Appendix 4 – Initial Modelling Cut-offs for Suspended Sediment and Sediment Deposition

To:	Michael Clarke	**From:**	Michael Wright
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Subject:	Initial Modelling Cut-offs for Suspended Sediment and Sediment Deposition		

In late 2020 ERIAS was asked by DeepGreen to develop initial cut-offs for suspended sediment concentrations and sediment deposition for input to plume modelling.

No good, comprehensive data has been found that describes the sensitivity and resilience of deep sea marine organisms and biological processes to elevated suspended sediment concentrations or sedimentation rates/burial by sediment, however some literature does exist for shallower waters and some for deep sea.

A number of documents were reviewed during the development of these cut-offs. This document summarises documents reviewed and proposes initial cut-offs for consideration.

Documents Reviewed

Existing Environment

CSA Ocean Sciences. 2020. NORI-D Metocean and Seasonal Studies Environmental Program Clarion-Clipperton Fracture Zone, Pacific Ocean Preliminary Draft Campaign 4d Field Survey Report. Report prepared for Nauru Ocean Resources Inc. Report number CSA-NORI-FL-20-80908-3415-S205-REP-01-VER02. December

- Turbidity Sensors:
  - Near-seafloor turbidity values generally ranged from 0 – 0.4 NTU.
  - Turbidity at 2,000 m water depth was less than 0.1 NTU with a relatively persistent 0.025 NTU variation in turbidity throughout the Campaign 4a deployment period.
- Sediment Traps:
  - Total mass flux averaged between 0.023 to 0.026 $g/m^2/day$ at sediment traps located at water depths of 2,000 m and approximately 3,800 m (500 m above the seafloor).
  - Total mass flux at the sediment trap located at 25 m above the seafloor at Reference Mooring #1 averaged 0.016 $g/m^2/day$.

CSA Ocean Sciences. 2020. NORI-D Metocean and Seasonal Studies Environmental Program Clarion-Clipperton Fracture Zone, Pacific Ocean Final Campaign 4a Field Survey Report. Report prepared for Nauru Ocean Resources Inc. Report Number CSA-NORI-FL-20-80908-3415-05-REP-01-FIN. June

- Average total suspended solids (TSS) (± standard deviation) via Niskin bottle sampling through water column:

Water depth (m)	TSS (mg/L)
30	4.46 ± 0.84
100	3.03 ± 0.48
190	4.30 ± 1.90
300	4.00 ± 1.18
600	2.30 ± 0.98
950	2.74 ± 0.62
1,150	3.50 ± 1.37
1,250	1.95 ± 1.32
1,500	3.10 ± 1.31
1,750	3.84 ± 0.51
2,500	2.58 ± 1.71
3,500	3.06 ± 1.24
Bottom -200 m (~4,000 m)	3.48 ± 1.20
Bottom -150 m (~4,050 m)	1.50 ± 0.50
Bottom -100 m (~4,100 m)	3.00 ± 1.57
Bottom -50 m (~4,150 m)	3.08 ± 1.99

- Average TSS concentrations generally ranged from 1.5 to 4.5 mg/L with no noticeable trend throughout the water column.

Literature

Jones, D., Kaiser, S., Sweetman, A., Smith, C., Menot, L., Vink, A., Trueblood, D., Greinert, J., Billett, D., Martinez Arbizu, P., Radziejewska, T., Singh, R., Ingole, B., Stratmann, T., Simon-Lledo, E., Durden, J. and Clark, M. 2017. Biological responses to disturbance from simulated deep-sea polymetallic nodule mining. PLoS ONE 12(2): e0171750. doi:10.1371/journal.pone.0171750

- Evaluated changes in faunal densities and diversity of benthic communities measured in response to these 11 simulated or test nodule mining disturbances using meta-analysis techniques. Disturbance studies in CCZ include OMI (DOMES Site A), JET, OMCO, OMA (DOMES Site C), BIE-II, IOM BIE and studies outside the CCZ include DISCOL, DVI and INDEX.

- Many past studies have limitations that reduce their effectiveness in determining responses. Recommendations to improve future mining impact test studies are provided.

- A meta-analysis approach to examine the impacts of mining activities in the studies listed above was used. Meta-analysis focuses on the direction and magnitude (represented by effect size) of the consequences of a treatment (in this case simulated mining disturbance) across studies. Use of a standardised measure of "effect size", the standardised mean difference between control and disturbed samples allowed the studies to be compared directly.

- The impact of disturbance on benthic fauna was only assessed at seven sites (OMA, OMCO, DISCOL, BIE II, JET, IOM BIE and INDEX). At DISCOL, a plough-harrow was used to bury nodules and disturb the sediment. With the exception of OMA, these sites were generally extensively studied and multiple faunal and physical measurements were made.
- The sampling design was reasonably robust in most studies: a control (i.e., undisturbed site) was investigated at five sites (OMCO, DISCOL, BIE II, JET, INDEX) and conditions prior to disturbance were assessed at five sites (DISCOL, BIE II, JET, IOM BIE, INDEX). Five sites were investigated more than once after disturbance (DISCOL, BIE II, JET, IOM BIE, INDEX) providing a time series to assess recovery.
- It appears that there are several reported and unreported limitations in the data available. The influences of these factors (listed below) is not possible to remove and difficult to evaluate.:
  - One primary limitation is in the accuracy of location. Many of the studies, particularly the older ones, relied on imprecise navigation and relocating disturbed areas was not always reliable. As a result, disturbed areas may have been missed or samples might have been inadvertently misassigned.
  - In the DISCOL megafaunal studies, photographs were in parts taken selectively by an operator (rather than at a continuous interval). This would lead to a general positive bias in the results (i.e,. no photos without organisms). Furthermore, the bias may change throughout the survey towards more charismatic or less common individuals.
  - Due to naturally low fauna density, undersampling is an issue with the studies investigated. This problem is often hidden in density measurements if they are standardised to a larger area or volume. Low faunal numbers make detection of impacts difficult by reducing statistical power.
- Found impacts are often severe immediately after mining, with major negative changes in density and diversity of most groups occurring. However, in some cases, the mobile fauna and small-sized fauna experienced less negative impacts over the longer term.
- Almost all studies show some recovery in faunal density and diversity for meiofauna and mobile megafauna, often within one year. However, very few faunal groups return to baseline or control conditions after two decades.
- Analyses show considerable negative biological effects of seafloor nodule mining, even at the small scale of test mining experiments, although there is variation in sensitivity amongst organisms of different sizes and functional groups.
- No discussion of suspended sediment concentrations is provided in the document.
- Sedimentation rates are briefly mentioned as follows (but are not meaningfully linked to biological impacts/recovery such that they can be used to develop initial cut-offs):
  - Disturbance activities at DISCOL resulted in a depositional footprint up to 30 mm thick.

- The benthic disturbers used in the BIE-II, JET, IOM BIE and INDEX experiments was specifically designed to create a plume, with an increase in suspended particles of 300% (from 49 to 150 mg m^2/day) observed during disturbance. This value is an average from 10 sediment traps deployed at 7 m above the seabed around the disturber site, so it is likely that maximum sedimentation rates would be considerably higher (the highest observed was 244 mg suspended particles m^2/day). The effects of this plume were observed to a maximum distance of 250 m from the tracks, although the accuracy of these measurements is uncertain.

- No good discussion around the effect of sedimentation rates/depositional footprint thickness on biological processes is provided.

Shirayama, Y. Biological results of the JET project: an overview. In: CHUNG, J. S. & SHARMA, R., eds. Proceedings of the 3rd Ocean Mining Symposium, 1999 Goa, India. 185-190 and **Yamazaki, T. 2011. Impacts of up-coming deep-sea mining. In Brunn, S.D. ed Engineering Earth: the impacts of megaengineering projects. Springer Science and Business Media, pp.275–295** and **Fukushima, T. & Tsune, A. 2018. Environmental condition 17-18 years after the Benthic Impact Experiment. Proceedings of the Twenty-eighth (2018) International Ocean and Polar Engineering Conference. Sapporo, Japan, June 10-15, 2018.**

- These three documents discuss the JET benthic disturbance experiment that occurred in 1994 and post-disturbance monitoring that occurred at the following intervals:
  - JET2 in 1994 (1 month post-disturbance).
  - JET3 in 1995.
  - JET4 in 1996.
  - JET 5 over the period 2011/2012.
- Sites were sampled during the exploration program to investigate meiofauna and sediment geochemistry, properties of sediment deposition and ocean currents.
- Camera surveys from 1995 to 1996 post-disturbance monitoring period confirmed the presence of tow tracks on the seafloor and studies indicated a “heavy deposition area” (defined as deposition >0.26 mm in thickness) extending approximately 100 m either side of the tow tracks.
- The biological and geochemical analyses and results are summarised as follows:
  - Metazoan meiofauna communities were assessed at vertical core horizons (0 to 2.5, 2.5 to 5.0, 5.0 to 7.5, 7.5 to 10, 10 to 20, 20 to 30 mm) and divided into dominant groups: nematodes, crustaceans, other. Foraminifera were excluded from analysis.
  - Total organic carbon (TOC), total nitrogen (TN) and calcium carbonate ($CaCO_3$) were analysed in cores.
  - Analysis focussed on distance from disturbance area. Data from horizon 0 to 10 mm was used for analysis, with distance from impact area up to 300 m studied.

  - Profiles of TN, TOC and $CaCO_3$ in 2011/2012 samples were more similar to pre-disturbance values (1994) than the post-disturbance monitoring values (1994 to 1996). For these three parameters, there were significant correlations with distance from disturbance in the 1994 to 1996 monitoring and these were most pronounced in surface-most core layers. However, there were no significant correlations with distance from disturbance in the 2011/2012 data.
  - Abundance of meiofauna increased progressively during the post-disturbance monitoring from 1994 to 1996. In 2011/2012, meiofauna abundance was within the range recorded in the baseline and in some cases higher. Natural variability is evident in the data and mean meiofauna abundance was lower than in 1996.
  - Megafaunal deposit feeders were more susceptible than filter-feeders.
  - Effects of JET disturbance were detectable immediately post-disturbance and the horizon depths of detectable impact reduced to 25 mm layer only from 1994 to 1996.
  - In 2011/2012, some 17 to 18 years after the disturbance, no correlations between indicators of disturbance and distance from impact were observable at any layers.
  - Meiofauna abundance decreased immediately after the disturbance (1994) but no significant difference was detected one year later (1995) and two years post-disturbance, meiofauna abundance returned to pre-disturbance levels.
- Conclusions should be considered within the context of limited spatial and temporal coverage of monitoring.

Miljutina, D., Miljutina, M., Martínez Arbizua, P. and Galéron, J. 2011. Deep-sea nematode assemblage has not recovered 26 years after experimental mining of polymetallic nodules (Clarion-Clipperton Fracture Zone, Tropical Eastern Pacific). Deep Sea Research Part I: Oceanographic Research Papers August 2011, Volume 58, Issue 8, Pages 885-897. dx.doi.org/10.1016/j.dsr.2011.06.003

- Investigated nematode assemblages inhabiting the 26-year-old track created by experimental deep-sea mining of polymetallic nodules, and two adjacent, undisturbed sites, one with nodules and one without nodules.
- Water depth 5,000 m.
- The nematode assemblage had not returned its initial state 26 years after the experimental dredging: the total nematode density and biomass within the dredging track were significantly lower than outside the track; the biodiversity indices showed significantly lower nematode diversity within the track; and the structure of the nematode assemblage within the track differed significantly from those in the two undisturbed sites outside the track.
- However, there were no significant differences in the mean body volumes of adult nematodes and adult–juvenile ratios between the track and reference sites.
- Parameters such as the rate of sediment restoration (which depends on local hydrological conditions) and the degree and character of the disturbance appeared to be of

considerable importance for the recovery rate of the deep-sea nematode assemblages and their ability to recolonize disturbed areas. The rates of recolonization and recovery may vary widely in different deep-sea regions.

- Most of meiobenthic organisms (i.e., metazoan animals living on the surface or within sediments and passing through a sieve with 1 mm mesh size but retained by a 40 μm mesh) inhabit the upper 0 to 50 mm layer of deep-sea sediments.
- In the abyss, about 70–90% of the nematodes inhabit the upper 10 to 20 mm layer of sediments.

Fathom Pacific. 2016. Clarion-Clipperton Zone Polymetallic Nodules Project. Benthic Biology Literature Review and Recommendations for Classification. Report prepared for Tonga Offshore Mining Limited. Report number 612_1_v3. March

- A comprehensive literature review.
- The vast majority of benthic meiofaunal and macrofaunal infauna (those living within the sediment) diversity and abundance resides in the top 50 mm of the sediment, with a small fraction of macrofaunal community extending to 100 mm.
- Burrowing megafauna can extend deeper into sediments with burrows extending to perhaps 300 mm depth.
- Meiofauna are common in marine sediments, occurring in relatively high abundance. They are among the first biota to recolonise areas of disturbance.
- Nematodes occur in most habitats on earth and are the most common meiofauna encountered in deep-sea sediments. Nematodes have been recorded in sediment cores to a maximum depth of 40 to 100 mm, in contrast to the maximum depths recorded for polychaetes of 10 to 40 mm.
- Macrofauna numbers are consistently highest in the 0 to 50 mm layer and at a finer scale the 0 to 20 mm layer is most abundant.
- Foraminifera are also abundant and are frequently associated with nodule-attached fauna.
- Published documents referred to in Fathom Pacific (2016) for above information are:
  - Rex, M. and Etter, R. 2010. Deep-Sea Biodiversity: Pattern and Scale. Cambridge, Massachusetts, Harvard University Press.
  - Kaiser, S. 2014. The taxonomy and biogeography of macrofaunal isopods of the Pacific abyssal fauna relevant to the CCZ. International Seabed Authority's Workshop to Standardize Macrofaunal Taxonomy for Polymetallic Nodules Exploration Areas in the Clarion-Clipperton Zone. Uljin-gun, Korea. 23-30 November 2014.

- Meadows, P., Reichelt, A., Meadows, A. and Waterworth, J. 1994. Microbial and meiofauna abundance, redox potential, pH and shear strength profiles in deep sea Pacific sediments. Journal of the Geological Society, London, 151, 377-290.
- Stoyanova, V. 2014. Status of Macrofauna Studies Carried Out by the Interoceanmetal Joint Organization (IOM). Workshop on Taxonomic Methods and Standardization of Macrofauna in the Clarion-Clipperton Fracture Zone. 23-30 November 2014.
- Yuzhmorgeologia. 2014. Macrofauna investigation on Russian exploration area of polymetallic nodules. International Seabed Authority's Workshop to Standardize Macrofaunal Taxonomy for Polymetallic Nodules Exploration Areas in the Clarion-Clipperton Zone. Uljin-gun, Korea.

Scottish Association of Marine Science, 2010. Final Report: Independent Evaluation of Deep-Sea Mine Tailings Placement (DSTP) in PNG. Project number 8.ACP.PNG.18-B/15.

- Scottish Association of Marine Science (SAMS) deep sea tailings placement (DSTP) study in Papua New Guinea at a pre-mining location (Ramu), an operating mine (Lihir) and a closed mine (Misima).
- Ramu: pre-mining sampling so not relevant to NORI Area D and not discussed further.
- Lihir: investigation at operating mine:
  - Three depth ranges were sampled to the east of Lihir island (impacted by tailings) and the west of Lihir Island (unimpacted/control): 800 to 850 m, 1,715 to 1,750 m and approximately 2,020 m.
  - At all three depths sampled, mean values for total density of metazoan[1] meiofauna were higher at control (unimpacted) than at tailings-impacted stations. The differences were statistically significant at 800 to 850 m and 1,715 to 1,750 m, but there was no significant difference at 2,020 m.
  - The metazoan meiofauna at all three tailings-affected stations was numerically dominated by harpacticoid copepods. In contrast, at three control stations nematodes and harpacticoid copepods were approximately equal in abundance, each comprising 40 to 50% of the community. Ostracods and minor metazoan groups were rare at all stations.
  - Living benthic Foraminifera were either entirely absent or present (only calcified species) in low densities at the impacted sampling sites. Living forams were present in samples from all three control sites off Lihir and included both calcified and organic-walled (allogromiid) species. At 2,020 m mean density of calcified forams was identical at impact and control stations, but the impact station differed in the absence of organic-walled taxa.

[1] multicellular eukaryotic organisms that form the biological kingdom Animalia.

- At all three depths sampled, mean values for total density of macrofauna were much higher at control (unimpacted) than at tailings-impacted stations). The differences were statistically significant at all three depths.
- The sparse macrofauna at the impact stations consisted almost entirely of small polychaetes, accounting for 83 to 97% of the total community. Only one or two polychaete families were represented at each station. Bivalves and peracarid crustaceans (tanaids and amphipods) were present in very low numbers.
- In contrast, the control stations supported more diverse communities in which Polychaeta was the most abundant major group (58 to 64% of the total) but did not dominate to the extent seen at the impact stations. Crustaceans and molluscs were well-represented at all three control stations. The number of polychaete families represented at the control stations ranged from 17 to 27. In terms of higher-taxon composition, the macrofaunal communities at the control sites were indistinguishable.
- In all samples, both meio- and macrofauna were virtually absent in the 50 to 100 mm depth horizon of the sediment column. In a typical core only isolated individuals, and often none at all, were found below 50 mm depth.
- At water depths of 1,715 to 1,750 m and 2,020 m, metazoans were heavily concentrated in the 0 to 10 mm horizon of the sediment (> 70% total individuals), with a steep decline in occurrence below this. At shallower water depths (800 to 850 m), metazoans were more evenly distributed across the upper 50 mm of the sediment column, although still with highest abundance in the 0 to 10 mm surface layer. There was no significant difference between control and impact stations at any water depth. The few calcified Foraminifera recorded at the 2,020 m depth impact station were all found in the uppermost 0 to 10 mm sediment horizon.

• Misima: post-mining study looking at seafloor environment three years after end of DSTP operations:

- Six seafloor sampling sites were selected within impacted and non-impacted zones, with water depths ranging between 1,250 and ,793 m.
- The geochemical fingerprint of the mine tailings is significantly different from that of the natural sediments of the area, having a higher concentration of heavy metals, allowing sediments derived from mine tailings to be distinguished from natural sediments on the seabed.
- Studies of the sediments and pore-waters indicate that geochemical processes occurring at the impacted sites bring about a release of metals to the porewater with a possible release of some metals to the overlying water column.
- Metazoan depth distribution in the sediment column was fairly uniform at the six seafloor sampling sites.
- Between 48% and 66% of all animals were found in the surface 0 to 10 mm layer, with numbers decreasing steadily below this.
- In most samples only a few individuals, mostly larger polychaetes, were found in the 50 to 100 mm depth horizon.

- Foraminiferan depth distribution was more variable but numbers were greatest in the 0 to 10 mm layer and then decreasing with sediment depth.
- Three years after the tailings discharge finished, the benthic community (living organisms on/in the seabed) in the impacted area (Bwagaoia Basin) was very different from that at local reference locations: the number of animals and the numbers of types of animal (i.e., biodiversity) was much lower at the three stations showing clear chemical signals of tailings in the bottom sediments.
- Polychaetes (bristle worms) were the largest contributor to the macrofauna at each of the sampling stations but there was a significant difference in the structure of the assemblage at impacted compared with references stations.
- These results suggest that seabed animal communities in Bwagaoia Basin were still significantly affected by tailings three years after the cessation of DSTP at Misima.

- As an update, Kingston Resources is seeking to recommence mining at Misima (including utilising DSTP) and is commencing an EIS which will include seafloor sampling to characterise the physiochemical and biological environment. This information will become available when the EIS is made public in late 2021 or 2022 and will provide an understanding of biological recolonization of a tailings footprint some 17 years post-closure.

Smit, M., Holthaus, K., Trannum, H., Neff, J., Kjeilen-Eilertsen, G., Jak, R., Singsaas, I., Huijbregts, M. and Hendriks, A. 2008. Sensitivity Distributions for Suspended Clays, Sediment Burial, and Grain Size Change in the Marine Environment. Environmental Toxicology and Chemistry, Vol. 27, No. 4, pp. 1006–1012. SETAC. 27. 1006-12. 10.1897/07-339.1

- Study from North Sea, so much shallower (average depth 80 m, maximum depth 800 m) and more turbid (up to 20 mg/L in the open North sea) than NORI Area D, but used data from a number of sources, including the internal literature database of the Dutch Organisation for Applied Scientific Research, Institute for Marine Resources and Ecosystem Studies (Den Helder, Netherlands), the internal literature database at Battelle (Duxbury, MA, USA) and the U.S. Environmental Protection Agency's AQUIRE database.
- Developed species sensitivity distributions (SSDs) for three nontoxic stressors – suspended clays, burial by sediment and change in sediment grain size.
- For suspended clays:
  - The data collection resulted in a database with effect concentrations for marine species for different effect types, such as survival, feeding behaviour, growth, mobility, reproduction, oxygen consumption, and effects on the gastrointestinal tract.
  - Most data were available for the species groups phytoplankton, zooplankton, crustaceans (excluding zooplankton), molluscs, and fish. Filter feeding molluscs are most sensitive to increased particle concentrations.

- 50% effect concentrations (EC50s)[2] for mortality were used to construct the SSDs for respectively barite and bentonite. For barite and bentonite, data on 15 and 12 different species were available, respectively.
- The SSDs based on collected EC50 values for mortality resulting from suspended barite and bentonite exposure, show that species are slightly more sensitive to bentonite than to barite. However, this difference is not statistically significant (analysis of variance, significance level 5%). The SSD for barite is based on data for 15 species in five taxonomic groups and for bentonite 12 species and four taxonomic groups. For barite the 50% hazardous concentration and HC5 (The HC5 is the concentration at which five percent of the species in the SSD exhibit an effect) correspond to 3,010 (752–12,000) and 17.9 (1.2–100) mg/L respectively (median value and 5 to 95% confidence interval). For bentonite these values are 1,830 (340–9,855) and 7.6 (0.25–58.1) mg/L respectively.

- For sediment burial:
  - The collected effect data for burial of sediment included depths of burial tested in mainly chronic exposure tests with marine species. No EC50 values have been reported for burial. However, a 1974 study used an indicator with a comparable concept: the escape potential of a given species can be identified as the probability (x) that the organism can escape with a given depth of burial (EPx).
  - The availability of no-effect levels was limited to four species, therefore only effect values with quantified and nonquantified effect magnitudes were considered in the study. The obtained effect level values were directly used in the SSD, except for three species for which values of zero were reported. For those species half of the lowest-observed-effect level was used in the SSD. For example, epifaunal suspension feeders, permanently attached to hard substrate could not escape burial of 1 cm depth, which was the lowest exposure level included in the experiments. In this case, the effect level for inclusion in the SSD was set at 5 mm.
  - The final data set contained data on 32 marine species.
  - No effect data were available referring to the thickness of a deposited layer or to the deposition rate. Therefore, test results using depth of burial as the endpoint were selected to derive the SSD. Effect data are based on instantaneous and complete burial.
  - The search for effect data for burial resulted in a dataset containing 39 effect values (different effect magnitudes) for 32 species (24 molluscs, five crustaceans, and three polychaetes). For burial the 50 and 5% hazardous levels were determined at 54 (37–79) and 6.3 (3.1–10.6) mm respectively (median and 5–95% confidence interval).

National Institute of Water and Atmospheric Research. 2009. Short-term Behavioural Responses of Selected Benthic Invertebrates Inhabiting Muddy Habitats to Burial by

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[2] The concentration which induces a response halfway between the baseline and maximum after a specified exposure time.

Terrestrial Clay. Report prepared for Auckland Regional Council. Report number TR2009/116. October

- Laboratory experiments were conducted on seven types of macrofauna common in the muddy sediments of Okura estuary, so shallow waters and therefore applicability to NORI Area D is reduced.
- Taxa studied were, the small bivalve *Nucula hartvigiana*, the snapping shrimp *Alpheus sp.*, the mud snail *Amphibola crenata*, polychaete worms from the family Nereidae *Aquilaspio aucklandica* and *Boccardia* sp. from the family Spionidae and Oligochaeta.
- A clay slurry was added to cores containing sediment and animals, at depths of 0, 5, 10, 15, 30, 60, and 90 mm. The animals were left to live in the sediment for either 24, 72 or 144 hours.
- Chemical profiles of cores were analysed using vertical voltammetry immediately following the deposition of the clay slurry. Within 1 hour of adding the clay, the original sediment had become anoxic, completely changing the original biogeochemical vertical profile.
- With clay layers of 5 to 15 mm thickness, the polychaetes and Oligochaeta were able to move into the clay layer. The snapping shrimps and snails were able to move through the clay to the surface.
- In cores with clay layers of 30 mm and greater, only the highly mobile snapping shrimps were able to move through to the surface. The slower snails and bivalves withdrew into their shells and the polychaetes suffered high mortality. Results for the bivalve Nucula were consistent regardless of clay thickness with the fitness of these bivalves decreasing with time buried.
- In general, levels of stress and mortality of the macrofauna increased with time, probably due to reduced access to food and oxygen at the surface of the clay and the changing chemical composition of the original sediment. Larger, more-mobile animals were less affected than small and slow-moving ones.
- This work demonstrates the potential for significant ecological change as a result of catastrophic deposits of terrigenous clay in the upper reaches of Okura estuary. It confirms the suggestion made by a 1999 report[3] that clay layers less than 2.0 cm thick are less likely to impact on the whole community.

Last, K., Hendrick, V., Beveridge, C. and Davies, A. 2011. Measuring the effects of suspended particulate matter and smothering on the behaviour, growth and survival of key species found in areas associated with aggregate dredging. Report for the Marine Aggregate Levy Sustainability Fund, Project MEPF 08/P76 and **Hendrick, V., Hutchison, Z., Last, K. and Davies, A (Eds.). 2016. Sediment Burial Intolerance of Marine**

[3] Norkko, A., Thrush, S., Hewitt, J., Norkko, J, Cummings, V., Ellis, J., Funnell, G., and Schultz, D. 1999. Ecological effects of sediment deposition in Whitford embayment. NIWA Client Report ARC90243.

Macroinvertebrates. PLoS ONE, vol. 11, no. 2, pp. e0149114. doi.org/10.1371/journal.pone.0149114

- Data from a multi-factorial experiment measuring burial responses incorporating duration, sediment fraction and depth is presented in the paper. Experiments were carried out in Paddle Vortex Resuspension Tanks.
- The choice of experimental organisms was based primarily on their prevalence in areas of interest for aggregate extraction i.e., southern North Sea and eastern English Channel, the diverse range of behavioural and physiological characteristics exhibited and, in some cases, their commercial and/or conservation importance.
- Survivorship under burial and ability to escape from burial were assessed for *Mytilus edulis* (the blue mussel); *Aequipecten opercularis* (queen scallop); *Sabellaria spinulosa* (ross worm); *Psammechinus miliaris* (green sea urchin); *Ophiura ophiura* (a brittlestar); *Sagartiogeton laceratus* (a sea anemone) and *Ciona intestinalis* (yellow sea squirt).
- Samples were collected from relatively shallow coastal waters offshore the United Kingdom or were cultured by local producers.
- Burial specimens were placed onto the base of the chambers and manually buried using kiln dried marine sediment.
- Three burial depths were chosen – shallow (20 mm), medium (50 mm) and deep (70 mm).
- Three sediment fractions were used: coarse (1.0 to 2.0 mm diameter), medium fine (0.25 to 0.95 mm) and fine (0.1 to 0.25 mm).
- Two suspended particulate matter (SPM) scenarios were generated in the chambers – low (~12 mg/L) and high (~71 mg/L).
- Burials were replicated for durations of 1, 2, 4, 8, 16 and 32 days, or a variation thereof depending on burial intolerance.
- Behavioural responses to burial:
  - Assessments revealed that the brittle star (*Ophiura ophiura*), the queen scallop (*Aequipecten opercularis*) and the sea squirt (*Ciona intestinalis*) were all highly intolerant to burial whilst the green urchin (*Psammichinus miliaris*) and the anemone (*Sagartiogeton laceratus*), showed intermediate and low intolerance respectively, to burial. The least intolerant, with very high survival was the tube-dwelling polychaete Ross worm (*Sabellaria spinulosa*).
  - Survival following burial was determined using a multi-factorial experimental design incorporating burial depth, duration of burial and size fraction of burial sediments.
  - With the exception of *C. intestinalis*, increasing duration and depth of burial with finer sediment fractions resulted in increased mortality for all species assessed. For *C.*

intestinalis depth of burial and sediment fraction were found to be inconsequential since there was complete mortality of all specimens buried for more than one day.

- When burial emergence was assessed, *O. ophiura* emerged most frequently, followed by *P. miliaris*. The former emerged most frequently from the medium and fine sediments whereas *P. miliaris* emerged more frequently from coarse sediment. Both *A. opercularis* and *S. laceratus* showed similar emergence responses over time, with *A. opercularis* emerging more frequently under coarse sediments. The frequency of emergence of *S. laceratus* increased with progressively finer sediment and *C. intestinalis* did not emerge from burial irrespective of sediment fraction or depth. The greatest ability to emerge from burial in all other species was from shallow (20 mm) burial.
- It became clear from the burial tolerance experiments that emergence from burial is a significant response in determining survival. The results suggest that even most species highly tolerant to burial events would eventually die after prolonged periods under sediment.
- Escape ability in particular was higher under 20 mm burials than under 50 mm burials in most of the test species.
- Although survival was consistently highly dependent on duration and depth of burial as expected, emergence behaviour was not as easily predictable, thereby confounding predictions.

- Behavioural responses to elevated SPM:
  - *M. edulis* displays an overt nocturnal shell gape cycle under both SPM and no SPM conditions. However, shell gape cycles were significantly reduced under high SPM compared with the control condition, a change in circadian clock expression that may have consequences on fitness.
  - *A. opercularis* does not display nocturnal shell gape cycles. However, shell closure events were significantly increased under both low and high SPM when compared to control conditions and is likely to be a reflection of increased efforts to clear the mantle of sediment. Significantly more ‘claps’ (considered an escape response) and ‘coughs’ (thought to be a mechanism for the expulsion of sediment) were also recorded in animals under high SPM when compared to control conditions. All three behaviours: shell closure events, clapping and coughing will confer energetic cost.
  - When individual *S. spinulosa* tube growth rates were assessed under different SPM treatments, significantly higher tube growth was achieved under high SPM when compared to low SPM or no SPM conditions. However more specimens also exhibited no growth under high SPM treatment suggesting that whilst elevated SPM will be tolerated and responded to, it may also impact the tube-building capability of worms.
  - *C. pagurus* maintained under high SPM conditions gained significantly less weight than those maintained under control conditions. There was no significant difference between SPM treatment and control for carapace width, however low replication in crab numbers limit confidence in this result.

  - All specimens survived both treatment and control conditions in the experiments to assess tolerance to elevated SPM, and hence this cannot be considered to impact survival of any of the four species in the short-term.

- The paper concludes that responses to burial are highly species specific and therefore tolerance generalisations are likely to be oversimplifications. Data may be used to inform environmental impact models that allow forecasting of the cumulative impacts of seabed disturbance and may provide mitigation measures for the sustainable use of the seabed.

Erftemeijer, P., Riegl, Hoeksema. B. and Todd, P. 2012. Environmental impacts of dredging and other sediment disturbances on corals: a review. Marine Pollution Bulletin 64 (2012) 1737-1765. dx.doi.org/10.1016/j.marpolbul.2012.05.008

- A review of published literature on the sensitivity of corals to turbidity and sedimentation with an emphasis on the effects of dredging. These are shallow water corals so applicability to NORI Area D is limited.
- Effects of sediment stress have so far been investigated in 89 coral species (~10% of all known reef-building corals).
- Reported tolerance limits of coral reef systems for chronic suspended sediment concentrations range from <10 mg/L in pristine offshore reef areas to >100 mg/L in marginal nearshore reefs.
- Some individual coral species can tolerate short-term exposure (days) to suspended-sediment concentrations as high as 1,000 mg/L while others show mortality after exposure (weeks) to concentrations as low as 30 mg/L.
- The duration that corals can survive high turbidities range from several days (sensitive species) to at least 5 to 6 weeks (tolerant species). Increased sedimentation can cause smothering and burial of coral polyps, shading, tissue necrosis and population explosions of bacteria in coral mucus.
- Fine sediments tend to have greater effects on corals than coarse sediments. Turbidity and sedimentation also reduce the recruitment, survival and settlement of coral larvae.
- Maximum sedimentation rates that can be tolerated by different corals range from <10 mg/cm^2/d to >400 mg/cm^2/d.
- The durations that corals can survive high sedimentation rates range from <24 h for sensitive species to a few weeks (>4 weeks of high sedimentation or >14 days complete burial) for very tolerant species.
- Given the wide range of sensitivity levels among coral species and in baseline water quality conditions among reefs, meaningful criteria to limit the extent and turbidity of dredging plumes and their effects on corals will always require site-specific evaluations.

Great Barrier Reef Marine Park Authority. Water Quality Guidelines for the Great Barrier Reef Marine Park. Revised Edition 2010

- The Water Quality Guidelines for the Great Barrier Reef Marine Park describe the concentrations and trigger values for sediment, nutrients and pesticides that have been established as necessary for the protection and maintenance of marine species and ecosystem health of the Great Barrier Reef.
- Obviously shallower waters than NORI Area D but the Great Barrier Reef is internationally iconic and a World Heritage Area. The goal of the Great Barrier Reef Marine Park Authority is the long-term protection and maintenance of the Great Barrier Reef Marine Park and World Heritage Area.
- Suspended sediment guideline trigger values:
  - Open coastal: 2.0 mg/L.
  - Midshelf: 2.0 mg/L.
  - Offshore: 0.7 mg/L.
- Sedimentation rates:
- Maximum mean annual sedimentation rate: 3 mg/cm^2/d.
- Daily maximum: 15 mg/cm^2/d.

Other Impact Assessments

- BGR modelled:
  - 10 to 10,000 mg/L sediment plumes.
  - 0.1 to >85 mm depositional footprint and 0.0001 to >20 mm depositional footprint.
- GSR modelled:
  - 0.01, 0.1, 1 and 10 mg/L sediment plumes.
  - 0.1 to >10 mm depositional footprint.
- GoIndia modelled:
  - >0.075 to <0.647 mg/L sediment plumes.
  - Can't find footprint modelling results in their report.
- It's a mixed bag with no clear justification for selection of modelling cutoffs.

Existing DHI Project Modelling

- Midwater plume:
  - >0.1 mg/L, >1 mg/L and >10 mg/L and also 0.01 to 20 mg/L sediment plumes.
  - No depositional modelling for mid-water plume.

Proposed Initial Modelling Cutoffs

- What are we trying to protect?

- Biota.
- Biological processes.
- Reputation.

Initial Total Suspended Sediments Concentration Cut-offs

- Little relevant deep water data exists for determination TSS modelling cut-offs.
- Based upon documents that have been reviewed, the following table lists a number of proposed initial modelling cut-offs for consideration, discussion and selection by the project team:

TSS (mg/L)	Source	Justification
0.01	Modelled by GSR	Consistency with other EISs for comparison of plume size and will avoid questions as to why this upper limit was not modelled
0.1	Modelled by GSR	Consistency with other EISs for comparison of plume size and will avoid questions as to why this upper limit was not modelled
0.7	Water Quality Guidelines for the Great Barrier Reef Marine Park	Offshore trigger value
1	Standard analytical reporting limit for TSS analysis (method SM 2450D) is 1 mg/L	Easiest minimum concentration to measure during monitoring
4.5	CSA water sampling activities	Top end of reported range
10	Environmental impacts of dredging and other sediment disturbances on corals: a review Modelled by GSR Modelled by BGR	Reported tolerance limits of coral reef systems for chronic suspended sediment concentrations Consistency with other EISs for comparison of plume size
1,830 (say 1,800)	Sensitivity Distributions for Suspended Clays, Sediment Burial, and Grain Size Change in the Marine Environment	50% hazardous concentration for organisms exposed to bentonite
3,010 (say 3,000)	Sensitivity Distributions for Suspended Clays, Sediment Burial, and Grain Size Change in the Marine Environment	50% hazardous concentration for organisms exposed to barite
10,000	Modelled by GSR	Highest concentration modelled in other EISs; provides a comparison of plume size and will avoid questions as to why this upper limit was not modelled

Initial Depositional Footprint Thickness Cut-offs

- Little relevant experimental deep sea data exists for determination depositional footprint modelling cut-offs.
- Shallow water studies do exist where the response of shallow water organisms to burial by sediment are available. It would appear that a common result in burial studies indicates the majority of shallow water organisms can survive burials to depths up to 20 mm.
- Deep water studies characterise sediment depths at which biota occur. The vast majority of benthic meiofaunal and macrofaunal infauna (those living within the sediment) diversity and abundance resides in the top 50 mm of the sediment and at a finer scale in the top 20 mm, with a small fraction of macrofaunal community extending to 100 mm.
- A hypothesis that could be put forward now is that organisms can tolerate burials up to the same depth at which they reside. In other words, if an organism occurs in the top 0 to 20 mm of sediments, the hypothesis would be that it is able to tolerate a burial of up to 20 mm (such an individual that is located in the top of this layer and is suddenly buried would now find itself in the bottom extent of its range and would be able to move to the surface).
- Assuming this hypothesis is correct, the limitation to this is that it does not consider the energy limitations in the deep sea. Energy in the deep sea is obtained from a thin organic surface layer that is replenished by surface detritus. Disturbance and redistribution of this layer by mining (and also potentially change in grain size) would likely affect the energy available to any biota that survive smothering.
- The JET experiment suggests that the seafloor does recover with time and it appear that the thin organic surface layer (via analysis of TN, TOC and $CaCO_3$) was relatively consistent with distance from disturbance some 17 to 18 years after disturbance.
- In lieu of good data, the above hypothesis is proposed to be included in modelling cut-offs.
- Based upon documents that have been reviewed, the following table lists a number of proposed initial modelling cut-offs for consideration, discussion and selection by the project team:

Depositional Thickness (mm)	Sedimentation rate ($g/m^2/day$)	Source	Justification
	0.016	CSA sediment trap 25 m above seafloor	Naturally occurring sedimentation rate but note density this material will be different from mine-derived plumes
	0.049	The benthic disturbers used in the BIE-II, JET, IOM BIE and INDEX experiments was specifically designed to create a plume, with an increase in suspended particles of 300% (from 49 to 150 mg m2/day) observed during disturbance. This value is an average from 10 sediment traps deployed at 7 m above the seabed around the disturber site	Allows comparison and contextualisation with disturber experiments, including with any future studies at these sites
	0.15	The benthic disturbers used in the BIE-II, JET, IOM BIE and INDEX experiments was specifically designed to create a plume, with an increase in suspended particles of 300% (from 49 to 150 mg m2/day) observed during disturbance. This value is an average from 10 sediment traps deployed at 7 m above the seabed around the disturber site	Allows comparison and contextualisation with disturber experiments, including with any future studies at these sites
0.1		Minimum modelled by GSR Modelled by BGR (minimum modelled by BGR was 0.0001 mm but this seems impossibly small and beyond model accuracy)	Consistency with other EISs for comparison of footprint size and will avoid questions as to why this lower limit was not modelled
0.26		JET experiment	Observed thickness defined as “heavy deposition area”, allows contextualisation with previous and any future JET studies
20		Hypothesis described above for top 20 mm of sediment	A hypothesis that is considered worth testing in lieu of better data
50		Hypothesis described above for top 50 mm of sediment	A hypothesis that is considered worth testing in lieu of better data
100		Hypothesis described above for top 100 mm of sediment	A hypothesis that is considered worth testing in lieu of better data
>200		Anything >200 mm	Double next highest value (unless the $g/m^2/day$ values are higher)

Appendix 5 - Global Stakeholder Workshop Details

GLOBAL STAKEHOLDER WORKSHOP PARTICIPANT LIST

Wednesday 5 February (8:15 AM to 5:00 PM) and
Thursday 6 February 2020 (8:30 AM to 5:00 PM)

The Pendry Hotel, 550 J Street, San Diego, California USA

ORGANISATION	PROFESSIONAL CATEGORY (SELF-IDENTIFIED)
Advisory Committee on Protection of the Sea	Academic, researcher or scientist | Technical expert | Government and non-government representative
Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research	Academic, researcher or scientist
Allseas	Industry expert
Amundsen Science, University Laval	Academic, researcher or scientist
Arkar	Researcher
BGR	Contractor - General
Blue Globe Solutions	Industry expert | Technical expert
Centre for Applied Research at NHH	Academic, researcher or scientist
CIIMAR	Academic, researcher or scientist
Colorado School of Mines	Academic, researcher or scientist
Conservation International	Academic, researcher or scientist | Conservationist
Cook Islands Seabed Minerals Authority	Government and non-government representative
CSA Ocean Sciences	Academic, researcher or scientist
CSA Ocean Services	Contractor - General
DHI Water & Environment Inc.	Industry expert | Technical expert
Duke University	Academic, researcher or scientist
Embassy of Costa Rica in Jamaica	Government and non-government representative
EMEPC	Industry expert
Equinor Energy AS	Industry expert
ERIAS Group	Technical expert

ORGANISATION	PROFESSIONAL CATEGORY (SELF-IDENTIFIED)
Federal Institute of Industrial Research Oshodi, Lagos, Nigeria	Academic, researcher or scientist
Federal University Birnin Kebbi, Kebbi State, Nigeria	Academic, researcher or scientist
Florida State University	Academic, researcher or scientist
Geology and Coastal Management Division, MFMRD	Government and non-government representative
Ghent University	Academic, researcher or scientist
Global Oceans	Contractor - CCZ | Contractor - General
Government of Nauru	Government and non-government representative
IDUM	Technical expert
Institute for Advanced Sustainability Studies (IASS)	Academic, researcher or scientist
Interoceanmetal Joint Organization	Academic, researcher or scientist | Contractor - CCZ
ISA LTC	Interested stakeholder
iSeaMC	Industry expert
Maersk Supply Service	Interested stakeholder
Mineral Resources Department	Government and non-government representative | Interested stakeholder
Ministry of Energy	Government and non-government representative
Monterey Bay Aquarium Research Institute	Academic, researcher or scientist
National Oceanography Centre	Academic, researcher or scientist
National Oceanography Centre, UK	Academic, researcher or scientist
NORCE Norwegian Research Centre	Academic, researcher or scientist
Pacific Islands Development Forum	Industry expert
Permanent Mission of Ghana to the United Nations	Government and non-government representative | Interested stakeholder
PIPA Conservation Trust	Conservationist
Scripps Institution of Oceanography, University of California, San Diego	Academic, researcher or scientist
SPC	Government and non-government representative
Steven Katona Consulting	Academic, researcher or scientist
Te Ipukarea Society	Government and non-government representative

ORGANISATION	PROFESSIONAL CATEGORY (SELF-IDENTIFIED)
Togo Mission to the United Nations New York	Government and non-government representative
UCSD	Academic, researcher or scientist
UCSD and NOAA	Academic, researcher or scientist
UK Seabed Resources	Contractor - CCZ
Universidad de Valparaiso	Researcher
University of California Santa Barbara	Academic, researcher or scientist
University of Gothenburg/NORCE	Academic, researcher or scientist	Contractor - CCZ	Researcher
University of Hawaii	Academic, researcher or scientist
University of Leeds, UK	Academic, researcher or scientist
University of the West Indies	Academic, researcher or scientist
Woods Hole Oceanographic Institution	Academic, researcher or scientist
World Economic Forum	Industry expert

GLOBAL STAKEHOLDER WORKSHOP AGENDA

Wednesday 5 February (8:15 AM to 5:00 PM) and Thursday 6 February 2020 (8:30 AM to 5:00 PM)

The Pendry Hotel, 550 J Street, San Diego, California USA

Parlour 2 and 3 or via webinar

Hosted by DeepGreen Metals Incorporated (DeepGreen) and Nauru Ocean Resources Incorporated (NORI)
Facilitated by Strategic Earth Consulting

Join us for a special global stakeholder workshop to engage in a thoughtful and collaborative exploration into sourcing battery metals from ocean nodules and provide guidance on NORI's program to assess environmental and social impacts

Metal production today generates a host of serious environmental and social issues. And yet, we will need to extract hundreds of millions of tonnes of virgin metal this century. Is sourcing metals from ocean nodules a better alternative for the planet and its people?

DeepGreen and NORI invite stakeholders to collaboratively explore the opportunities and challenges of collecting deep sea nodules as a source for metals and transitioning to a green society, and to learn about and provide feedback on DeepGreen's proposed Environmental and Social Impact Assessment (ESIA) program for collection in the Clarion Clipperton Zone (CCZ).

FORMAT An interactive forum involving a multidisciplinary group of experts, scientists, policy makers and conservationists.

DAY 1 - WEDNESDAY, FEBRUARY 5 WHY COLLECT NODULES FROM THE CCZ SEABED?

TIME	ITEM	DETAIL	SPEAKER
8:15 AM	**Sign in and be seated**	Please sign in, collect your name badge and make yourself comfortable.	
8:30 AM	**Official welcome and remarks**	Workshop participants will be welcomed and introduced to DeepGreen leadership.	Gerard Barron, Chairman and CEO, DeepGreen
8:40 AM	**Participant introductions**	Participants will be provided with an overview of the workshop approach, confirm meeting agreements, and be invited to introduce themselves and to share their intentions for attending the workshop.	Strategic Earth Consulting
9:00 AM	**Context and stakeholders**	*Who has a stake in the future of the planet and our oceans?*	Dr Gregory Stone, Chief Ocean Scientist, DeepGreen
10:00 AM	**Metal supply and demand in the 21st century**	*How much more metal do we need? Can recycling help meet demand?*	Alex Laugharne, CRU
10:45 AM	**MORNING TEA**		
11:00 AM	**Environmental and social impacts of virgin metal supply**	*Where should metals for the green transition come from?*	Dr. Steven Katona, College of the Atlantic / Daina Paulikas
12:00 PM	**International Seabed Authority's environmental requirements**	*What are the relevant regulatory processes and the environmental obligations of contractors in the CCZ during the ESIA process?*	Wanfei Qiu, Programme Manager (Marine Environment), ISA
12:45 PM	**Sponsoring state perspective**	*What is the legacy of terrestrial mining in Nauru, and what does the future look like for Nauru?*	Margo Deiye (Nauru) Permanent Representative to the ISA
1:15 PM	**CATERED LUNCH**		
2:15 PM	**Additional perspectives**	*What are the major concerns with collecting nodules?*	Facilitated discussion led by Strategic Earth Consulting
3:45 PM	**AFTERNOON TEA**		
4:00 PM	**DeepGreen**	*What motivates us? How do we plan to evolve our business? What are our commitments?*	Gerard Barron, Chairman and CEO, DeepGreen
4:45 PM	**Day 1 recap**	Recap of day 1 and expectations forday 2.	Strategic Earth Consulting / Dr. Gregory Stone, Chief Ocean Scientist, DeepGreen
5:00 PM	**Adjourn**		
5:30 PM	**INFORMAL DRINKS AND APPETISERS - SIDE BAR, 536 MARKET STREET BETWEEN FIFTH & SIXTH AVE, SAN DIEGO**		

DAY 2 - THURSDAY, FEBRUARY 6 — HOW CAN WE ASSESS AND MANAGE THE ENVIRONMENTAL IMPACTS OF NODULE COLLECTION IN THE CCZ?

TIME	ITEM	DETAIL	SPEAKER
8:25 AM	**Sign in and be seated**	Please sign in, collect your name badge and make yourself comfortable.	
8:30 AM	**Welcome and introductory remarks**	Participants will be welcomed and provided with an overview of the workshop approach that reflects information shared and discussions on day 1.	Strategic Earth Consulting
8:40 AM	**Deep sea environment in the CCZ**	*What do we know and what do we not know about the abyssal plains environment in the CCZ?*	Larry Madin, Woods Hole Oceanographic Institution
9:10 AM	**Deep sea nodule collection system**	*How does it work? What type of impacts are expected?*	Tony O'Sullivan, Chief Development Officer, DeepGreen
9:40 AM	**ESIA process**	*What does a successful ESIA process look like?*	Dr. Jennifer Durden, National Oceanography Centre, Southampton
10:10 AM	**MORNING TEA**		
10:25 AM	**DeepGreen's ESIA**	*What are the key objectives? What does the work program look like?*	Dr. Michael Clarke, Environmental Manager, DeepGreen
10:55 AM	**Environmental management**	*With so many unknowns, how can we manage the impacts?*	Dr. Michael Clarke, Environmental Manager, DeepGreen
11:25 AM	**Serious harm**	*How do we define it and measure it? How do we avoid it? What can we accept as society?*	Dr. Jason Smith, Environmental Scientist, DeepGreen
12:30 PM	**CATERED LUNCH**		
1:30 PM	**DeepGreen's key environmental studies**	*What questions will we work to answer over the next three years? What new scientific knowledge do we expect to generate?*	Dr. Jason Smith, Environmental Scientist, DeepGreen
1:45 PM	**Work Package 1 overview**	*How are we assessing the sediment physical and biogeochemical properties?*	Professor Andrew Sweetman, The Lyell Centre, Heriot Watt University / Dr. Clare Woulds, University of Leeds
1:55 PM	**Work Package 2 overview**	*How are we assessing marine mammals, near-surface animals and birds in the CCZ?*	Dr. Adrian Flynn, Fathom Pacific
2:05 PM	**Work Package 3 overview**	*How are we assessing benthic biology? What does it look like?*	Dr. Daniel Jones, National Oceanography Centre / Dr. Thomas Dahlgren, University of Gothenburg / NORCE
2:15 PM	**Work Package 5 overview**	*What Specialist Technical Services are required for the ESIA's support studies?*	Brian Balcom, CSA Ocean Sciences Inc.
2:25 PM	**Mooring and Plume Modelling**	*What can we learn from ongoing physical and chemical oceanography studies and sediment plume modelling?*	Dr. Chris Kelly, CSA Ocean Sciences
2:35 PM	**AFTERNOON TEA**		
2:50 PM	**NORI's Terms of Reference (ToR) and Scoping Report**	*What are the core tasks and delivery methods? What are our initial priority topics and studies?*	Dr. Michael Clarke, Environmental Manager, DeepGreen
3:50 PM	**Work Package 4 overview**	*How are we assessing pelagic biology?*	Dr. Jeff Drazen, Department of Oceanography, University of Hawaii (Via webinar)
4:05 PM	**Trust, transparency and commitment**	*How can key stakeholders follow and engage with the ESIA process? What if we discover that serious harm is unavoidable?*	Gerard Barron, Chairman and CEO, DeepGreen
4:45 PM	**Workshop recap and feedback form**	Recap of workshop key discussions and next steps. Participants will be invited to complete a workshop feedback form to provide constructive feedback on their experience.	Strategic Earth Consulting
5:00 PM	**Adjourn**	Thank you for participating in today's workshop.	Gerard Barron, Chairman and CEO, DeepGreen

ZOOM WEBINAR LOGIN INFORMATION

Download Zoom: https://zoom.us/download
Find your local number to call in to the workshop: https://zoom.us/u/ayyXzmBWQ
Zoom Help Center: https://support.zoom.us/hc/en-us?_ga=2.231433372.242581812.1580334970-303990915.1578592950

Please plan to join the webinar 10 – 15 minutes in advance of the meeting to allow time for troubleshooting.

DAY 1 - WEDNESDAY, FEBRUARY 5 8:15 AM – 5:00 PM PST

Join Zoom Meeting: https://zoom.us/j/942924693?pwd=QWg5dHRGYzNNaIh1bUgrVzVxT3prUT09
Meeting ID: 942 924 693
Password: 194641

DAY 2 - THURSDAY, FEBRUARY 6 8:00 AM – 5:30 PM PST

Join Zoom Meeting: https://zoom.us/j/516219759?pwd=azY4TndPTllBVjFVbnAwUGp5OE8rZz09
Meeting ID: 516 219 759
Password: 149425