric Research (NIWA)

Sara Bury	National Institute of Water and Atmospheric Research (NIWA)
Sven Petersen	GEOMAR (Germany)
Takumi Onuma	Japan International Cooperation Agency (JICA)
Teina Mackenzie	Te Ipukarea Society (Cook Islands)
Tracey Sutton	Nova Southeastern University (USA)
Vira Atalifo	Pacific Community (SPC)
Willie Atu	The Nature Conservancy (Solomon Islands)
William Saleu	Nautilus Minerals

