# Preliminary Scientific Consideration of Selective Harvesting Methodology Proposed by Impossible Mining

## Contributors

This document is a summary of the issues and considerations discussed by scientists in relation to the concept of selective nodule harvesting, via two roundtable sessions held on 5 April 2022 and 3 May 2022. The sessions were facilitated by Renee Grogan, Chief Sustainability Officer of Impossible Mining.

Scientists involved in these preliminary studies, as well as other scientists with expertise in the field of benthic ecology and abyssal ecosystems, are encouraged to contact Renee Grogan (renee.grogan@impossiblemining.com) if they would like to be involved in further scoping and subsequent environmental studies related to the selective harvesting methodology proposed by Impossible Mining.

The scientists who contributed to the discussions summarised in this document are as follows:

- Michael Wright - ERIAS Group, Australia
- Elisabetta Menini - Duke University, USA
- Travis Washburn
- Rudy Helmons - Delft University of Technology / Norwegian University of Science and Technology, Norway
- Phil Weaver Geosed Ltd, UK
- Sandra Brooke - Florida State University, USA
- Patrick Collins - Queen's University Belfast, UK
- Erik Cordes - Temple University, USA
- Daniel Jones - National Oceanography Centre, UK
- Jon Copley - University of Southampton, UK

## Introduction

The definition of "serious harm", or "serious adverse impacts" has previously been proposed to be used, via impact assessment, as a bar from which to approve or deny applications for mining (e.g. Levin et. al. 2016, ISA 2019). Impossible mining is proposing to take an opposite approach to considering serious harm - to design its mining system and mining approach in a way that ensures "serious adverse impacts" and "serious harm" are engineered out, or avoided, from the design phase onwards. This includes both engineering around the autonomous underwater vehicle (AUV) technology, and also in relation to mine design and the methodology for avoiding/leaving a percentage of nodules untouched, in order to preserve ecosystem function at both the regional and local scale.

In developing its preliminary concept design for selective harvesting of nodules, Impossible Mining has considered the specific concerns of the scientists who signed the Seabed Mining Science Statement, as follows:

- Loss of species and populations as a result of destruction or elimination of habitat
- Production of large sediment plumes
- Interruption of ecological processes connecting midwater and benthic ecosystems
- Resuspension and release of sediment and toxins from dewatering discharge
- Noise pollution and impacts to marine species;
- Impacts on carbon sequestration dynamics and deep ocean carbon storage.

The preliminary concept design aims to address each of these concerns, and to incorporate engineering solutions to ensure each concern is mitigated to the satisfaction of independent expert scientists. These objectives have been clearly communicated to the scientists participating in these roundtable discussions.

## Purpose

The purpose of this roundtable discussion is for Impossible Mining to gather initial feedback from leading scientists in relation to studying the impacts and management of selective nodule harvesting - and to challenge the thinking in terms of what is needed for an environmental impact assessment for a harvesting method that has not been previously considered.

## Acknowledgement of Impacts

It was generally acknowledged that there will still be an impact with any kind of nodule harvesting and this is important to recognise. In this context, however, it was generally agreed that to leave behind a mosaic/patchwork of functioning, unimpacted nodule areas would be a vast improvement on other potential harvesting methods such as dredging, and should better enable the ecosystem to continue to function (noting that this hypothesis would obviously need to be tested, as would the efficacy of the selective harvesting system itself, in achieving the outcomes of the Seabed Mining Science Statement).

The notion of “qualitative preservation” was raised in this context, acknowledging that while there still will be an impact, and while preservation of all quantitative measures is not possible, the preservation of the sediment structure and infauna, as well as preservation of a connected nodule habitat is a positive approach.

Several scientists also noted that it is possible to measure ‘success’ at a broader scale, by removing some of the predicted impacts associated with other mining techniques, such as broad scale smothering, habitat and biodiversity removal, mid-column plumes and large noise footprints.

## Consideration of Fauna

It was acknowledged that the majority of the biomass in abyssal nodule fields is sediment infauna, and that there is divergent opinion on the extent to which nodule presence impacts on infauna biodiversity and abundance (e.g.Washburn et al., 2021 found that macrofaunal abundances were correlated with nodule abundance for some studies but not others, and that family richness was related to nodule abundance while species richness was not. For meiofauna, Pape et al., 2021, Haquier et al., 2019, and Miljutina et al., 2010 actually found decreases in nematode density with more nodules while Pape and Haquier found diversity was not really affected). In relation to nodule fauna, numerous studies have found correlations between nodule density and megafaunal diversity and abundance (e.g. Amon et. al. 2016, Simon-Lledo et. al. 2019, Stratman et. al. 2021). More investigation is clearly needed. In addition, more studies are required to determine if the sediment infauna does in any way rely on, or interact with, nodules (for shelter, etc.). If so, then replacement with artificial nodules and/or leaving areas with nodules behind, should be investigated (see below).

In addition to the consideration of infauna, avoiding impacts to nodule fauna and megafauna (such as avoiding coral tendrils) was highlighted as being important, and in particular to ensure the artificial intelligence developed by Impossible Mining uses as wide a dataset of available imagery of benthic fauna as possible.

One scientist noted that the patterns of nodules left behind, and the percentage left behind, may have effects that vary for different taxa, and as such it may be necessary to prioritise certain taxa in certain areas.

There was general consensus that the way nodules are left behind (i.e. the pattern/mosaic implemented) will be important for ecosystem function. Because many species are not highly motile, leaving undisturbed areas close by to disturbed areas, and in patterns that promote/facilitate connectivity, will be essential (e.g. strips, corridors, closely connected islands).

As discussed below, nodule density is also considered a key factor, and leaving behind representative habitat of different nodule densities may also be an important management strategy. As such, mapping of nodule densities across the entire contract area (with some consideration required for the methodology of assigning cutoff values for different density categories) is highly relevant to designing studies, in order to achieve the outcome of preserving a percentage of habitats in each nodule density category.

Other factors that may be relevant to the concept of habitat/community mapping include organic carbon flux, and topography, and there was some discussion (without consensus) about the importance of these factors in comparison to nodule density.

Several scientists also noted that the concept of selective harvesting and use of AUVs over a riser system may limit impacts (when compared to a traditional dredging and riser system) to fauna in the mid-column, and also potentially sound sensitive fauna.

## Consideration of Baseline Nodule Density

Several scientists discussed a potential natural analogue for percentage of nodules left behind after selective harvesting, which is the natural or baseline nodule density, indicating that there are some data relating nodule density to species density/diversity, but these studies are limited in their findings. A general trend mentioned is that the increase in biodiversity levels off at between 5-20% nodule density, but that there are species that prefer higher densities too, which would mean that ideally pockets of high density nodules would be left behind to account for different habitats.

It was acknowledged that a strong predictor of biodiversity does seem to be the baseline density of nodules, and therefore the mosaic of nodules left behind should be reflective of the baseline density (i.e. a certain percentage of different density categories should be left behind), at least as a starting point from which to study the effectiveness of such an approach.

The majority of scientists expressed support for the value of leaving areas untouched in a connected manner, and very close to impacted/harvested areas, provided it can be demonstrated that there are no impacts (i.e. sedimentation) on those areas.

It was also noted that there is clearly a level of natural influence over nodule density, otherwise the baseline would not be so naturally variable. As a result, using nodule density as an analogue will not be perfect, unless there is an understanding of why the density varies under natural conditions, but again, it was considered a reasonable starting point, from which adaptive management could be implemented following some early studies.

**Potential for Artificial Nodule Placement**

The potential value of leaving artificial nodules behind was raised several times, in the context that a key aspect in the structure of benthic ecosystems may be bottom shear stress affects caused by the nodules, which may mean that an artificial substrate would have beneficial impacts to both infauna as well as provide additional habitat for nodule fauna. It was noted that this is something that could be studied in the future (although clarity on the objective(s) of the studies are required), if the engineering required for depositing nodules (as opposed to collecting them) is able to be deployed on proof of concept vehicles. It was agreed that studying unimpacted areas, areas subjected to harvesting, and areas subjected to harvesting but that have had artificial nodules replaced, would be beneficial as part of an environmental impact assessment.

It was also noted that the 're-seeding' of artificial nodules, if conducted, would need to be done gently, so as not to create a sediment plume and cover the artificial nodules. Some scientists questioned the practicality of this approach, and also mentioned the potential for negative effects (e.g. geochemical changes associated with the construction material of the artificial nodules).

**Concept of "Significant Harm" or "Significant Impacts"**

In terms of turning a legal concept into a measurable concept, i.e. quantifying the significance of a harmful impact, one scientist mentioned the concept referred to by the Intergovernmental Panel on Climate Change (IPCC) of "envelopes of variability", and the extent to which these envelopes are likely to be exceeded. This was described as a potentially useful approach to determining significance of harm or adverse impacts, in the context of the natural variability of both variable baseline nodule density, and variability of oceanographic conditions due to climate change.

One scientist also mentioned that significance is a function of rarity and robustness, noting "it's about understanding - is it a dandelion (robust and widely distributed) or a vakita (sensitive and rare)?".

Several impacts were discussed that had the potential to be minor in nature, and the consideration of whether some impacts may be discounted as being "not significant" was also raised (without achieving consensus). For example, the way the bottom water interacts with the seabeds will impact on the benthic biology, however it was noted that this impact may be minor and/or difficult to measure. Similarly, there is likely to be a small impact associated with removing a compacting force (the nodule) on the sediment, which is also likely to be difficult to measure. Some discussion was had (again with no definitive conclusion) on whether the difficulty of measuring or observing such impacts, by definition, would place such impacts outside the realm of "serious or significant".

It was also noted that some of these questions are not likely to be answerable in the short term. There are proxy studies that could be conducted in a flume tank, for example, and while it is worth pursuing all questions intellectually, at some point a decision on significance of impacts will need to be made, in order to focus scientific efforts.

**Potential Management Strategies**

One scientist recommended undertaking photographic surveys and/or opto-acoustic imaging as a pre-survey to improve the accuracy of the Artificial Intelligence system, and to pre-program the percentage of nodules to be left behind relative to the baseline nodule densities. The opto-acoustic imaging would also potentially assist in identifying fauna (such as the long-tentacled anemones) that require a wider exclusion zone or area of surrounding nodules avoided, in order to prevent any damage to the anemone itself).

Several scientists expressed support for the idea of incorporating a variety of different patterns and percentages of nodules left behind in the first year of production, with a view to studying these variables and the resultant function of the ecosystem, and using this data to both adaptively manage the mining approach in subsequent years, and also to publish the results such that the learnings may be understood by other regulators for consideration in future mine project management strategies (or contractual requirements). It was also noted in the same vein that the possibility of obtaining much more localised and detailed scientific data by monitoring the impacts of selective harvesting is an additional value to the selective harvesting approach that should be considered by stakeholders.

It was suggested that high resolution imaging, combined with sediment coring targeted at habitat classifications, may be enough to monitor the success of management strategies in the short term, but not for the long term due to likely productivity events associated with climate change - e.g. ecosystem function. As such, long term instrumentation to measure productivity changes over time in both impact and regional areas would likely be required, to understand the macro-effects of climate change. Such an approach to localised and regional monitoring would support the "envelope of variability" concept for quantifying impacts mentioned above.

Finally, the concept of whether it is possible to implement effective protective measures without fully understanding the environmental values (i.e. whether it is possible to protect the sediment in-fauna while never fully understanding or describing it) was discussed. Several scientists expressed support for this approach, in the context that the precautionary approach may be more readily achieved with selective harvesting than dredging, given the opportunity to implement both management strategies and detailed scientific studies, at both the local and regional scale.

It was also acknowledged by several scientists (although consensus was not sought on this issue) that, given the potentially low impacts to infauna as a result of selective harvesting, box coring may be more appropriately applied to the concept of characterising communities and habitats (for the purposes of defining both impacts and areas to leave untouched, according to habitat and community type), rather than aiming to achieve a flat species accumulation curve for all infauna, which could require obtaining tens or even hundreds of samples in each area, based on current studies.

**Recommendations for Study**

While there was not necessarily consensus on each recommendation, the following recommendations were made in relation to the potential studies to be undertaken in relation to quantifying the impacts of selective harvesting, and the ability of the methodology to conserve ecosystem function and biodiversity at the local and regional scale:

- Opto-acoustic imaging to map and categorise baseline nodule density, and to identify large sessile fauna for avoidance;
- Visual survey for nodule fauna and megafauna;
- Coring survey for infauna, aligned with different nodule density categories, to attempt to quantify the baseline infauna diversity and biomass relative to the baseline nodule density (and/or other habitat and community categories, if applicable);
- Trial different percentages of nodules left behind, and different mosaic patterns, using baseline nodule density as an analogue, ensuring representation of each baseline density category in the strategy;
- Publish the results of these trials transparently, for both adaptive management purposes and to inform other stakeholders and regulators of the efficacy of the approach;
- Trial replacement of nodules with artificial substrates at a local scale (if feasible), and study the rate of recolonisation of hard substrates, and the effect of adding the hard substrate on sediment infauna (again, with a view to minimising the amount of coring due to the likely impact this will have on the fauna itself).

**Further Work**

Renee confirmed at the conclusion of the facilitated sessions that Impossible Mining will be progressing work in this area by:

- Designing and implementing environmental studies to be undertaken as part of both shallow-water and deep-water prototype testing, in line with the recommendations of the scientists; and
- Further engaging with scientists to scope the studies required to confirm whether its approach to selective harvesting of nodules adequately addresses each of the issues raised in the Seabed Mining Science Statement.