CIIC SEABED RESOURCES LTD

# APPLICATION FOR EXPLORATION LICENCE – EEZ – THE COOK ISLANDS

## Section VI

## Narrative of Environmental Component

### Objectives / Methodology


| | |
|---|---|
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**Signed: ..... On Behalf of: CIIC-SR**

**Name: Eusenio Fatialofa.....Date: 11 December 2020**

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# Abbreviations

| | |
|---|---|
| CCZ | Clarion Clipperton Zone |
| EEZ | Exclusive Economic Zone |
| EIA | Environmental Impact Assessment |
| EIS | Environmental Impact Statement |
| EMP | Environmental Management Plan |
| EMMP | Environmental Management and Monitoring Plan |
| GSR | Global Sea Mineral Resources nv |
| ISA | International Seabed Authority |
| MP | Monitoring Plan |
| MSR | Marine Scientific Research |
| NGO | Non-Governmental Organisation |
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# 1. Introduction

As detailed in Schedule 3 of the Seabed Minerals (Exploration) Regulation 2020, the environmental management programme:

a) establishes a proposed programme of work for environmental baseline studies, environmental assessment, and the management of potential environmental effects of exploration activities on the marine environment; and
b) is subject to the requirements of the Environment Act 2003, associated regulations and applicable guidelines; and
c) is considered by the National Environment Service and the National Environment Council in connection with the application for environmental approval

Environmental considerations are currently covered by the Environment Act 2003, with further regulations planned in order to include seabed mineral activity.

# 2. Objectives of environmental data acquisition

The key overall objectives of CIIC-SR's environmental data acquisition program include:

- Establishing a baseline to characterise surface, water column and seafloor environments;
- Providing an understanding of the characteristics of the environmental and socioeconomic receptors that could be exposed to effects from the potential future exploitation;
- Gaining an understanding of how receptors might respond to effects from mining;
- Modelling the impacts and effects of seafloor polymetallic nodule mining;
- Conducting mining system component trials and monitoring them to validate impact and effect predictions;
- Conducting an environmental impact assessment (EIA) which will define the expected environmental effects from a full-scale nodule extraction operation including evaluating and developing ways to prevent or otherwise minimize impacts as far as possible to the environment from full-scale operations;
- Developing a robust Environmental Management Plan (EMP) and Monitoring Plan (MP) for full-scale operations, including the delineation of protected areas and/or representative areas of habitat and biodiversity of the type that will be potentially affected by seabed minerals extraction operations;
- Conducting ongoing environmental monitoring to ensure that no serious harm is caused to the marine environmental from exploration activities.

# 3. Methodology used

## 3.1 Baseline studies

Environmental baseline studies will be conducted according to the regulations in place. At the time of writing, the Seabed Minerals Authority has not defined specific recommendations in that regard. As such, CIIC-SR will for the time being refer to the *Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area (ISBA/25/LTC/6/Rev.1)* developed by the International Seabed ISA (2020) provides details of the expectations of the ISA and its stakeholders for environmental baseline data acquisition. These are summarised in Table VI-1 grouped by major study area, which serves to describe the magnitude and level of detail required to support the EIS.

*Table VI- 1: Summary of ISA-recommended Environmental Baseline Studies.*

| Study area | Study summaries | ISBA/25/LTC/6 |
|---|---|---|
| Physical Oceanography | **Parameters**<br>Pressure, currents, conductivity / salinity, oxygen, turbidity & other optical properties, particulate matter and turbulence intensity.<br>Satellite-based observations of SST & productivity over multiple years at synoptic scale.<br>**Minimum effort**<br>Water column profiles, spacing ~ topography. Moorings every 50km.<br>Currents: 0 - 200m above seafloor ~ topography<br>Amplitude tidal & seasonal variability currents (ref. annex I paragraph 13). Monitoring for "several years" required (ref; annex I paragraph 21).<br>Sediment traps @ 10m, 500m and 2000m above the seafloor. | Paragraph 15 (a)<br>Annex I paragraph 9-13 and 15, 21 |
| Chemical Oceanography | **Parameters**<br>Metals and other elements that may be released during mining in both particulate and dissolved form, oxygen concentration, pH, carbonate system ($CO_2$, alkalinity), nutrients such as phosphate, nitrate, nitrite, silicate, organic matter (dissolved & particulate).<br>**Minimum effort**<br>Samples at the same locations of physical oceanographical sampling. Specific focus on the depth range of the oxygen minimum zone and discharge depths. Temporal variation on tidal, seasonal and interannual scales | Paragraph 15 (b)<br>Annex I paragraph 16 - 19 |
| Biological communities (water column) | **Parameters**<br>Taxonomy, diversity, abundance, biomass & community structure, primary productivity, bacterial productivity, vertical migration, DNA analysis of some of the taxonomic groups<br>**Taxonomic groups**<br>Zooplankton, phytoplankton, nekton (fish), megafauna, seabed scavengers, … with focus on planned return water discharges depth's<br>**Minimum duration**<br>Temporal variation on seasonal and inter-annual scales; Paragraph 46 indicates sampling is required "for one test-mining & one PRZ with a minimum annual sampling over at least 3 years" | paragraph 15(d)<br>Annex I paragraph 41, 44 and 51. |

| Study area | Study summaries | ISBA/25/LTC/6 |
|---|---|---|
| Biological communities (seabed) | **Parameters**<br>Taxonomy, diversity, abundance, biomass & community structure, DNA analysis of all taxonomic groups. *faunal succession following tests**<br>**Taxonomic Groups**<br>Megafauna, seabed scavengers, macrofauna, metazoan meiofauna, foraminifera, nodule biota, microbiology<br>**Minimum duration**<br>Temporal variation on at least inter-annual scales. Minimum 1 year of time-lapse camera deployment to cover resuspension events & megafauna<br>Paragraph 46 however indicates sampling is required "for one test-mining & one PRZ with a minimum annual sampling over at least 3 years" | paragraph 15(d)<br>annex I paragraph 42, 49. |
| Ecosystem functioning | **Parameters**<br>Oxygen consumption. Food-web linkages & fluxes in and between pelagic & benthic habitats.<br>Sediment bioturbation. | paragraph 15 e, f, g, h<br>annex I paragraph 52, 53 |
| Plume modelling | **Parameters**<br>Dispersal of particles & dissolved substances.<br>Al water depths where discharge and accidental spills could occur. | annex I paragraph 14, 20, 21 and 23 |
| Ecotoxicity assessments | **Parameters**<br>Trace metals in muscle and target organs of demersal fish & invertebrate species. Whole organism concentrations of trace metals sampled at gradients from disturbance experiments. Bioassays of algal fluorescence and experiments to determine toxicity at multiple trophic levels<br>**Minimum duration**<br>Sampled over time to determine natural variability, and thereafter at least annually once mining operations begin. Paragraph 46 indicates sampling is required "for one test-mining & one PRZ with a minimum annual sampling over at least 3 years" | annex I paragraph 45 |
| Underwater noise | **Parameters**<br>Natural background soundscape across depth profile and especially in the SOFAR channel<br>**Minimum duration**<br>1 year of data from continuous recordings | annex I paragraph 43 |
| Geological Properties | **Parameters**<br>High-res. bathymetry. Granulometry & basic properties seabed sediments, heavy metal & trace metals in sediments, nodules and porewater. Porewater profiles down to 20cm ~ removal depth of the seafloor. Nutrients, specific gravity, density, dissolved and particulate organic & inorganic carbon, sediment redox system.<br>Characteristics of sediments resettled after disturbance | paragraph 15 (c)<br>annex I paragraph 24, 25, 26, 27, 28 |

*Note this list is a summary and is not exhaustive

Where possible, CIIC-SR will connect and collaborate with other sea users who may be interested in forming local partnerships to conduct environmental studies, and in particular seasonal and/or regional studies.

Appendix A presents a list and some details about the methodologies that are envisaged to be used. The baseline data for the environmental impact assessment will be established using the best available technology and sampling methodology.

## 3.2 Impact assessment

A key objective of the environmental program of the exploration phase is to develop an Environmental Impact Assessment (EIA), culminating in an Environemntal Impact Statement (EIS) and Environmental Management Plan (EMP) and Monitoring Plan (MP) for future mining operations. During exploration, the baseline environmental conditions will need to be understood, as described in Section 3.1, and an environmental impact assessment will need to be completed in order to assess the likely impacts and effects a mining operation will have on the environment.

CIIC-SR will gather important data about the potential effects of polymetallic nodules collection including through field trials. At this stage, it is planned that the Patania II pre-prototype seafloor nodule collector will be deployed in the Cook Islands EEZ (est. 2025). An environmental impact assessment and monitoring plan will be developed and submitted to the Seabed Minerals Authority prior to the activity taking place (as per requirement of the Part 5 of the Environment Act 2003), to understand and monitor the potential effects of this small-scale operation. Patania II is being developed as part of GSR's polymetallic nodule project in the CCZ and will be first deployed in the GSR CCZ contract area in 2021. From a scientific point of view, the Patania II trial offers an important opportunity to assess in situ environmental effects that may arise from a potential future nodule mining operation on the seafloor. For the CCZ trial, Patania II will clear nodules from a small area of seafloor (approximately 0.1 km²) at a water depth of ~4,400 m during a 4-day period. This is the minimum time and space required to achieve the objectives. GSR is conducting this small-scale component test to help inform engineering design of the full-scale system and to reduce unknowns about environmental effects of full-scale polymetallic nodule mining. In the spirit of transparency, GSR has agreed that a consortium of independent scientists[1] will monitor the upcoming Patania II trial, with a key aim of reducing existing knowledge gaps and uncertainties surrounding environmental effects. Knowledge gained will be incorporated into the next phase of engineering design.

The Patania II trial in the Cook Islands EEZ will benefit from the learnings gained during the CCZ trial. CIIC-SR will ensure that any effects that might be specific to the Cook-Islands marine ecosystems are taken into consideration and addressed in the prior-EIA/EIS.

Lessons learned from the Patania II trial will be dedicated to improving the final design of the Patania III, the prototype commercial-scale seafloor nodule collector, including enhancing environmental performance. The commercial scale collector is expected to operate very similarly to Patania II, incorporating progressive adjustments and improvements, whilst operating according to the same design-principles.

[1] GSR is collaborating with the European research project 'MiningImpact2'. Scientists from 28 European institutes will join efforts with BGR (German CCZ Contractor), to independently monitor the trials planned for 2021 to help understand the environmental effects of collecting mineral resources from the seafloor. MiningImpact2 is a project of the Joint Programming Initiative Healthy and Productive Seas and Oceans (JPIO).

## 3.3 Why methodology is appropriate

For the past 40 years, a considerable amount of research has been undertaken, focusing on the environmental effects of polymetallic nodule mining on the deep seafloor. A summary of important studies can be found in **Appendix B.** To date, the main geographical focus is on the CCZ area of the Pacific and a few studies have been conducted in the Peru Basin.

The common trend highlighted is the complexity with conducting research at abyssal depths.
The ISA has hosted workshops for Contractors and experts with the aim of standardizing methodologies (see, for example, ISA workshop proceedings documents [ISA 1999, 2002] and technical studies [ISA 2011, 2014]) and has developed *Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration of marine minerals in the Area* (ISBA/25/LTC/6/Rev.1). The methodology described above and in **Appendix A** aligns with these recommendations which have been developed through a transparent process and multi-stakeholder approach, including scientific experts, regulators, Member States, Sponsoring States, Contractors, NGOs, among others.

## 3.4 How proposed work relates to recovery operations and understanding of the ecological setting and how it is going to advance the knowledge and lead to ultimate sustainable recovery operations

The exploration phase is crucial to develop a socially and environmentally acceptable mineral recovery operation. As explained earlier, understanding the receiving environment is necessary to (1) understand the impacts & effects due to the extracting activity, (2) reduce the remaining uncertainties related to polymetallic nodule mining, and (3) develop tailored environmental management plans for future seafloor polymetallic nodule mining to minimise and mitigate environmental effects to the extent possible.

Indeed, the achievement of high environmental standards is integral to the CIIC-SR approach.
Detailed baseline studies will be conducted at the proposed mineral extraction site (once it has been identified through exploration work) and at other sites in order to establish a reference area, or areas as needed, away from the impact of mining. The purpose of this reference area is two-fold:

1. To study natural variability away from mining
2. To ensure the protection of habitats and biota representative of what will be lost or impacted as a result of mining.

CIIC-SR intends to take a transparent, inclusive and multi-stakeholder approach to project planning. CIIC-SR will specifically partner with the scientific community to review and develop environmental plans, conduct the baseline studies, progress the environmental impact assessment (EIA) culminating in an environmental impact statement (EIS), including developing ways to mitigate and minimize impacts. Collaborating scientists will be free to publish their findings, ensuring CIIC-SR is transparent and also contributes to the global knowledge of ocean processes. Partnering with scientific experts helps to ensure the science is done well and that any project or regulatory decisions are made based on the best available scientific evidence.

Members of CIIC-SR have a history of collaboration with world-leading scientific institutes and projects, such as:

- **Marine Biology Research Group (MBRG) of Ghent University** have been involved with GSR's CCZ project since the inception of its exploration program, to ensure that internationally renowned expertise is directly available to assist with the development and

implementation of the biological oceanography baseline program. Since the 1970s, MBRG has researched the marine environment and has specialized mainly in the ecology of the seafloor, a field also known as marine benthic ecology. MBRG has already shown its interest in conducting scientific research in the EEZ of the Cook Islands (see Letter of Intent attached in the section 10 of the present Exploration Application).

- **The oceanographer Jon Wood, from Ocean Data Technologies Inc. (ODT) (Hyannis, MA, USA**) in involved the GSR CCZ Project's oceanographic data acquisition and brings much knowledge and extensive expertise and experience.
- **Professor Thomas Peacock, a physical oceanographer and environmental fluid dynamics expert from the independent Massachusetts Institute of Technology (MIT), Cambridge, MA, USA,** is leading the characterization of the sediment plume generated by deep sea nodule harvesting. MIT has already shown its interest in conducting scientific research in the EEZ of the Cook Islands (see Letter of Intent attached in the section 10 of the present Exploration Application).
- As mentioned above, GSR has agreed that a consortium of independent scientists[2] will monitor the upcoming Patania II trial, with a key aim of reducing existing knowledge gaps and uncertainties surrounding environmental effects. Knowledge gained will be incorporated into the next phase of engineering design.
- GSR is partnering with the scientific community to develop an EIA Scoping Report for its seafloor polymetallic nodule project in the CCZ. This draft 300+ page document provides the results of the scoping process undertaken. It presents an outline description of GSR's CCZ project, the environmental and social setting for the project, presents the proposed key issues for the EIA (based on Environmental Risk Assessment), and describes the proposed approach to the EIA, including further data collection, assessment methods and assessment criteria. To date, over 40 relevant international scientific experts have provided input to the Scoping Report, which is due for completion in Q1 2021.

CIIC-SR is eager to include scientists from the Cook Islands and the Pacific Islands. CIIC-SR is indeed interested in exploring with the Cook Islands ways to maximize the involvement of Cook Islanders in environmental work, including training and capacity building initiatives in the field of marine science and/or other relevant areas of interest.

[2] GSR is collaborating with the European research project 'MiningImpact2'. Scientists from 28 European institutes will join efforts with BGR (German CCZ Contractor), to independently monitor the trials planned for 2021 to help understand the environmental effects of collecting mineral resources from the seafloor. MiningImpact2 is a project of the Joint Programming Initiative Healthy and Productive Seas and Oceans (JPIO).

# References

National environment service of the Cook Islands. 2003. Environment Act 2003.

Seabed Minerals Authority of the Cook Islands, 2020. Seabed Mineral (Exploration) Regulations 2020

ISA. 2020. Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in the Area (ISBA/25/LTC/6 Rev.1).

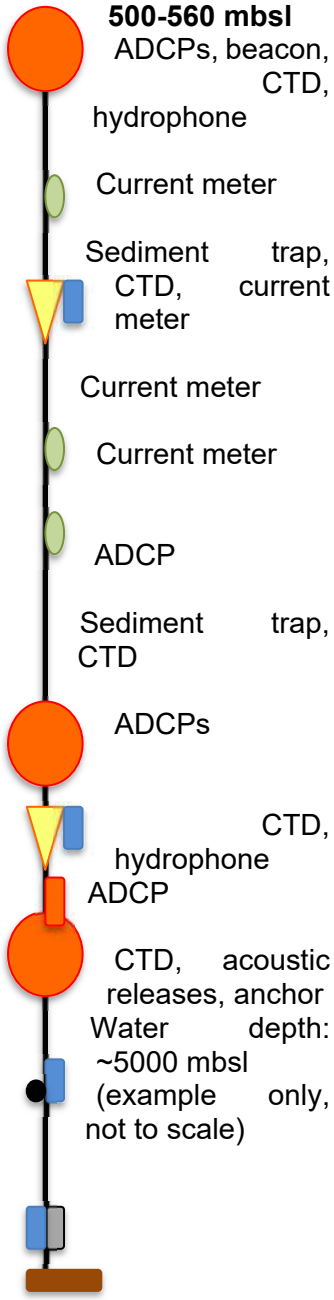
ISA (International Seabed Authority). 1999. Deep-seabed polymetallic nodule exploration: development of environmental guidelines. Proceedings of the International Seabed Authority's Workshop held in Sanya, Peoples Republic of China, 1–5 June 1998.

ISA. 2002. Standardization of Environmental Data and Information: Development of Guidelines; Proceedings of the International Seabed Authority's Workshop, Kingston, Jamaica, June 25–29, 2001. Kingston Jamaica: Office of Resources and Environmental Monitoring, International Seabed Authority (ISA/02/02).

ISA. 2011. Marine Benthic Nematode Molecular Protocol Handbook. Kingston Jamaica: International Seabed Authority (ISA Technical Study No. 7).

ISA. 2014. Deep sea macrofauna of the Clarion-Clipperton Zone. Kingston Jamaica: International Seabed Authority (ISA Technical Study No. 13).

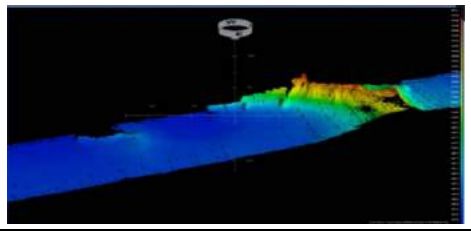
# Appendix A: List of environmental baseline studies and approaches to complete them. *(Images: Google Images)*

<table>
<tr><th colspan="3">Study Area: Physical Oceanography (Long-term Studies)</th></tr>
<tr><td rowspan="8"> 
</td><td>Platform</td><td>Multiple moorings installed on the seafloor</td></tr>
<tr><td>Study Objective</td><td>To understand the currents around the extraction site over a 12 to 36 month period (depending on the mooring). Study enables modelling the extent and duration of plumes that may be formed during full-scale operations.</td></tr>
<tr><td>Technique Description</td><td>Moorings will be anchored to the seafloor and will include instrumentation such as single point current meters, acoustic doppler current profilers (ADCPs), sediment traps, CTDs, transmissometers, and other instruments, along with buoyancy devices. Moorings will be of multiple lengths and most will focus on bottom-water currents, with at least one envisaged to cover almost the entire water column (example shown). Moorings will be retrieved on a ~6 to 12 monthly basis for data download, equipment maintenance and mooring reinstallation. Following data acquisition, hydrodynamic modelling of plume extent and duration will be performed.</td></tr>
<tr><td>Project Stage</td><td>EIA</td></tr>
<tr><td>General Comments</td><td>Moorings are usually anchored using scrap metal or cement blocks. The moorings will be affixed to the anchor with dual acoustic releases, which are triggered from the ship using a “Deck Box” when equipment retrieval is necessary.</td></tr>
<tr><td>Area Disturbed</td><td>Small, corresponds to size of the anchor which is typically less than 2 m x 2 m.</td></tr>
<tr><td>Environmental impact[3]</td><td>Very low. Note that the depth of the shallowest instrument will need to be determined in consultation with the Cook Islands government and local fisheries to ensure there is no chance of entanglement by fishing nets or lines.</td></tr>
<tr><td>Technique used in Marine Scientific Research (MSR)</td><td>Yes. These are standard techniques used by MSR groups and environmental agencies.</td></tr>
</table>

[3] Environmental impact beyond standard vessel operations.

| Study Area: Physical Oceanography (Opportunistic Current Profiles) | |
|---|---|
|   | |
| **Platform** | **L-ADCP (Lowered Acoustic Doppler Current Profiler)** |
| **Study Objective** | To understand the currents above and around the extraction site at a single point in time – will help to 'calibrate' the long-term moorings over a larger area of study. Study enables an estimate of the extent and duration of plumes that may be formed during full-scale operations. |
| **Technique Description** | A Lowered-Acoustic Doppler Current Profiler (ADCP) is tethered to the ship by a long cable and is used to obtain water column current (speed and direction) profiles in a simple vertical down and up cast. |
| **Project Stage** | EIA |
| **General Comments** | Data needs to be carefully processed following collection to remove interferences from ship movements and deployment method (i.e. the movement associated with the instrumentation traveling through the water column). |
| **Area Disturbed** | Nil. No physical contact made with the seafloor. |
| **Environmental impact[4]** | None. No physical contact made with the seafloor. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[4] Environmental impact beyond standard vessel operations.

| Study Area: Geology (High Resolution Bathymetry) | |
|---|---|
|   | |
| **Platform** | **Deep Tow / AUV** |
| **Study Objective** | To produce Geographic Information System regional maps with high resolution bathymetry showing major geological and geomorphological features to assess the heterogeneity of the environment. These maps will be produced at a scale appropriate to habitat variability. This information will also assist with the placement of study locations and mooring installations. |
| **Technique Description** | The Deep Tow method employs an underwater sled that is tethered to the ship by a long (fibre-optic) cable. The sled is towed several meters above the seafloor and can be up to 5000 m behind the vessel.<br>A typical deep-tow method uses two side-mounted sonars to map the seafloor on each side of the instrument. The sonars emit low power[5] sound waves, which are reflected off the seafloor and recorded by receivers on the sidescan instrument. <<just side scan or MBES too?>> |
| **Project Stage** | Early Exploration |
| **General Comments** | Deep Tow: sled can remain in the water for up to 2 days at a time. A typical survey area may take several weeks to complete. |
| **Area Disturbed** | Nil. No physical contact made with the seafloor. |
| **Environmental impact[6]** | Negligible. No physical contact made with the seafloor. Sound levels not high enough to cause physical damage to marine animals. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[5] Power and frequency levels dependent on specific technique used.

[6] Environmental impact beyond standard vessel operations.

| Study Area: Geology (Heavy Metals and Trace Elements) | |
|---|---|
|    | |
| **Platform** | **Multiple Corers or Mega Corers** |
| **Study Objective** | To collect information on the potential for heavy metal and trace element release during full-scale mineral extraction operations, and their concentrations. |
| **Technique Description** | A multi corer is a bottom sampling tool used for sampling in chemical, geo-chemical and biological applications. The coring head is hydraulically damped to ensure undisturbed samples. It is deployed from a research vessel with a deep-sea wire. The design of the system allows for multiple cores to be retrieved from a single deployment/retrieval cycle, increasing the chances of successful core retrieval in areas of difficult seabed terrain (i.e. hard bottom, seamounts, and undulating bathymetry).<br><br>Cores are brought up to surface, sectioned and preserved following best practice technique. |
| **Project Stage** | EIA |
| **General Comments** | Multi corers generally have between four and twelve individual corers that will separately penetrate the seafloor once contact is made. Multi corers can be outfitted with additional instrumentation such as altimeters, CTDs, and penetrometers.<br>Casts are usually completed within several hours. |
| **Area Disturbed** | Varies depending on how many corers, but the diameter of the base of a mega corer (twelve core tubes) is ~ 2.8 m. |
| **Environmental impact[7]** | Very small, restricted to area where sample is taken. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[7] Environmental impact beyond standard vessel operations.

| Study Area: Geology (Heavy Metals and Trace Elements) | |
|---|---|
|     | |
| **Platform** | **Box Corers** |
| **Study Objective** | To collect information on the potential for heavy metal and trace element release during full-scale mineral extraction operations, and their concentrations. |
| **Technique Description** | Bottom sampling tool designed for minimum disturbance of sediment and overlying features. It is deployed from a research vessel with a deep-sea wire. Upon contact with seafloor, the outer shovel is released and the sample taken. |
| **Project Stage** | Early Exploration, EIA |
| **General Comments** | Box cores typically have an area of approximately 2500 $cm^2$. Retrieval and deployment time depends on winch capabilities and water depth, however, total time generally does not take more than several hours at depths of ~5000 m. Box corers can be outfitted with additional instrumentation such as altimeters, CTDs, and penetrometers. |
| **Area Disturbed** | Maximum area of 0.75 m x 0.75 m with 0.65 m depth penetration per sample if largest known box corer is utilized. |
| **Environmental impact**[8] | Very Low. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

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[8] Environmental impact beyond standard vessel operations.

| Study Area: Chemical Oceanography (Water Column Chemistry) | |
|---|---|
|    | |
| **Platform** | **Water Sampling Carousel / Rosette, CTD** |
| **Study Objective** | To understand baseline water quality conditions in the water column overlying the site targeted for nodule extraction, capturing at least two summer/winter seasons (seasonal studies). |
| **Technique Description** | Water sampling bottles (or "Niskin" bottles) are arranged in a rosette formation around other sensors (e.g. CTD). The instrument package is tethered to the ship by a long cable and is used to obtain water column samples and profiles in a simple vertical down and up cast. Each bottle can be triggered individually to enable sampling from various locations.<br><br>A CTD, which is commonly attached to the water sampling carousel, provides profiles of chemical and physical parameters through the entire water column by detecting its conductivity and temperature (which in turn relates to concentration of salt and other inorganic compounds in seawater). By analyzing these parameters, scientists can make inferences about the occurrence of certain biological processes. |
| **Project Stage** | EIA |
| **General Comments** | Casts are usually completed within several hours. |
| **Area Disturbed** | None. No physical contact made with the seafloor. |
| **Environmental impact**[9] | Negligible. No physical contact made with the seafloor. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups to characterize water chemistry of the deep sea. |

[9] Environmental impact beyond standard vessel operations.

| Study Area: Chemical Oceanography (Sediment Pore Water) | |
|---|---|
|    | |
| **Platform** | **Multiple Corers or Mega Corers** |
| **Study Objective** | To understand baseline water chemistry conditions in sediment pore waters. To collect information on metal and other elements that may be released during the nodule extraction process. |
| **Technique Description** | A multi corer is a bottom sampling tool used for sampling in chemical, geo-chemical and biological applications. The coring head is hydraulically damped to ensure undisturbed samples. It is deployed from a research vessel with a deep-sea wire. The design of the system allows for multiple cores to be retrieved from a single deployment/retrieval cycle, increasing the chances of successful core retrieval in areas of difficult seabed terrain (i.e. hard bottom, seamounts, and undulating bathymetry).<br><br>Cores are brought up to surface, sectioned and preserved following best practice technique. |
| **Project Stage** | EIA |
| **General Comments** | Multi corers generally have between four and twelve individual corers that will separately penetrate the seafloor once contact is made. Multi corers can be outfitted with additional instrumentation such as altimeters, CTDs, and penetrometers.<br>Casts are usually completed within several hours. |
| **Area Disturbed** | Varies depending on how many corers, but the diameter of the base of a mega corer (twelve core tubes) is ~ 2.8 m. |
| **Environmental impact[10]** | Very small, restricted to area where sample is taken. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

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[10] Environmental impact beyond standard vessel operations.

| Study Area: Sediment Properties | |
|---|---|
|     | |
| **Platform** | **Box Corers, Multiple Corers** |
| **Study Objective** | To study baseline sediment conditions and predict the behavior of mineral extraction on sediment composition. To determine the basic properties of the sediment, including measurements of soil mechanics and composition to adequately characterize the surficial sediment deposits which are the potential source of deep-water plume. |
| **Technique Description** | See *Heavy Metals and Trace Elements* study for Box coring techniques.<br>See *Heavy Metals and Trace Elements* and *Sediment Pore Water* studies for Multiple corer techniques.<br>Sediment to be sampled taking into account the variability of the seabed. |
| **Project Stage** | EIA |
| **General Comments** | See Box corer methods.<br>See Multi corer methods. |
| **Area Disturbed** | Small, area equivalent to the size of the box corer (typically 0.25 to 0.56 $m^2$ per deployment) or multi corer (base diameter ~2.8m). |
| **Environmental impact**[11] | Very small, restricted to area where sample is taken. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

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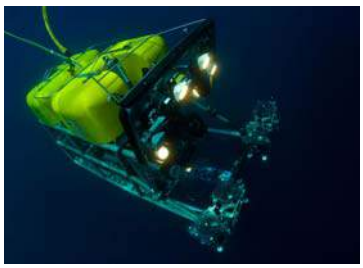
[11] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities - Meiofauna [32-250 micron], Microfauna [<32 micron] | |
|---|---|
|    | |
| **Platform** | **Multiple Corer** |
| **Study Objective** | To understand baseline biological conditions within the seafloor sediments and predict the impact of mineral extraction on biological communities. Samples of fauna to be representative of variability of habitats, bottom topography, depth, seabed and sediment characteristics, abundance and mineral resource being targeted. |
| **Technique Description** | See *Sediment Pore Water* study for a description of the sampling technique. Meiofauna: One complete core to be dedicated to metazoan meiofauna (sieved through a 32 micron mesh), a second core for molecular meiofauna analysis with the top 0-5 cm processed. A separate core should be provided for foraminiferal meiofauna, sliced into 1-cm thick layers down to 5 cm depth. Microfauna: Microbial metabolic activity should be determined using adenosine triphosphate or other standard assay. In soft sediment, vertical profiles should be obtained with suggested intervals for sampling as follows: 0-0.5, 0.5-1.0, 1-2, 2-3, 3-4, 4-5 cm. Samples should then be preserved as appropriate. |
| **Project Stage** | EIA |
| **General Comments** | Multi corers generally have between four and twelve individual corers that will separately penetrate the seafloor once contact is made. Multi corers can be outfitted with additional instrumentation such as altimeters, CTDs, and penetrometers.<br>Casts are usually completed within several hours. |
| **Area Disturbed** | Varies depending on how many corers, but the diameter of the base of a mega corer (twelve core tubes) is ~ 2.8 m |
| **Environmental impact**[12] | Very small, restricted to area where sample is taken. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[12] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities - Macrofauna [250 micron], Nodule Fauna | |
|---|---|
|    | |
| **Platform** | **Box Corer** |
| **Study Objective** | To understand baseline biological conditions within the seafloor sediments an on hard substrates and predict the impact of mineral extraction on biological communities. Samples of fauna to be representative of variability of habitats, bottom topography, depth, seabed and sediment characteristics, abundance and mineral resource being targeted. |
| **Technique Description** | See *Heavy Metals and Trace Elements* study for a description of the sampling technique. Macrofauna: information obtained on abundance, species structure, biomass and diversity. Vertical profiles with a suitable depth distribution (i.e. 0-1 , 1-5, 5-10 cm) should be obtained. Where possible, whole box core samples should be used and should not be sub-cored or divided. Nodule Fauna: information obtained on abundance, biomass and species structure should be determined from nodules taken from the top of the box corers. |
| **Project Stage** | EIA |
| **General Comments** | Box cores typically have an area of approximately 0.25 $m^2$. Retrieval and deployment time depends on winch capabilities and water depth, however, total time generally does not take more than several hours at depths of ~5000 m. Box corers can be outfitted with additional instrumentation such as altimeters, CTDs, and penetrometers. |
| **Area Disturbed** | Maximum area of 0.75 m x 0.75 m with 0.65 m depth penetration per sample if largest known box corer is utilized. Note: it is recommended that a 0.25 $m^2$ box core be used to allow comparisons with CCZ macrofauna work. |
| **Environmental impact**[13] | Very Low. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[13] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities – Fauna Sampling by ROV (Megafauna [>2 cm]) [Draft] | |
|---|---|
|    | |
| **Platform** | **ROV** |
| **Study Objective** | To understand baseline biological conditions of visible fauna (megafauna - 2 cm and bigger) at the seafloor and predict the impact of mineral extraction on biological communities. Samples of fauna to be representative of variability of habitats, bottom topography, depth, seabed and sediment characteristics, abundance and mineral resource being targeted. |
| **Technique Description** | Select target species , combined taxonomy and genetic studies (study to be confirmed – possibly not practical due to low numbers of animals expected in nodule provinces). |
| **Project Stage** | EIA |
| **General Comments** | The ROV is lowered to the seafloor and surveys are completed and discrete samples can be taken. The ROV is powered by electricity and is hydraulically controlled from the support ship using an umbilical.<br>ROV is typically underwater for 6 to 12 hours at a time, depending on whether or not samples need to be recovered to surface. |
| **Area Disturbed** | None – very little contact with seafloor, if any |
| **Environmental impact[14]** | Very low, confined to limited removal of individual animals. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

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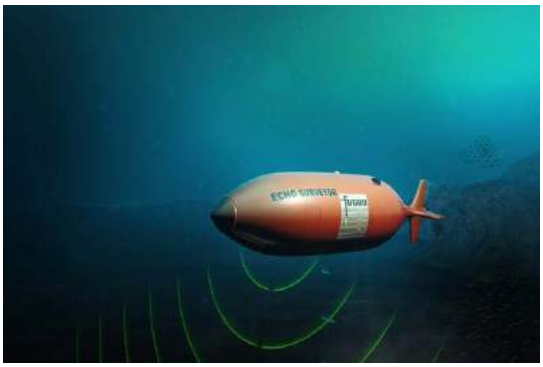
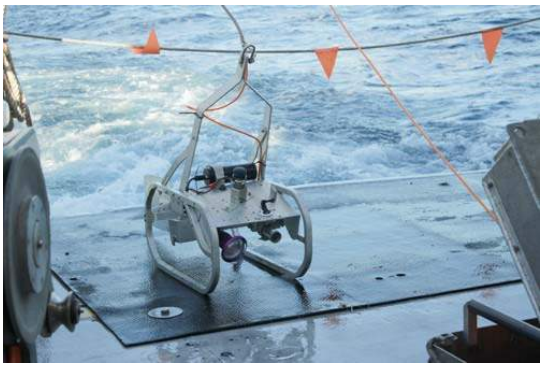
[14] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities – Photo/video Transects (Seafloor and Near-Bottom Megafauna) | |
|---|---|
|   | |
| **Platform** | **ROV/AUV/Towed Camera System (TBC)** |
| **Study Objective** | To understand baseline biological conditions at and immediately above the seafloor and predict the impact of mineral extraction on biological communities. |
| **Technique Description** | Follow pre-established transect lines and record observed biota. Assess density and biodiversity of megafauna (animals >2 cm). |
| **Project Stage** | EIA |
| **General Comments** | See ROV, AUV, and Towed methods |
| **Area Disturbed** | None – no contact with seafloor |
| **Environmental impact**[15] | None – no contact with seafloor (see ROV) |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

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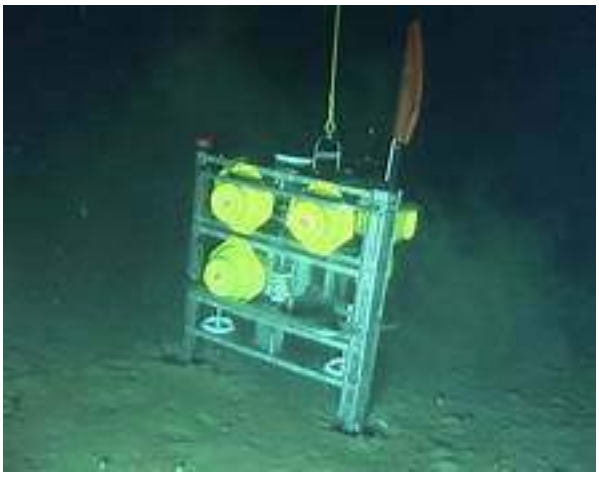
[15] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities (Demersal Scavengers) | |
|---|---|
|  | |
| **Platform** | **Moored Time Lapse Camera(s), Baited Time Lapse Cameras** |
| **Study Objective** | To understand baseline biological conditions at and immediately above the seafloor and predict the impact of mineral extraction on biological communities. |
| **Technique Description** | Recording device is set up within suitable distance of time lapse camera (TLC) anchored bait to observe behaviour of demersal scavengers. |
| **Project Stage** | EIA |
| **General Comments** | Likely to be deployed during ROV operations |
| **Area Disturbed** | Minimal, confined to area where TLC anchor has contact with seafloor, estimated to be less than 2 m x 2 m. |
| **Environmental impact**[16] | Negligible. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[16] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities (Pelagic Communities) | |
|---|---|
|    | |
| **Platform** | **Plankton nets, fishing gear, etc.** |
| **Study Objective** | To assess the pelagic communities in the water column and near-bottom (in the benthic boundary layer) that may be impacted by operations (e.g. the operational and discharge plumes) and to assess their baseline metal concentrations. |
| **Technique Description** | Pelagic monitoring moorings will comprise of a buoyed camera unit to monitor a separate baited/weighted line suspended in the water column |
| **Project Stage** | EIA |
| **General Comments** | Pelagic monitoring rigs will be deployed opportunistically<br><br>See Plankton net methods |
| **Area Disturbed** | Nil if suspended in water column. |
| **Environmental impact[17]** | Negligible. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

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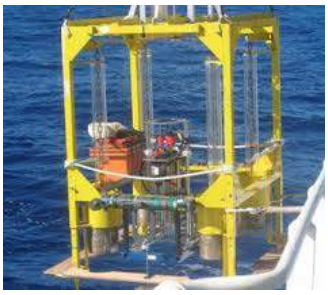
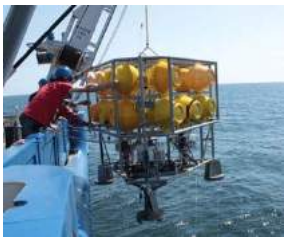
[17] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities – Marine Animal Observations | |
|---|---|
|  | |
| **Platform** | Ship |
| **Study Objective** | To record sightings of marine mammals, other near-surface large animals (such as turtles and fish schools) and bird aggregations, identifying the relevant species and behaviours where possible. Details to be recorded in transit to and from areas of exploration and on passage between stations. Temporal variability should be assessed. |
| **Technique Description** | Opportunistic sightings. Use binoculars where possible. Marine Animal Observation Log filled out on the bridge of the ship. |
| **Project Stage** | EIA |
| **General Comments** | All crew of research vessel will be instructed to notify onboard environmental contractor of all sightings of marine animals while at sea. Sightings will properly be recorded by qualified personnel. |
| **Area Disturbed** | None. |
| **Environmental impact**[18] | None. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

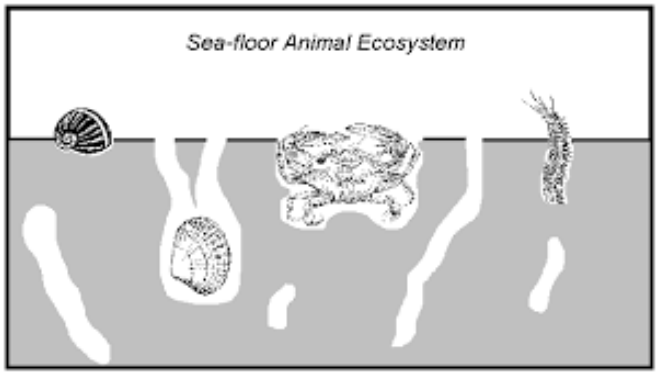
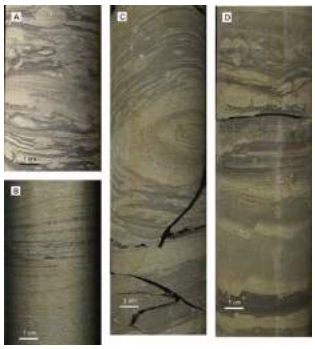
[18] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities (Connectivity) | |
|---|---|
|    | |
| **Platform** | Ship. |
| **Study Objective** | To assess the regional distribution of species and genetic connectivity of key species. |
| **Technique Description** | Samples taken as per methods described above (e.g. ROV, box corer, multiple corer) and specimens are processed, preserved and analysed appropriately. |
| **Project Stage** | EIA |
| **General Comments** | See above for the relevant technique. |
| **Area Disturbed** | See above for the relevant technique. |
| **Environmental impact**[19] | See above for the relevant technique. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[19] Environmental impact beyond standard vessel operations.

| Study Area: Biological Communities (Oxygen Consumption Experiments) | |
|---|---|
|    | |
| **Platform** | **Lander** |
| **Study Objective** | To understand baseline biological activity within the seafloor sediments and predict the impact of mineral extraction on biological communities. |
| **Technique Description** | Landers are used to measure the sediment-water exchange of nutrients by placing a chamber over the sediment and taking water samples with syringes from the chambers at fixed moments in time. The oxygen concentrations in the chambers are also measured. This gives us an idea of the uptake of oxygen by the sediment. We can compare this measured oxygen uptake to that calculated from profiles of oxygen measured in sediment cores. |
| **Project Stage** | EIA |
| **General Comments** | N/A |
| **Area Disturbed** | Small – equivalent to size of lander (~2 m x 2 m) |
| **Environmental impact**[20] | Negligible. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

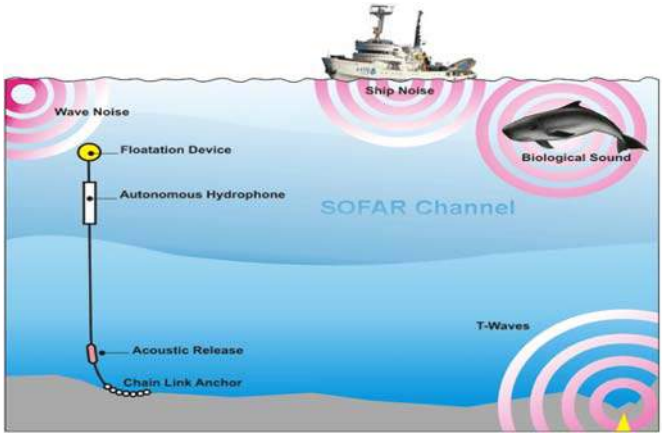
[20] Environmental impact beyond standard vessel operations.

| Study Area: Bioturbation | |
|---|---|
|  |  |
| **Platform** | **Multiple Corer** |
| **Study Objective** | To gather data on the mixing of sediments by organisms and to predict the impact of extractive activities on biological communities. |
| **Technique Description** | See multiple corer methods. Rates of bioturbation (i.e. the mixing of sediments by organisms) must be measured to analyse the importance of biological activity prior to a mining disturbance and can be evaluated from profiles of excess Pb-210 activity in the cores. Excess Pb-210 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). |
| **Project Stage** | EIA |
| **General Comments** | |
| **Area Disturbed** | None – no contact with seafloor. |
| **Environmental impact**[21] | Negligible. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[21] Environmental impact beyond standard vessel operations.

| Study Area: Fluxes to the Sediment (Sedimentation) | |
|---|---|
|   | |
| **Platform** | **Moored Time Lapse Sediment Traps** |
| **Study Objective** | To gather time series data on the flux and composition of materials from the upper water column to the deep sea. To understand baseline sedimentation rates and to evaluate the effects of mineral extraction activities (especially plumes) on these rates. |
| **Technique Description** | It is currently envisaged that time lapse sediment traps will be incorporated into the moorings used for physical oceanography studies (see above), or as stand-alone moorings. Measurements will be focused near the seafloor. Traps will be in place for a minimum of 12 months and one sample collected per month to obtain seasonal data. Besides weight/volume, the material collected in the traps will also be analysed to determine nutrient and trace element transport to deep sea environments. |
| **Project Stage** | EIA |
| **General Comments** | In addition to providing sedimentation data, analyzation of trace elements can help with understanding local upwelling phenomena. |
| **Area Disturbed** | None – no contact with seafloor. |
| **Environmental impact**[22] | Negligible. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR groups. |

[22] Environmental impact beyond standard vessel operations.

| Study Area: Noise | |
|---|---|
|  |  |
| **Platform** | **Moored Hydrophones** |
| **Study Objective** | To determine the baseline noise levels, for example from marine mammals and shipping, and estimate impact of mineral extraction activities. |
| **Technique Description** | It is currently envisaged that hydrophones will be incorporated into the moorings used for physical oceanography studies (see above), or as stand-alone moorings. |
| **Project Stage** | EIA |
| **General Comments** | Hydrophones for this application are not off the shelf. Some design development will likely be needed and may represent a collaboration opportunity. |
| **Area Disturbed** | Very little. Possibly the area of an anchor to keep it in place on seafloor (0.5-1 $m^2$) |
| **Environmental impact**[23] | Negligible. |
| **Technique used in Marine Scientific Research (MSR)** | Yes. These are standard techniques used by MSR and environmental agencies in shallower waters. |

[23] Environmental impact beyond standard vessel operations.

# Appendix VI-02: Key Environmental Impact Assessment Work for Nodule Provinces in the Deep Sea

| Study Name (location, year) | Entity | Key Focus Areas | Objectives/Findings |
|---|---|---|---|
| **DOMES (CCZ, 1970s)** | USA | Baseline studies, impact prediction | DOMES identified three key future EIA study areas:<br>• benthic community impacts due to nodule removal<br>• near-surface biota impacts due to plumes from discharge water (assumes surface discharge)<br>• benthic community impacts due to deposition of suspended sediments.<br>The study suggested test harvesting was needed to confirm predictions made. |
| **ECHO-1 (CCZ, 1983)** | USA | Revisited DOMES Site C post test mining in 1978 | Objective was to examine benthic recolonization using box core samples following small-scale test mining by OMA some five years earlier. No significant differences were found between macrofauna and meiofauna from mining tracks and a nearby control area. Dick and Foell (1985) [cited in Morgan et al. 1999] determined that the tests were inconclusive due in part to the techniques used, which had low positional accuracy. |
| **Acute Mortality Experiment (CCZ, late 1980s?)** | USA | Studied impacts of sedimentation on fauna | Known amounts of sediment were added to corers positioned on the seabed with the expectation to learn the amount of sedimentation required to smother or entomb benthic animals. This project experienced technical difficulties with core recovery from the sea floor. General conclusions were that there was little evidence of serious disturbance to macrofauna when subjected to burial <1 cm of sediment, while burial under 4 cm of sediment appeared to cause entombment of 25% to 50% of the macrofauna in six days. |
| **Quagmire II Expedition (CCZ, 1990)** | USA | Revisited DOMES Site C post test mining in 1978 | Examined benthic recolonization using precision sampling techniques (RUM-III vehicle) following small-scale test mining by OMA in 1978. Carried out a critical-dose experiment to determine the sensitivity of benthic fauna to sedimentation levels. The major cruise objectives were not achieved. |
| **DISCOL (Peru Basin, 1989 to 2015)** | Germany | Large-scale disturbance-recolonization | The work involved baseline data gathering, ploughing ~11 $km^2$ of the sea floor using a “plough-harrow” down to 10 |

| | | | |
|---|---|---|---|
| | | experiment (Peru Basin) | to 15 cm depth. ~20% of the area was affected by the plough harrow, ~70% was covered by various thicknesses of sediment, and ~10% remained unaffected. Following the disturbance, studies were conducted immediately after the impact, after six months, then at three and seven years to determine the rate of recolonization of the impacted areas. Due to the impact, the abundances of all fauna decreased significantly, then three years after the impact, densities of major faunal groups significantly exceeded what had been found during baseline studies, although diversity was lower. After seven years, the tracks remained clearly visible. The undisturbed areas remained more or less constant. For the megafauna, animals that depend on hard substrates (nodules) remained absent while more mobile animals dominated. A further offshore study at the DISCOL site was conducted in 2015, some 26 years post disturbance (as part of MIDAS and JPIO; jpio-miningimpact.geomar.de).<br>The researchers noted that while the faunal densities of most taxa recovered rather quickly and were almost back to pre-disturbance conditions after seven years, the diversity and community composition had not recovered 26 years after the impact. The study highlighted that to minimise large-scale impacts, there is a need for marine spatial planning, including the establishment of set-aside areas. It should be noted that no impact minimisation, mitigation, or restoration activities were trialled as part of the original disturbance experiment. |
| **Benthic Impact Experiment; BIE (CCZ, 1993)** | Collaboration between Russia, USA, and Japan | Studied the effects of sediment redeposition on benthic fauna | Work included baseline studies (including current meters, box cores and sediment traps), then blanketing an area with sediment by towing through an area 150 × 3,000 m in a NE–SW direction, resulting in the suspension of ~4,000 $m^3$ of sediment. Bulk of sediment travelled north and settled quickly as a sediment-laden fluid flow. Of the 71 macrofaunal families analysed, only two appeared to be impacted by sediment redeposition. Overall species diversity remained |

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| | | | unaffected by sediment redeposition. However, the resultant sediment thickness was not attainable due to wide dispersion causing no measurable significant accumulation outside the disturbance area. Therefore, no relationship between faunal succession and sediment was accomplished. |
| **Japan Deep-Sea Impact Experiment; JET (CCZ, 1993)** | Japan | Studied the effects of sediment redeposition on benthic fauna | Used the same device as BIE in a western CCZ location. Samples before and after disturbance were collected and then collected again after 1 year. Abundances and vertical distributions of meio- and microfauna were studied. Again, there was no quantification of the resedimentation thickness. The extended effects of disturbance on the abundances of each faunal component were different. Changes in abundance in total fauna were greatest in the upper layers of sediment. |
| **Interocean-metal Joint Organization Benthic Impact Experiment; IOM-BIE (CCZ,1995, 1997, 2000)** | IOM, COMRA (China) | Studied the effects of sediment redeposition on benthic fauna | IOM-BIE monitored ecosystem changes following a sediment disturbance. Immediately following the disturbance, intense feeding activity by megabenthos was observed, presumably due to additional availability of food sources. Meiobenthos abundance decreased and their vertical distribution was altered. During the 2000 campaign, the results collected indicated the abyssal meiobenthos in the control area had been affected by (assumed) natural processes. By 2000, abundances at the 10M site had reverted to control area levels. |
| **Indian Deepsea Experiment; INDEX (CIOB, 1997 to 2007)** | India | Studied the effects of sediment redeposition on benthic fauna (Central Indian Ocean Basin; CIOB) | INDEX utilized the Deep Sea Sediment Resuspension System (Brockett and Richards 1994) to resuspend >6,000 $m^3$ of sediment over a nine-day period. Monitoring over a decade showed that the CIOB has highly heterogeneous environmental conditions in terms of spatial variation. India reported at an ISA workshop held in 2010 that the monitoring of environmental conditions after the benthic disturbance experiment indicated the benthic conditions were steadily moving towards restoration and the effects of disturbance are waning with time. |
| **Kaplan Study (CCZ, 2002 to 2007)** | International; USA, UK, Japan, France | Baseline Studies (biological) | The Kaplan study was designed to study biodiversity, species ranges, and gene flow in the abyssal Pacific nodule province, with specific reference to |

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| | (JM Kaplan Fund and ISA funded) | | predicting and managing the impacts of deep seabed mining. The Kaplan study aimed to i) estimate, using, molecular methods and rigorous statistical techniques, the number of polychaete, nematode and foraminiferal species at three stations spaced at 1,500 km intervals across the Pacific nodule province; ii) evaluate species overlap and rates of gene flow; iii) communicate findings and make specific recommendations on minimizing the risks to biodiversity resulting from mining. Based on the data collection and analysis, the researchers recommended that the ISA establish a network of MPAs across the CCZ to safeguard biodiversity that could be affected by mining activities. This eventually led to the establishment of APEIs within the CCZ. |
| **EqPac (JGOFS EqPac) (CCZ, 1992)** | USA | Equatorial Pacific Process Study; Baseline studies | The EqPac process study was conducted along 140°W. Four process cruises took place, with a fifth benthic cruise and sediment trap legs adding to the overall study. The scientific objectives of this study were to determine the fluxes of carbon and related elements, and the processes controlling these fluxes between the Equatorial Pacific euphotic zone and the atmosphere and deep ocean. |
| **NIXO/NIXO 47 (CCZ, 2004)** | France | Studied long-term effects of physical disturbance made by a dredge (OMCO) in 1978 | This study compared surface sediments in and outside a dredge track. 26 years after the dredging event, the track was still visible. The physical and chemical properties of the disturbed sediment sampled in the track had not changed significantly over time and had not shown any recovery since the disturbance. On the other hand, the biological activity measured in the track with a respirometer did not differ from the unperturbed site, which suggests that the benthic fauna have completely recovered, as have nutrient fluxes at the water–sediment interface (Khripounoff et al. 2006). |
| **NaVaBa Program (CCZ, 1996 to present)** | China | Natural variability baseline studies | 10 cruises were conducted from 1998 to 2010, focusing on environmental baseline work for the COMRA contract area. Initial studies examined spatial variability/heterogeneity and functional relationships between fauna. |

| | | | |
|---|---|---|---|
| **MiningImpact 1 (CCZ, 2015-2017)** | Europe | Assess the long-term impacts of polymetallic nodule mining on the deep-sea environment | This campaign determined that:<br>• Nodule ecosystems support a highly diverse fauna of sessile and mobile species.<br>• Faunal communities & environmental parameters show a high variability even on a very local spatial scale.<br>• Benthic fauna communities differ significantly between seamounts and nodule habitats.<br>• Loss of seafloor integrity by nodule and sediment removal generally reduces population densities and ecosystem functions. Biogeochemical remineralization processes (see next page) and the productivity of the benthic community are both impacted by nodule removal.<br>• Disturbance impacts on nodule ecosystems last for many decades, affect numerous ecosystem compartments and functions |
| **Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) MiningImpact 2 (CCZ, 2018 to 2022)** | Europe | Environmental monitoring of the PATANIA II pre-prototype vehicle system trial | This programme will examine various environmental effects of seabed mining. A significant part of the programme will be devoted to a comprehensive monitoring programme around the industrial-like test of the PATANIA II pre-prototype vehicle system. The test will involve harvesting nodules from an area between 0.022 km² and 0.1 km² (depending on actual nodule abundance and in-situ nodule pickup and discharge efficiency) of the seabed in the GSR and the Federal Institute for Geosciences and Natural Resources (BGR, Germany) Contract Areas of the CCZ. MiningImpact 2 will collect independent scientific information on the environmental impacts of the test operation |

CCZ = Clarion-Clipperton Zone; DOMES = Deep Ocean Mining Environmental Study; EIA = Environmental Impact Assessment; OMA = Ocean Mining Associates ; BIE = Benthic Impact Experiment; IOM = Interoceanmetal Joint Organization; MPA = Marine Protected Area; COMRA = China Ocean Mineral Resources Research and Development Association; CIOB = Central Indian Ocean Basin; OMCO = Ocean Minerals Company.

# References

Brockett T, Richards CZ. 1994. Deep sea mining simulator for environmental impact studies. Sea technology 35(8):77–82.

Khripounoff A, Caprais J-C, Crassous P, l'Etoubleu J. 2006. Geochemical and biological recovery of the disturbed seafloor in polymetallic nodule fields of the Clipperton-Clarion Fracture Zone (CCFZ) at 5,000-m depth. Limnology and oceanography 51(5):2033–2041.

Morgan CL, Odunton NI, Jones AT. 1999. Synthesis of environmental impacts of deep seabed mining. Marine georesources and geotechnology 17:307–356.