Technical review of Coastal Research Limited's marine dumping consent application

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Prepared by:
Daniel Leduc, Owen Anderson, Serena Cox, Krista Hupman, David Thompson

For any information regarding this report please contact:

Daniel Leduc
Benthic Ecologist
Coast & Oceans Centre
+64-4-386 0379
Daniel.Leduc@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Private Bag 14901
Kilbirnie
Wellington 6241

Phone +64 4 386 0300

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Executive summary

A review has been undertaken of the description of the biological community at the Northern Disposal Area east of Great Barrier Island, and the monitoring approach proposed by Coastal Resources Limited in its application for a marine dumping consent. In this application, Coastal Resources Limited is seeking to continue offshore disposal of dredged sediment at the Northern Disposal Area and to increase the disposal limit from 50,000 to 250,000 m^3 per annum.

The review specifically examines sections of the report by Bioresearches Limited on its robustness in analysing the composition of the biological community at the Northern Disposal Area and surrounding area. The review also examines whether the proposed monitoring approach represents best practice, is adequate to understand the effects of proposed dumping activities on the marine environment, and uses appropriate variables to be monitored including methodologies, analysis, and reporting.

We identified key methodological and analytical shortcomings in the information provided on the biological community at the Northern Disposal Area, particularly pertaining to benthic communities. These shortcomings limit the conclusions that can be drawn regarding impacts of past sediment dumping activity and assessment of future impacts.

Gravity corers such as the one used for obtaining benthic biota samples in the Northern Disposal Area are rarely used in monitoring studies because they are not deemed capable of consistently retrieving undisturbed core samples. It is not possible to evaluate to what degree the cores may have been disturbed based on the information provided. The validity of the analyses provided in the Bioresearches Limited report may therefore be seriously compromised.

There was little consistency in the dimensions of the cores, the nature of the replicates, or the core processing methods used during the six benthic biota surveys conducted from 2013 to 2016. As a result, interpretation of abundance data as they are presented is not straight forward, and meaningful comparisons of taxon richness, diversity and community structure among surveys is either compromised or impossible. Statistical analyses are not always appropriate and sometimes lacking.

Foraminiferans dominated the benthic biota, however a stain was used to differentiate live from dead specimens during only one of the six surveys.

Despite these limitations, the Bioresearches Limited report demonstrates that a dramatic decline in benthic biota occurred at the disposal centre site. However, it is not possible to draw firm conclusions about any sediment disposal effects on the abundance, diversity or community structure of benthic biota beyond the disposal centre site, where any potential impacts will be less pronounced and therefore less easy to detect.

It is stated in the Bioresearches Limited report that the greatest threat of spreading non-indigenous species to areas not previously colonized would be due to natural dispersal of larval or planktonic larvae from released dredge spoil. However, the biofouling organisms on the barge and any accidental spillage of material in transit are both significant vectors for the spread of non-indigenous species and neither of these were discussed in the report.

Based on data from a nearby area, we consider it likely that small patches of hard substrate with epifaunal communities are present within the Northern Disposal Area. Epifaunal communities, which could include protected taxa such as stony corals, are typically vulnerable to physical disturbance and will likely be impacted if they are in the vicinity of a sediment disposal site. The sampling that has been conducted to date within the NDA is not appropriate for determining the distribution and extent of epifaunal communities.

We make several recommendations to improve the proposed monitoring approach.

Monitoring of the disposal mound will be conducted using bathymetric surveys and sediment core sampling, which are appropriate methods. However, given the level of accuracy normally achieved at continental shelf depths, it is unlikely that bathymetric surveys will provide an accurate picture of the extent of the disposal mound. It is therefore important that the methods used for obtaining sediment cores be better explained, and likely modified, to ensure that the plume is detected and its growth accurately described. Bathymetry maps obtained during surveys of the NDA should be provided to the EPA.

Accumulation of sediment is expected to occur outside the NDA at a rate of up to 6-7 mm per year. It is not clear, however, how thick a layer of settled dredge spoil sediment deposited either immediately after disposal or through dispersal of fines by currents needs to be detected at a particular site before the mound is considered to have extended to that location. Unless a clear sediment thickness threshold is set, determining whether the mound has extended beyond the NDA boundary will remain a subjective process.

A sampling design similar to the one used in previous surveys is proposed for monitoring the benthic biota. Given the substantially larger quantities of sediment disposal, and to provide more robust analyses, we recommend that additional control sites be sampled, as well as additional sites within the Northern Disposal Area located 1000 m from the disposal centre.

Future analyses of benthic biota data need to be framed using clearly stated hypotheses and tested using defined statistical tests. In his evidence, David Hay proposes consent conditions which define the magnitude of change deemed ecologically significant. However, details of how long-term average values of benthic biota parameters are derived, as well as of the ability to detect these changes in the future (i.e., statistical power), need to be provided.

Limitations associated with the coring device, and lack of consistency in sampling methodology, need to be addressed. Protocols for processing foraminiferans need to be better described, and the use of a stain such as Rose Bengal need to be used to differentiate between live and dead specimens. Whenever possible, organisms should be identified to species. We recommend that meiofauna be considered for monitoring purposes, in addition to macrofauna.

The likely presence of small patches of hard substrate and associated epifaunal communities is not taken into consideration in the impact assessment. Evaluating the presence and distribution of epifaunal communities will require representative, high resolution seabed image/video transects to be carried out across the Northern Disposal Area.

With regards to monitoring of marine mammals we recommend that at least two observers be present at the time of dumping to cover each side of the vessel, that the hydrophone data be interpreted by a qualified passive acoustic monitoring operator, that both high and low frequency hydrophones be used so that both toothed and baleen whales can be detected, and that efforts be made to reduce vessel noise when acoustic monitoring is undertaken. The use of permanent hydrophones should also be considered to examine whether acoustic detections change over time.

Biosecurity risks arising from dredge and barge biofouling should be appropriately addressed through compliance with the Ministry for Primary Industries' 'clean hull' requirements. It should also be noted that under the Biosecurity Act, no person can knowingly transport any material or equipment which may contain Unwanted Organisms without undertaking suitable measures to ensure the pest is removed or rendered non-viable.

1 Background

In 2013 Coastal Resources Limited (CRL) was granted a Dumping Permit from Maritime New Zealand (MNZ) for the disposal of 50,000 m^3 per annum of dredged material at the Northern Disposal Area (NDA), a circular area of 1,500 m radius at about 140 m water depth and located east of Great Barrier Island immediately outside the 12 nautical-mile limit. The NDA replaced the Auckland Explosives Dumping Ground (AEDG) site for the disposal of dredged spoil from Auckland as it was considered by MNZ that the continued use of the AEDG site did not meet the requirements of the Convention of the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Convention), to which New Zealand is a signatory. No other marine disposal grounds have been consented to service the Auckland region since that time.

CRL has recently lodged an application for a marine disposal consent to continue offshore disposal of dredged sediment at the NDA and to increase the disposal limit from 50,000 to 250,000 m^3 per annum. If the application is successful, the NDA would become the main site for the disposal of dredge spoil in the Auckland Region and possibly for some marinas in the Waikato region.

CRL has contracted Bioresearches Limited to undertake an assessment of sediment chemistry, suspended solids and biological community within the NDA based largely on samples obtained from 2013 to 2016. CRL also contracted Beca to undertake a desktop assessment of the existing environment and the expected oceanographic effects of disposal of dredged sediments at the NDA. The reports by Bioresearches Limited and Beca provide the bulk of the environmental information supporting CRL's application.

The Environmental Protection Authority (EPA) has contracted NIWA to review (1) the description of the biological community at the Northern Disposal Area, and (2) the monitoring approach proposed by CRL in its application for marine dumping consent. The background and experience of the NIWA authors is provided in Appendix 1.

2 Review of report by Bioresearches Limited

The Bioresearches Limited report provides an overview of the environmental and biological information which has been obtained to date from the NDA, and which is used in CRL's consent application to determine the potential effects of sediment disposal on surrounding ecosystems. The Bioresearches Limited report includes information on source dredge material characteristics, a description of sediment physico-chemical characteristics, water quality, and biological communities within the NDA, and an evaluation of potential impact of sediment disposal.

For this review, we were asked by the EPA to evaluate sections of the report by Bioresearches Limited on their robustness in analysing the composition of the biological community at the NDA and surrounding area. The following sections of the Bioresearches Limited report were considered in this review:

- 3.5 – Biological Composition and Activity
- 4.3 – Benthic Fauna Mortality and Recovery Rates
- 4.4 – Potential for Spread of Invasive Species
- 4.5 – Fin Fish, Birds & Mammal disruption
- 4.7 – Biological Diversity & Integrity of Species, Ecosystems and Processes
- 4.8 – Vulnerable Ecosystems & Habitats of Threatened Species

Evidence provided by Simon West, David Hay and Simon Childerhouse on behalf of CRL on 25 October 2018 was also considered. This review specifically considers the potential impacts of the increased volume of dumped material on the surrounding ecosystems, how extensive (around the NDA) is the ecosystem-type that is represented in the NDA, and whether there are other vulnerable ecosystems in the area surrounding the NDA.

2.1 Biological composition and activity

This section of the Bioresearches Limited report describes biological sampling and monitoring undertaken at the Northern Disposal Area as required by the MNZ Permit 568 and EPA consent EEZ900012, which included sampling of sediment cores for benthic biota and audio recording of marine mammals since the Dumping permit was granted in 2013 until November 2016.

2.1.1 Benthic fauna

2.1.1.1 Sampling and methodology

Prior to the MNZ Permit 568 being granted, the proposed disposal area was monitored before (June 2009 and January 2010) and after (June 2010) the test disposal under MNZ Permit 555. Benthic cores were obtained at a total of ten sites: one site at the centre of the disposal area (DC), four sites at 500 m from the centre of the disposal area on North-South and East-West axes (500N, 500S, 500E and 500W), four sites at 1500 m from the centre of the disposal area on North-South and East-West axes (1500 N, 1500 S, 1500 E, and 1500 W), and one control site approximately 2.5 km south of the centre of the disposal area. Subsequent sampling was undertaken under MNZ Permit 568 and EPA consent EEZ900012 at six of the sites listed above (DC, 1500N, 1500S, 1500E, 1500W and the control site) following the disposal of 10,000 m^3 (10K; August 2013), 50,000m^3 (50K; April 2015), and 100,000 m^3 (100K; August 2015). Following the disposal of 150,000 m^3 (150K; November 2016), all ten sites were again sampled.

To comply with the EPA consent, the aim of these surveys was to test for disposal impacts at and beyond the four 1500 m sites after each disposal trigger volume (10K, 50K, 100K and 150K). Impacts could include changes in total abundance, number of species, diversity and community structure of the benthic biota. The sampling design, which includes sampling of a control site and sites within the disposal area both before and after disposal, should theoretically enable the detection of such impacts, although it is not clear whether the intention was for the data to be analysed by ANOVA-based BACI design (Before-After Control Impact techniques) or by gradient technique (Ellis et al. 2000, Hewitt et al. 2001). Moreover, clearly stated hypotheses regarding the expected impact of disposal at the sites, which can be tested by specific statistical comparisons of benthic parameters across sites and disposal volumes, are lacking from the report but would be helpful. It is often not clear what specific statistical tests are used (if any) to support the conclusions.

The monitoring of the benthic biota was based on analyses of organisms large enough to be retained on a 0.5 mm mesh (commonly termed "macrofauna"). It seems no consideration was given to the smaller but more abundant organisms that are sampled by using a finer mesh (i.e., "meiofauna", typically sampled using a 0.063 mm mesh). These organisms provide several advantages over macrofauna, such as requiring relatively smaller sample volumes, greater abundance, and higher sensitivity to environmental conditions (Kennedy & Jacoby 1999). Analyses have also shown that meiofauna also require less time for sampling and processing than macrofauna (Rogers et al. 2008).

Sediment cores were obtained using a gravity corer, which typically collect one sediment core per deployment. However, no information is given about the design of the corer, its ability to recover undisturbed samples by minimisation of bow wave effects typically associated with this type of instrument, or any quality checks conducted on the cores prior to processing (apart from stating that the depth of the sediments in each sample was typically 150 mm, and at least 100 mm). This is important as quantitative analyses of benthic fauna have to be based on data from sediment samples that are undisturbed or relatively undisturbed and which have been obtained in a consistent manner. The limited information provided in the Bioresearches Limited report does not allow to evaluate whether this was the case or not.

Different core sizes were used in the benthic surveys. In the initial pre- and post-disposal surveys conducted in June 2009 and 2010, samples each consisted of a single, relatively small 70 mm diameter core (we assume that this dimension refers to the inner diameter of the core), and no replicate samples were obtained. During the 10K survey, cores were also obtained using a 70 mm diameter core, however each sample consisted of four combined cores, and three replicate samples were obtained at each site (i.e., 4 cores per replicate × 3 replicates = 12 cores per site). During the 50K, 100K and 150K surveys, 100 mm diameter cores were used; each replicate sample consisted of two combined cores, and three replicates were obtained at each site (i.e., 2 cores × 3 replicates = 6 cores per site). This lack of consistency in core surface area and in the number of cores combined for each replicate makes the interpretation of the results difficult at best, particularly for analyses of taxon richness, diversity, and community structure (see below). This inconsistency also diminishes the ability to detect differences among sites and/or surveys, and therefore the ability to detect impacts of sediment disposal.

There is some uncertainty about the number of samples (replicates) that were obtained in the initial 2009 and 2010 surveys. In the text (p.64) it is stated that one sample per site was obtained, but in Appendix 7 it appears that up to three replicates per site were obtained. It is not always possible to determine from which site a particular replicate was obtained due to the layout of the tables. Pre-disposal data from June 2009 and January 2010 are presented together in the same table and it is not possible to differentiate between the two surveys. It appears that pre- and post-disposal data from the 2009 and 2010 surveys were combined and labelled "pilot" in Figures 3.28-3.32. This may have had the effect of smoothing any seasonal difference in the composition of benthic biota between the two surveys.

Core processing methods differed between surveys. In the initial pre- and post-disposal surveys, core samples were frozen, de-frosted in a bath of 10% formalin, sieved on a 0.5 mm mesh, then preserved in 70% isopropyl alcohol. Freezing generally results in many of the soft bodied organisms (such as polychaete worms) disintegrating, leading to underestimation of their true abundance. In the subsequent surveys, core samples were sieved on a 0.5 mm within 6 hours of collection, and preserved in a 10% glyoxal, 70% ethanol seawater solution. It is not clear what effect the different core processing methods may have had on estimates of benthic fauna parameters.

When studying the distribution of foraminiferans it is crucial to ascertain whether individuals were alive or dead at the time of sampling because shells can remain in the sediments for very long periods (centuries or more) after the death of the organism inside, to the extent that dead shells outnumber shells with living foraminiferans. Stains such as Rose Bengal are used to differentiate live (stained) from dead (not stained) individuals. Rose Bengal was only used during the 100K survey. The report states that "…no benefit was observed with the use of Rose Bengal stain…" (p.65), which was therefore not used subsequently. Instead, live organisms were identified solely based on the physical condition of the shells (uneroded), which is a method of doubtful validity. It is not clear why the Rose Bengal stain was considered of "no benefit". Elsewhere in the report, it is stated that differences in the abundance of biota in the cores between the pre-disposal and 10K surveys, and between the 10K and 50K surveys, were "…likely due to the way in which the foraminifera were enumerated" (p.75); however, no details are provided about any differences in the way foraminiferans were quantified between surveys. Together, the factors outlined above put into serious doubt the validity of the foraminiferan data presented in the report and of the analyses based upon these data, including analyses of benthic biota abundance. We consider the data on the abundance of animals (i.e., organisms other than foraminiferans, which are unicellular protists) to be more reliable, despite their low abundance at the study sites.

Organisms were not always identified to species level; several taxa were identified at family to phylum level. This relatively coarse level of identification will diminish the ability of the analyses to pick up any changes in benthic communities, which could therefore go undetected. The level of identification, however, appear to have been consistent among surveys.

2.1.1.2 Data and analyses

Trends would be much clearer in Figures 3.28, 3.29 and 3.30 if averages were shown for all 500 m sites combined and all 1500 m sites combined rather than each site separately. The abundance of benthic biota in Figure 3.28 (vertical axis) should be expressed as number of individuals per unit area rather than per sample.

The effect of different core surface area on abundance data can be corrected by using the same units across all surveys (e.g., individuals per m^2), which was done to some extent in the report. However, the use of small (70 mm diameter) cores in the initial surveys likely led to high variability among replicates and will therefore affect the ability to detect any spatial and temporal differences (i.e., it will decrease the power of the analyses). This can be seen for example on Figure 3.29 when comparing the size of error bars between initial pre- and post-disposal surveys and subsequent surveys. Conversely, combining several cores together to form a replicate, as was done in post 2010 surveys, will have the effect of underestimating the true variability of benthic communities.

No analyses were conducted to quantify the power of the statistical analyses, meaning that it is not possible to know how large a difference the analyses are able to detect. It is therefore not possible to know the analyses would enable the detection of ecologically meaningful change given the natural variability of benthic communities in the area.

Despite the limitations of the abundance data, the very low abundance of biota (two non-foraminiferan individuals) collected from six, 10 mm diameter cores at the DC site during the 150K survey is indicative of impact from sediment disposal. Little can be said about any other potential spatial or temporal trends in the abundance of benthic organism, including the existence of any difference between the1500 m sites and the control site. Therefore little can be said about any effects of sediment disposal on the abundance of benthic biota at the edge of the NDA.

The report refers to “number of species”, however a substantial proportion of the taxa identified are only identified from family to phylum level. The terms “taxon richness” are therefore more accurate. The difference in core dimensions and number of cores per replicate among the surveys prevents any meaningful comparison of taxon richness and diversity between the 2009-10 (initial pre- and post-disposal; replicate surface area = 38.5 cm^2) and subsequent surveys (10K, 50K, 100K and 150K; replicate surface area = 153.9-157.1 cm^2). The effect of replicate surface area is most obvious on Figure 3.28 for the 1500 m and control sites; which exhibit markedly higher taxon richness in the 10K, 50K, 100K and 150K surveys than during the initial pre- and post-disposal surveys. This means that any changes in taxon richness pre- and post-disturbance at the study sites cannot be quantified. Instead, any effect of sediment disposal on diversity/richness can only be evaluated through spatial comparisons among the sites during each of the 10K, 50K, 100K and 150K surveys. This limitation reduces the ability to determine whether any differences in diversity at the NDA sites are related to sediment disposal or other environmental factor(s). Having said this, the report states that taxon richness and diversity declined significantly following disposal (no details of statistical test given), except for an apparent increase during the 100K survey. This increase is said to be related to variation in the location of the DC site (150 m east of original site; no reason is given for this variation in location). Everything else being equal, the difference in core size between the initial pre- and post-disposal surveys and subsequent surveys should lead to an apparent increase in measured taxon richness and diversity with time; the fact that the opposite trend was observed indicates that the decrease in taxon richness and diversity at the DC site must have been pronounced and is probably real (i.e., benthic diversity was affected by sediment disposal in the centre of the NDA).

There is no statement in the report related to any potential difference in taxon richness or diversity between the NDA sites and the control site. Figures 3.28 and 3.30 appear to show no difference between the 1500 m sites and the control sites (i.e., no effect on diversity from sediment disposal at edge of NDA), however this is not formally tested using statistics.

The 500 m sites appear to have lower taxon richness, and potentially diversity, than the control site, but this is not formally tested. The report states that taxon richness increases with distance from the DC site, but that this increase is not statistically significant. However, it is not stated for what survey these comparisons are made, and what statistical tests were conducted; furthermore, a clear gradient in taxon richness seems to be present during the 150K survey, when taxon richness at the DC site is close to zero, whilst ranging from about 10 to 20 at the 500 and 1500 m sites. It is therefore questionable that there was "… little, if any, effect beyond the immediate disposal centre site, …" (p.71). Instead, the data indicate that the effect of sediment disposal on taxon richness may have reached beyond the DC site.

Interpretation of the multivariate analyses are complicated by factors outlined above, i.e., the limitations associated with the way foraminiferan data were obtained, and differences in core surface area between initial pre- and post-disposal surveys ("pilot") and subsequent surveys. Although abundances of taxa can be corrected for surface area, small cores tend to collect fewer individuals than large cores and therefore fewer species, which can affect multivariate community patterns. This is particularly true when abundance data are transformed in a way which increase the effect of rare species on multivariate community patterns (in this case, fourth-root transformation was applied).

The two-dimensional MDS ordination (Fig. 3.31) shows that samples obtained in the initial pre- and post -disposal survey (based on replicates consisting of a single 70 mm core) are distinct from all other surveys. Samples from the 10K survey (based on replicates consisting of four 70 mm cores) are also clearly distinct, whilst the 50K, 100K and 150K surveys (all based on replicates consisting of two 100 mm cores) cluster close together. This pattern suggests that the different methodologies used are responsible, at least to some extent, for the difference in multivariate community structure among surveys. Considering each survey separately, the following can be observed: the DC site is clustered with the other sites during the initial survey but becomes progressively more distant (i.e., distinct) from the other sites in the following surveys, (2) the 1500 m sites and the control site are relatively close together during all surveys (i.e., have similar community structure), and (3) the 500 and 1500 m sites cluster together during the 150K survey. Another MDS ordination plot focusing on the initial survey and 150K survey (Figure 3.33) shows the control site to be somewhat distinct from other sites during the initial survey (although this seems to depend to some degree on how the data are rotated), but not during the 150K survey. No statistical analyses of the multivariate data were conducted, and therefore potential impacts of sediment disposal on benthic community structure were not formally tested or quantified.

The report provides no information about how widespread the benthic communities found within the NDA may be in the wider region apart from providing data from the control site approximately 1 km away from the NDA boundary.

The report shows that sediment disposal had an impact on benthic communities at the DC site perhaps as early as August 2013 (10K survey), as suggested by a decline in abundance and shift in community structure. In November 2016 (150K survey), the benthic community was all but obliterated with dramatic declines in abundance, richness and diversity and marked shift in community structure. However, due the limitations outlined above, it is not possible to draw firm conclusions about any sediment disposal effects on the abundance, diversity or community structure of benthic biota beyond the DC site, where any potential impacts will be less pronounced and therefore less easy to detect. We therefore disagree with the conclusion that there has been "no effect as a result of the disposal activity has occurred at or beyond the 1500 m disposal boundary during or following the disposal of the 150,000 m^3 of sediments between November 2012 and November 2016" (p.75).

2.1.2 Marine mammals

Prior to each disposal event, a 30 minute hydrophone recording was made. On one occasion a sound assumed to originate from a marine mammal was identified. This recording was subsequently lost, and the origins of the sound were not confirmed. A review of the literature provides evidence for the presence of several marine mammal species off the northeast coast of New Zealand, including Bryde's whales, Humpback whales, Fin whales, Blue whales, common dolphins, and Bottlenose dolphins. Potential impacts of sediment disposal on mammals are discussed in a later section of the Bioresearches Limited report (see section 2.4).

2.1.3 Finfish

No fish surveys were conducted as part of the monitoring of the NDA, and no published data are presented in the report about the abundance and distribution of demersal and pelagic fish within the disposal area. A study is cited which recorded a sea perch and another unidentified fish 20 km northwest of the NDA. In the report, the abundance of demersal fish is assumed to be low due to the absence of reef habitats, and pelagic fish are expected to occasionally pass through the area. Potential impacts of sediment disposal on finfish are discussed in a later section of the Bioresearches Limited report (see section 2.4).

2.2 Benthic Fauna mortality and recovery rates

The dramatic decline in the abundance of benthic biota at the DC site following sediment disposal strongly suggests that there was mass mortality of benthic organisms due to smothering and/or burial. This decline in abundance (and taxon richness) was observed following the disposal of 10,000 m^3 of sediment and was most pronounced after the disposal of 150,000 m^3 of sediments. Although interpretation of the data is limited by methodological inconsistencies outlined in section 2.1.1, these findings tend to suggest that disposal of even modest amounts of sediments can lead to localised mortality of organisms at the seabed. This strong negative response of the benthic biota to sediment disposal may be related to the relatively deep (140 m water depth) location of the NDA. As noted in the report, benthic communities at these depths are naturally less exposed to wave- and current-induced disturbances than shallower communities and will therefore be more vulnerable and less resilient to human-induced disturbance.

It should be noted that whilst a decline in the abundance of benthic biota was also observed at NDA boundary sites and the control site following the disposal of 50,000, 100,000, and 150,000 m^3 of sediments, this decline was much less pronounced than at the DC site and is likely to have reflected either an artefact of sampling/processing methodology or the effect of changing environmental conditions in the wider region. It is not known whether any mortality occurred outside of the DC site.

It is not possible to determine exactly what the recovery rates of the benthic biota may be due to the short intervals between sediment disposal events. The gradual decline in abundance of benthic biota over time and with increasing cumulative sediment volumes suggests that little if any recolonization occurred. No information is given in the report about how soon the benthic sampling was conducted after the latest sediment disposal event. Sampling occurring immediately after sediment disposal may yield estimates of fauna abundance that are lower than if some time had elapsed (e.g., days, weeks, months) since the most recent sediment disposal, which would have allowed the more mobile species to burrow back to the surface and possibly recolonization by planktonic larvae. Obtaining core samples both immediately before and after each threshold sediment volume would have allowed to estimate the extent of any recovery since the last threshold was reached as well as immediate impacts of sediment disposal.

It is stated in the report that individuals present in the dredge sediments did not become established at the disposal site. It is impossible to verify this statement without data on the species composition of the sediment biota at the dredged sites.

It is stated that mortality is limited to less than 500 m from the DC site, which is consistent with the physical dimensions of the sediment mound estimated to be 375 m long from east to west, 250 m long from north to south, and 1.25 m thick in its centre (it is not stated in the Bioresearches Limited report whether multibeam or core data were used to derive these estimates and what uncertainty is associated with these estimates). However, it is not possible to judge the validity of this statement due to the way the data are presented and analysed in section 3.5 of the Bioresearches Limited report. Although mortality of benthic biota may be mostly limited to the mound footprint, no projections are given about the future dimensions of the mound as greater volumes of dredge spoil sediment are disposed within the NDA. The extent of future benthic mortality is therefore not clear.

It is stated that "mobile biota at the disposal site are not common, (…)" (p.80). However, no information is given as to which species/taxa are mobile and which are sessile. An analysis of functional traits of the benthic biota, including mobility, feeding modes, and life-cycles characteristics is among the most useful and meaningful method to assess the ability of natural communities to withstand sedimentation and turbidity impacts as well as their ability to recover following these impacts (Bremner 2008).

Estimates of recovery times for benthic communities following disturbance are provided using examples from New Zealand and abroad. Recovery times range from six months to four years depending on the nature of the communities. Because the benthic community at the NDA is relatively deep and undisturbed, recovery from disturbance is likely to be at the higher end of this range.

The potential effects of increased frequency of sediment disposal are not considered in addition to effects of increased volumes. More frequent disposals are likely to further limit the ability of benthic communities to recover.

Differences in the physico-chemical characteristics of the dredged spoil sediments and of sediments naturally occurring at the NDA will also likely interfere with recovery. The introduction of sediment with different properties may lead to the development of a different benthic community composed of species with different requirements than the species present pre-disposal. Colonisation by new species may take longer because they inhabit different environments not in the immediate vicinity of the disposal area.

2.3 Potential for spread of invasive species

The terms 'invasive' and 'non-indigenous' are used interchangeably in the Bioresearches Limited report, however this is incorrect. A non-indigenous species is one which is not native/indigenous to a particular country, whereas an invasive species is a non-indigenous species which demonstrates invasive characteristics in an area of establishment. Several of the non-indigenous species discussed are not actually considered invasive.

The information provided on each invasive species is based on benthic sampling conducted between 2013 and 2016 using sediment cores and benthic invertebrate identification. There does not appear to be any reference to literature or online resources which contain a more up to date account of the presence of invasive species in some of the source areas (particularly those located within the Waitmata Harbour or in close proximity) – for example, the Marine Biosecurity Porthole and the MPI Marine High-Risk Site Surveillance Technical reports. It is also good practice to cite sources of ecological information.

It is stated in the report that the greatest threat of spreading non indigenous species to areas not previously colonized would be due to natural dispersal of larval or planktonic larvae from released dredge spoil. However, the biofouling organisms on the barge and any accidental spillage of material in transit are both significant vectors for the spread of non-indigenous species and neither of these have been discussed in the Bioresearches Limited report.

In his evidence, Simon West states that hull biofouling is the most likely path for the spread of non-indigenous species. We agree with this statement.

With regards to the Unwanted Organisms which have been described in the report and known from several of the marina areas which will be dredged, under the Biosecurity Act no person can knowingly transport any material or equipment which may contain these organisms without undertaking suitable measures to ensure the pest is removed or rendered non-viable. Consideration needs to be given to the dredge spoil from areas where the Unwanted Organisms are known. While we agree with Simon West's evidence (statement 10.1) that the risk of spillage is probably low during transportation of dredge spoil to the dump site, the dredged sediments will contain Unwanted Organisms under the Biosecurity Act, which could survive if the spill occurred in shallower water.

There is no reference made to the translocation of toxic dinoflagellate cysts. These organisms have microscopic resting stages which can remain viable in seabed sediments for long periods. Seven species of dinoflagellate cysts were collected from sediments in the Port of Auckland during 2006, two of which are known to be toxin-producing (*Lingulodinium polyedrum* and *Gymnodinium catenum)*. Blooms of both species may cause problems for aquaculture and recreational harvesting of shellfish. Dinoflagellate cysts transported in the dredged sediment would likely survive the dredging and transportation process. In addition, the disposal of dinoflagellate cysts into colder offshore waters may mean that cysts remain viable for a longer. Sediments which remain suspended in the upper water column might be spread from offshore to nearshore by tides and currents. Both *G. catenatum* and *L. polyedrum* are widespread around the Hauraki Gulf, and could potentially cause a problem if cysts of either species were disturbed by dredging and dumping.

Because of the high buoyancy of eggs and larvae of invertebrates relative to sediment particles, the spread of planktonic larvae should be modelled using surface trajectories rather than mid-water trajectories only. Surface trajectories tend to result in a greater probability that planktonic larvae will reach the shorelines to the west of the disposal area.

In the summary of the Mediterannean fan worm *Sabella spallanzanii*, the Bioresearches Limited report states that since no fan worms were detected on soft sediments of the source locations, the risks of spread through transport of dredged sediments is low. However, *Sabella spallanzanii* is very common on soft sediments throughout the Waitemata Harbour, and they should therefore be considered to pose moderate risk. The barge and associated vessels should be considered as potential vectors for the spread of *S. spallanzanii*. This worm is a prolific vessel fouler and its spread would be more likely to occur through biofouling than within the dredge spoil.

No consideration has been given to the translocation of clubbed sea-squirt *Styela clava* and encrusting bryozoan *Watersipora subtorquata* through biofouling. The latter species in particular is a prolific vessel fouler. While it is unlikely that they will survive on the sediment at the disposal site, they may survive at a shallower site if dislodged in transit.

In his evidence, Simon West states that *Undaria* distribution in New Zealand is strongly linked to commercial ports, which suggests that it is being transported around the regions by attachment to commercial ships. This is incorrect. *Undaria* is a prolific hull fouler of every vessel – including slow moving tugs and barges. While it is prolific in commercial ports, it is also well established in marinas and harbours. Translocation of *Undaria* is possible through biofouling on the dredge and tow vessel, and this can only be managed through hull management plans.

2.4 Finfish, birds and mammal disruption

2.4.1 Fish

Lack of any data on the distribution of pelagic and demersal fish in the NDA makes predicting impact of sediment disposal difficult. The authors did not make use of publicly available sources, which include reports (e.g., Anderson et al. 1998; https://nzobisipt.niwa.co.nz/resource?r=obisprovider), books (e.g., Roberts et al. 2015), and databases (MPI, Te Papa) to provide a list of species either known to be present or likely to be present in the region surrounding the NDA. It is therefore not possible to assess whether any rare species or species with restricted geographical distribution may be present in the area.

If we assume that the sediment plumes generated by sediment disposal are confined well within the NDA and are relatively short-lived (MacDiarmid et al. 2011), direct impacts on pelagic fish are likely to be limited. Indirect impacts through effects of increased turbidity on surface primary production are also likely to be negligible whether disposal occurs during the day or night.

Impacts on demersal fish are likely to be more pronounced than for pelagic species. Impacts may occur directly through burial following rapid sinking of the heaviest sediment particles or through the generation of fine sediment plumes immediately following disposal which may prevent visual predators from foraging and create unfavourable living conditions. Accumulated fine sediments from dredge spoil disposal at the seabed may be prone to resuspension by currents and also create more persistent turbid conditions. The creation of sediment mounds at the disposal sites will also negatively impact benthic prey species (see section 2.1.1) and therefore force demersal fish to forage elsewhere. These impacts are likely to be limited to areas in the immediate surroundings of the disposal sites, which will expand if greater volumes of sediment are disposed of.

2.4.2 Mammals

The northeast region of New Zealand, including the Northern Disposal Ground is a known habitat for a number of marine mammal species, and is used as a migratory corridor in addition to regular feeding and nursery grounds. Considering that during each disposal event the majority of sediment is expected to fall directly to the sea bed, it is unlikely that the increased volume of dumped material will affect marine mammals in this area. The current consent controls, which help prevent disposal of material if marine mammals are present in the area, provide largely adequate mitigation of adverse effects to marine mammals.

While marine mammals are distributed widely around the NDA, there is no known hotspots of marine mammal activity within the area as opposed to the surrounding areas and there are no known vulnerable ecosystems that provide habitat in the area.

2.4.3 Birds

Section 4.5 of the Bioresearches Limited report notes that any effects on seabirds will be indirect, localised to the disposal area and could potentially include reduced prey availability. The report goes on to conclude that any small reduction in prey availability in the NDA is not likely to adversely affect any bird species. While this conclusion is reasonable, there are other potential effects on seabirds that have not been considered. For example, increased turbidity following disposal of material has the potential to reduced foraging efficiency in those seabird species that pursue and capture prey underwater. Again, this temporary and localised effect is unlikely to adversely affect seabirds, which are highly mobile, and which occupy relatively large ranges relative to the area affected by disposal of material.

The evidence of Simon West includes a list of 34 seabird taxa that could occur within the NDA, together with conservation status information, population estimates and whether breeding occurs on nearby islands. The list does not include any albatross taxa, several of which could be expected to occur within the NDA from time to time, but overall the list is comprehensive. Mr West notes that black petrel is the species of greatest potential concern based on a number of criteria, including a relatively low population size, nearby breeding sites and a threatened conservation status. New Zealand storm petrel also satisfies these criteria and could also be a species of potential concern. Mr West considers an extensive range of potential adverse effects on seabirds: prey availability, increased turbidity, contaminants, vessel movements and vessel lighting, underwater noise and cumulative effects. Overall, Mr West concludes that potential effects on seabirds, including cumulative effects, will be less than minor to negligible and that the disposal of marine sediments at the NDA is not expected to adversely affect any seabirds at population level. These conclusions are reasonable.

2.5 Biological diversity and integrity of species, ecosystems and processes

It is clear from the data presented in the report that the abundance, diversity and community structure of the benthic biota directly below the disposal site has been impacted by sediment disposal. However, due to inconsistencies in sampling methodologies and limitations of the methods and analyses used, it is not possible to determine conclusively how far the impact may reach within or beyond the NDA. Given the relatively small size of the mound created since the beginning of sediment disposal, it is unlikely that impacts of sediment disposal to date have reached beyond the NDA boundary.

The current assessment of impacts is based on the disposal of 150,000m^3 of sediments over approximately six years, or about 25,000 m^3 per annum on average. CRL is requesting a permit which would allow a five-fold increase in the limit of sediment disposal (from 50,000 to 250,000 m^3 per annum), which could represent up to a 10-fold increase in the volume of sediment disposal per annum. Impacts of sediment disposal on the environment are therefore likely to become more severe and widespread if the disposal consent is granted. The extent and severity of these impacts will largely depend on the location of disposal site(s) and the frequency at which sediment disposal occurs. The proposed sediment disposal scheme (section 5 of Bioresearches Limited report) would expand the disposal of sediment outwards to sites 200 and 400 m away from the DC site. The mounds created at each of these sites, where it is planned to dump 250,000 m^3 of dredge spoil sediment, will likely exceed the dimensions of the current mound (estimated as 375 m by 250 m and 1.25 m thick). The effects of sediment disposal will therefore extend beyond 500 m from the DC site and may well reach 1000 m from the DC site, and possibly further.

In order to determine whether soft sediment habitats cover the entirety of the NDA, it is necessary to obtain and analyse multibeam backscatter data across the entire area. Without such analyses, it is impossible to rule out the presence of hard substrates which may harbour species different from those inhabiting soft sediments, including vulnerable taxa such as stony corals. The core sampling which has taken place to date only covers a small proportion of the NDA and the absence of coral in these samples does not conclusively show that they are absent.

A recent underwater video study was conducted off Great Barrier Island, with the southwest corner of the study area coming within 10 km of the NDA boundary (Lee et al. 2015). The aim of the study by Lee et al. (2015) was to provide a baseline to support research and management should the area become a reserve. The study found that at 90 to 140 m depth, most of the seabed was muddy with occasional patches of rocks and boulders. These patches of hard substrates harboured diverse epifaunal assemblages of sponges, coral and bryozoans. Given the proximity of the area studied by Lee et al. (2015) to the NDA, we consider it likely that similar small patches of hard substrates with epifaunal communities are present within the NDA. Such epifaunal communities are typically vulnerable to physical disturbance and will likely be impacted if they are in the vicinity of a sediment disposal site. The sampling that has been conducted to date within the NDA is not appropriate for determining the distribution and extent of epifaunal communities, which are not taken into consideration in the impact assessment. Evaluating the presence and distribution of epifaunal communities can only be done using high quality seabed image/video data.

2.6 Vulnerable ecosystems and habitats of threatened species

We accept that no vulnerable marine ecosystems, sensitive marine benthic habitats, or threatened benthic invertebrate species have been encountered within the NDA. However, the section 4.8 of the Bioresearches Report is fairly brief, reflecting perhaps the assumption that such ecosystems and species do not exist in the NDA.

The order Scleractinia (stony corals) includes many species, most of which are colonial. Although the deeper, azooxanthellate stony corals don't form coral reefs in the way that many shallower species do, some colonial species do form extensive three-dimensional thickets that can cover broad areas of the seafloor and are recognized as sensitive marine benthic habitats (MacDiarmid et al. 2013). As noted in the Bioresearches Limited report, these and a range of other coral species are protected by a recent amendment to Schedule 7A of the Wildlife Act (1953), meaning that it is illegal to deliberately collect or damage these species. It is also noted that there are a few records of some shallower occurring species from north of the NDA but exact localities are not provided. The NIWA Invertebrate Collection (NIC) database contains numerous records of Scleractinian corals along the continental shelf east of Great Barrier Island and although none of these appear to be within the NDA, some are very close (within 5 km) including *Kionotrochus suteri*. Other scleractinians recorded from nearby (within about 25 km) include mostly solitary cup corals such as species of *Flabellum*, *Stephanocyathus*, and *Caryophyllia*, but a shallow thicket forming species (*Goniocorella dumosa*) has also been recorded nearby at about 350 m water depth. Although this is deeper than the NDA, *G. dumosa* can occur in depths of less than 100 m. In addition, one or two records of other species protected under the Wildlife Act, i.e., Antipatharia (black coral) and Gorgonian coral species (*Antipathella* sp., *Saropathes* sp., Pleaxauridae) have been recorded nearby at about 350 m water depth, and these species too are known to occur within the depth range of the NDA.

Other sensitive marine habitats (*sensu* MacDiarmid et al. 2013) or Vulnerable Marine Ecosystems (VMEs; Parker et al 2009) such as sponge gardens, brachiopod beds, rhodolith beds, and sea-pen fields that could potentially occur in the NDA are not specifically considered in the Bioresearches Limited report. An examination of the literature and online databases would help to confirm whether or not such habitats exist or are likely to exist in the NDA.

The Department of Conservation published a list of threatened marine species which should be considered in relation to the known distributions of such species and the recorded biodiversity of the

NDA region and surrounding area based on monitoring surveys and publicly available databases (Freeman et al. 2014).

Although it may be unlikely that the NDA hosts any substantial or unique ecosystems or collections of threatened species given the apparently relatively uniform, flat, sand/mud substrate typical of the continental shelf of the broader region, and that none were collected during predisposal or post disposal monitoring studies, the records noted above indicate that is quite possible that some individuals of a limited number of protected coral species do exist there. These delicate and immobile species would have little chance of surviving being smothered in dredge spoils.

A further consideration is the smothering effect of the sediment plume on benthic organisms such as corals, sponges, and bryozoans that live down-current from the NDA. Modelling by BECA indicates that the sediment plume dissipates rapidly, but consideration should be given to review of the literature regarding the vulnerability of sensitive organisms to varying levels of smothering.

3 Assessment of proposed monitoring – understanding the effects of the proposed dumping activity

This section provides a review of the proposed monitoring outlined in section 8 of CRL's application document entitled "Marine consent to dump application and supporting impact assessment", sections 5 and 6 of the Bioresearches report entitled "Northern disposal area: assessment of source material, ecological and sediment quality effects assessment of disposal", and chapter 7 of the Beca report entitled "Northern disposal area: physical oceanography assessment, dredge material disposal options and international deep water disposal sites". Evidence provided by Simon West, David Hay and Simon Childerhouse on behalf of CRL on 25 October 2018 was also considered. When undertaking the review we specifically aimed to : (1) assess the adequacy of the monitoring proposed in the application documents to understand the effects of the proposed dumping activities on the marine environment, (2) describe the features of an effective monitoring approach in the circumstances and recommend to the Decision-making Committee what, if any, changes, or additions, could be made to the proposed approach in order for the monitoring approach to be effective at understanding the effects of the proposed dumping activity, and (3) recommend any additional information, if any, that would assist the Decision-making Committee in determining what would be an effective monitoring approach in the circumstances.

3.1 Disposal mound

Accurately measuring changes in the dimensions of the disposal mound is essential to estimate the extent of sediment disposal effects on the surrounding ecosystem. It is important to ensure that disposal material does not spill over the boundary of the NDA due to lateral transport of sediment, as this is a condition of the consent being sought.

Until now, sediment disposal has occurred at a single site at the centre of the NDA. The disposal of a cumulative 150,000 m^3 of sediment (as of November 2016) has resulted in an elongated disposal mound estimated to be approximately 375 m long (east-west axis) and 250 m wide (north-south axis). The Applicant proposes to expand the area where sediment disposal occurs to accommodate larger sediment volumes (up to 250,000 m^3 per annum). It is proposed that disposal occurs at 13 adjacent sites, each measuring 100 m in diameter, located within a 500 m radius of the disposal centre. Disposal will alternate between the 13 sites each time a cumulative volume of 250,000 m^3 has been reached at a given site. These measures were proposed to prevent the formation of a single, large sediment mound that may be prone to slumping whilst keeping the disposed sediments well within the NDA boundary. The Applicant believes that the benthic biota at the 500 m and 1000 m sites will likely be impacted, but that impacts will not reach the NDA boundary.

Given what we know about the dimensions of the existing mound, it is clear that the mounds created at each of the 13 sites will spill over into adjacent sites and coalesce to form a large mound which will extend beyond the 500 m central radius of the NDA. It is unclear how far the new coalesced mound will reach, and it is therefore important to monitor the growth of the new mound to ensure it does not reach the NDA boundary. Monitoring will need to be adaptive given the uncertainty regarding the growth of the disposal mound.

In his evidence, David Hay states that accumulation of sediment may occur outside the NDA at a rate of up to 6-7 mm per year due to the plume dispersal by currents. This accumulation of fine sediments each year could lead to the accumulation of a relatively thick layer of disposal sediments outside the NDA over a period of several years. This raises the question as to what is considered to be part of the sediment mound, and how thick a layer of settled dredge spoil sediment (deposited either immediately after disposal or through dispersal of fines by currents) needs to be detected at a particular site before the mound is considered to have extended to that location. Unless a clear settled sediment thickness threshold is set, determining the extent of the disposal mound will remain a subjective process.

Monitoring of the disposal mound to date has been conducted using two methods, i.e., bathymetric surveys and sediment core sampling. The same methods are to be used under the new application and monitoring is to be conducted annually or after every 125,000 m^3. Bathymetric surveys will be conducted using equipment achieving MB-2 accuracy or better and will also include multibeam acoustic backscatter and/or side scan sonar to provide an additional measure of the accumulated seafloor sediments. This methodology is appropriate for quantifying changes in seafloor topography at the disposal site and the wider NDA, but it has limited ability to detect relatively subtle changes in sediment thickness resulting from sediment disposal. More specifically, it is stated in the Bioresearches Limited report that the current disposal mound, which is conical in shape, is estimated to be 1.25 m thick at its center, but the accuracy for LINZ standard MB-2 at 100 and 150 m water depth is 1.58 and 2.30 m, respectively. Given this relatively low level of accuracy of the bathymetry data, it is unlikely that bathymetric surveys will provide an accurate picture of the extent of the disposal mound, particularly its outer edge. We recommend that maps based on the bathymetry surveys be provided to the EPA in the future to help understand how the data are being interpreted to determine the extent of the mound.

Sediment core sampling provides a potentially more sensitive method to detect the extent of the disposal mound through analyses of sediment colour, grain size, and contaminants. The proposed sampling design, including spatial distribution and frequency of sampling, appears appropriate. However, in order to provide confidence in their ability to detect the presence of disposal sediments, the Applicant needs to provide more details of the methods used to obtain sediment data from cores.

First, analyses need to be based on relatively undisturbed cores which preserve the uppermost layer of sediments. If the cores are obviously disturbed due to bow wave effects of the gravity corer or the closing mechanism, then it is impossible to gauge what sediment layers are being characterized; if the surface layer of disposal sediments is lost, the extent of the mound may be underestimated. Issues with core disturbance can only be addressed through modification and testing of the existing gravity coring device or use of a more appropriate instrument such as a box-corer or a grab designed to eliminate 'washout' on ascent.

Visual observations of sediment characteristics (e.g., colour) must be made with appropriate colour charts and comparators. If no such tools are used, observations will most likely suffer strongly from perception bias, and will likely differ among analysts, sites and/or surveys. Such variation would make colour observations of limited value. The ability to detect the presence of colour difference associated with the presence of dredge spoil sediment will diminish in proportion with the time elapsed since the last sediment disposal event. Reoxidisation of suboxic dredge spoil sediments following disposal will decrease the colour contrast between the 'old' sediments and newly settled sediment. The timing of coring should therefore maximise the ability to detect colour differences and be as consistent as possible among surveys.

The analysis of grain size may provide a useful tool for the early detection of disposal sediment at the seabed, however only few details about the methodology used for these analyses are given in the proposed monitoring plan. It is not clear which sediment layers were used (and are to be used) for grain size analyses. It appears that past analyses may have been conducted on vertically homogenised samples (top 5 cm), which would lead to the dilution of any signal present at the sediment surface and would therefore not be very sensitive in detecting settlement of fine disposal sediments. In his evidence, Simon West argues that since bioturbation will result in rapid mixing of any recently settled dredge disposal sediments into the top 7 cm of underlying sediments, it is not useful to analyse vertical sections of sediments. Bioturbation, however, can occur at varying rates depending on local conditions and the nature of the benthic biota. It is not clear how long it would take for freshly settled disposal sediments to be bioturbated at the NDA sites, but it is conceivable that settled sediments may remain at the surface for elongated periods (i.e., weeks to months) given the relatively deep location of the NDA, the low density of benthic biota, and apparent absence of large bioturbators such as burrowing urchins. Since settlement of a relatively thin layer of sediments (in the order of 1 cm or less) is likely to be ecologically significant (Gibbs & Hewitt 2004, Lohrer et al. 2006), detection of such a layer is deemed important for monitoring purposes. We therefore recommend that grain size analyses be conducted on three sediment layers, for example: surface (0-2 cm), shallow subsurface (2-5), and deep surface (5-bottom of core). This kind of sampling scheme would be more likely to detect the settlement of fine disposal sediment by providing stratified vertical grain size information. A similar vertically stratified sampling scheme would be advisable for colour and contaminant analyses to provide greater sensitivity. It should be noted that this sampling scheme relies on obtaining undisturbed sediment cores.

3.2 Benthic biota

3.2.1 Sampling design

The sampling design proposed by the Applicant for monitoring of the benthic biota is not optimal. Sampling is to be initially conducted at the disposal centre site, four NDA boundary sites (1500 m) and a control site. It is stated that: "additional sites will be sampled at 500 m intervals along the axes from the disposal centre site to the 1500 m sites, once presence of disposal material has been detected within 250 m of the sample site" (p. 94). We recommend the following improvements to the sampling design:

- Sampling should be conducted at two additional control sites more or less evenly distributed around the NDA and at similar depths (140 m). Whilst this additional sampling will require more time and resources, it will reduce the risk of observing a significant difference in community parameters between the control and NDA boundary sites due to environmental variability that is restricted to the control site. Such variability is apparent in analyses of community structure in the Bioresearches Limited report (see Figure 3.32). By including control sites from other locations around the NDA, the effect of variable environmental conditions on benthic biota surrounding the NDA will be averaged out, and it will therefore be less likely that a difference is found between the control sites and NDA boundary sites when in fact there is none. Additional control sites will also provide more robust analyses.
- Given the relatively long intervals between core sampling events (every 125,000 m^3), it is likely that by the time disposal material is detected within 250 m of a 500 m, 1000 m, or 1500 m site, the benthic biota will already have been affected. The opportunity of comparing pre- and post-disposal communities would consequently be lost. We therefore recommend that four sites, located along the axes and 1000 m from the disposal centre, be added to the sampling design. Regularly sampling these sites would provide information on pre-disposal communities and an early warning sign that the sediment mound is approaching the NDA boundary.
- We see less value in sampling the 500 m sites because they may have already been impacted by sediment disposal and there is little doubt that future sediment disposal will reach these sites as greater volumes of sediment are dumped. Priority should therefore be given to sampling the 1000 m sites and additional control sites as recommended above.

3.2.2 Hypotheses and statistical tests

Clearly stated hypothesis(es) regarding the expected impact of disposal at the sites, which can be tested by specific statistical comparisons of benthic parameters across sites and disposal volumes, are lacking from the Bioresearches Limited report but need to be included in future analyses. We recommend that in the future, the following hypothesis be explicitly tested at every survey:

- That the abundance, taxon richness, diversity and community structure of benthic biota at the NDA boundary sites (1500 m) do not differ significantly from the control site(s)

This hypothesis will test for the effect of sediment disposal at the edge of the NDA, which is an important condition needing to be met for benthic biota monitoring under MNZ Permit 568 and EPA consent EEZ900012. We emphasise that without clearly stated statistical tests for each of the community parameter, the EPA will not be able to verify whether this condition has been met.

Whilst detecting a significant change in community parameters may indicate an impact from sediment disposal, the magnitude of this impact may not be deemed ecologically significant. In his evidence (Attachment one, 5c) David Hay proposes to introduce a consent condition stipulating that the activities shall not result in a change (presumably a reduction) in overall abundance or number of macrofaunal taxa by more than 50% of the long-term average at any of the NDA boundary sites. The long-term average is defined as the average of all prior monitoring results obtained under MNZ Permit 568 and EPA consent EEZ900012 at each of the respective sampling sites. This new condition helps better define the extent of the impact deemed to be ecologically significant. However, it is problematic due to the many inconsistencies in the way the macrofaunal data were obtained. We recommend that data from the 50,000, 100,000 and 150,000 m^3 surveys be used instead, because the benthic biota were sampled in a relatively consistent manner across the three surveys. We note however that it is not clear from the Bioresearches Limited report whether foraminiferans were processed and quantified in a consistent manner across these three surveys. Whichever data end up being used to define the long-term average, we recommend that the exact abundance and taxon richness figures be supplied to the EPA to avoid any confusion. We also recommend that a power analysis be conducted to determine the likelihood of detecting a 50% change in macrofaunal abundance and taxon richness at the NDA boundary sites using the proposed sampling methods. A power of 0.8 (i.e., a 80% likelihood of detecting a specified difference) or higher is typically deemed sufficient. If the power of analyses is too low, it will be necessary to change the sampling design. Determining the power of analyses is the best way to provide confidence that ecologically significant impacts from sediment disposal at the NDA boundary will be detected, and that the consent conditions will therefore be met.

We recommend that future reporting of analyses includes details of statistical analyses (for example, details of ANOVA for univariate metrics and PERMANOVA for multivariate metrics) so that the robustness of the findings can be evaluated.

3.2.3 Methodology

More details of the coring instrument used, core quality check procedures, and any considerations for alternative sampling methods, have to be provided. This is because analyses of sediment and benthic biota need to be conducted on undisturbed or relatively undisturbed cores. The Applicant may need to consider a box-corer or a grab designed to eliminate 'washout' on ascent if the gravity corer cannot obtain sufficiently undisturbed cores.

It is important that analyses of benthic biota be based on cores of consistent sediment depth (e.g., 10 cm). It is not clear how much variation in core depth was present in previous surveys, which may have introduced additional variability in benthic biota community parameters. Core dimensions (surface area and depth) need to be kept consistent during all surveys. During the last three surveys (50K, 100K and 150K), each replicate consisted of two 10 mm diameter cores combined. Whilst combining cores to form replicates is not usually recommended, the same procedure should be used in future surveys for the sake of consistency and to allow meaningful comparisons among surveys.

Consistent methods need to be used for the chemical fixation/preservation of core samples. Ideally, samples should be fixed in 10% buffered formalin before being transferred to 70% ethanol, or samples should be transferred directly to a 70% ethanol solution. Benthic biota should never be frozen because this method leads to fragmentation of soft-bodied taxa which may get lost from the sample or become unidentifiable.

We have serious reservations regarding the quality of the benthic biota dataset obtained during past surveys (see section 2.1.1). Foraminiferans were the dominant organisms in the core samples yet no stain was used to differentiate between dead and live individuals except in one survey. It also appears that unspecified inconsistencies in the way foraminiferans were enumerated between surveys have led to large variation in community parameters. In future surveys it is essential that measures such as the use of Rose Bengal stain be used to differentiate between live and dead foraminiferans, and that the same methods be used for their enumeration during every survey. Estimates of benthic biota community parameters may also have been affected by the loss of the surface sediment layer (where most of the benthic biota is usually found) due to the use of a gravity corer. This could potentially explain why the abundance of benthic biota was low in the NDA and control site. We reiterate the importance of using a sampling device capable of retrieving undisturbed sediment cores.

We recommend that benthic biota be identified to species whenever possible. Impact analyses based on higher taxa (genus and above) are less meaningful and sensitive than analyses based on species data.

It his evidence (Attachment one, 8dii), David Hay introduces a consent condition stating that a photographic record of the seabed macrofauna will be obtained from each of the NDA boundary sites. We understand that this condition was introduced in response to input from the Department of Conservation. However, it is unclear to us whether photographic records refer to images of the core samples, the biota extracted from those samples, or images of the seabed. It is also unclear what information these photographic records are meant to provide and for what purpose.

The applicant should consider sampling meiofauna (small organisms retained on a 0.063 mm mesh) in addition to macrofauna. Meiofauna provide several advantages over macrofauna, such as requiring relatively smaller sample volumes, greater abundance, and higher sensitivity to environmental conditions (Kennedy & Jacoby 1999). Analyses have also shown that meiofauna also require less time for sampling and processing than macrofauna (Rogers et al. 2008). The use of meiofauna could help circumvent issues related to the low densities of macrofaunal at the NDA.

The timing of each coring survey relative to the most recent sediment disposal event should be kept as consistent as possible among surveys due to the potential of recovery following disposal. Obtaining core samples both immediately before and after each threshold sediment volume would allow to estimate the extent of any recovery since the last disposal as well as the immediate impacts of sediment disposal.

We recommend that analyses of functional traits be conducted on benthic biota datasets from past and future surveys. Analysis of functional traits including mobility, feeding modes, and life-cycles characteristics is among the most useful and meaningful method to assess the ability of natural communities to withstand sedimentation and turbidity impacts as well as their ability to recover following these impacts (Bremner 2008).

3.3 Vulnerable ecosystems and habitats of threatened species

As outlined in section 2.5 of this report, we consider it likely that small patches of hard substrate with associated sessile epifaunal communities are present within the NDA based on the presence of such substrates and communities in nearby areas (Lee et al. 2015). The Department of Conservation also commented that other habitats could be present within or near the NDA. Sessile epifaunal communities, which could include protected organisms such as stony corals, are typically vulnerable to physical disturbance and will likely be impacted if they are in the vicinity of a sediment disposal site. Potential impacts from smothering by the sediment plumes of organisms such as corals, sponges, and bryozoans that potentially live within and down-current from the NDA need to be considered. Modelling by BECA indicates that the sediment plume dissipates rapidly, but we recommend that the literature regarding the vulnerability of sensitive organisms to varying levels of smothering be reviewed.

Marine charts provide bathymetry data at a coarse level and are not meant to be used to identify the presence of smaller reefs or hard substrates beyond the shallow subtidal zone. In addition, the sampling that has been conducted to date within the NDA is not appropriate for determining the distribution, extent or composition of epifaunal communities. The likely presence of these communities is not taken into consideration in the impact assessment. Evaluating the presence and distribution of epifaunal communities will require representative, high quality seabed image/video transects to be carried out across the NDA.

3.4 Marine mammals

The Approved Disposal Site Management and Monitoring Plan (which is referred to in Appendix 9 of the CRL application) outlines specific measures to ensure that sediment disposal does not significantly affect marine mammals within the NDA. These measures include:

- Both hydrophone and visual observations will be used to detect marine mammals from the tug/barge. Thermal imaging will also be used to detect marine mammals at night.

- The site is checked for marine mammals by the tug/barge skipper for at least 30 minutes immediately prior to any dumping activity to confirm there are no marine mammals in the disposal area.
- If a marine mammal is detected, disposal can only occur after any observed marine mammals have moved outside of the disposal area, or in the event that the marine mammal has dived, they are not observed visually or heard on the hydrophone for 30 minutes following the dive.
- Visual and acoustic monitoring will be conducted from at least 200 meters from the location of the barge where the disposal takes place.
- Hydrophone recordings will be retained for a year by the permit holder and will be made available to the EPA upon request.

Overall, we find the proposed monitoring for management of risks to marine mammals satisfactory. However, improvements could be made as explained below.

3.4.1 Visual detection of marine mammals

The proposal does not state the distance a marine mammal must disperse from the disposal area before disposal can occur. We recommend that disposal should only occur after a marine mammal has moved two kilometers outside of the disposal area (as determined by reticule binoculars). However we recognize that this may not be practical if sediment disposal occurs at night.

The proposal states that one tug/barge operator will be responsible for marine mammal visual detections. We suggest that two marine mammal observers conduct visual observations to increase the chance of detecting mammals from either side of the vessel.

The proposal does not include the use of trained marine mammal observers for visual detections. We understand that employing trained marine mammal observers for 30 minutes of monitoring for a 20-24 hour trip may not be practical or cost effective, despite the increased level of efficiency this may provide. Below we recommend the use of a trained passive acoustic monitoring operator to detect real time acoustic data. This passive acoustic monitoring operator should also be a trained marine mammal observer who could assist and train the tug operator with visual observations.

We note that visual observations are proposed at night however this method is not 100% effective due to the limited field of view and limited effectiveness of thermal imaging for marine mammals (due to their large blubber layer). The use of a hydrophone at night for acoustic detections will be a much more robust method for identifying marine mammals. The effectiveness of acoustic detection will however be dependent on the types of hydrophones used and the level of experience of the persons operating this equipment. To limit the reliance on acoustic equipment, disposal operations could be limited to daylight hours to increase the chance of detecting marine mammals within the region. Efforts should be made to conduct visual monitoring as close to the disposal location as possible to increase the likelihood of detecting mammals in the vicinity.

3.4.2 Acoustic detection of marine mammals

The proposal states the type of hydrophone and recorder to be used for acoustic detections but does not state how real time data will be interpreted from the hydrophone. For example, if the hydrophone is going to be used for 30 minutes before the disposal activity to detect marine mammal presence, then acoustic recordings will need to be interpreted in real time.

The proposal does not specify the qualifications of the individual(s) who will be operating or interpreting the hydrophone recordings. Recordings should be interpreted by a qualified passive acoustic monitoring operator (PAMO).

The SQ26-08 hydrophone detects and records sound up to 40kHz and therefore will not be able to detect very high frequency sounds (i.e. small cetaceans such as the Māui dolphin). A high and low frequency hydrophone could be used to expand the detection range.

The proposal states that the hydrophone will be deployed from the tug vessel. As tug vessels usually have a strong low frequency noise this will likely mask any detections from baleen whales (which also produce low frequency vocalisations). To improve the detection of baleen whales the tug should stop when hydrophones are being used and all operational noise should be reduced to a minimum (i.e. generators, ecosounders and engine noise reduced).

Efforts should be made to conduct acoustic monitoring as close to the disposal location as possible to increase the likelihood of detecting mammals in the vicinity.

Hydrophone recordings should be retained for a year by the permit holder and be made available to the EPA and research providers (i.e. Universities or CRIs) upon request.

3.4.3 Record keeping and alternative technology

The proposal does not state how marine mammal visual or acoustic monitoring or detections will be recorded. We recommend that the person(s) conducting observations should follow a similar methodology outlined in the Seismic Code of Conduct (https://www.doc.govt.nz/our-work/seismic-surveys-code-of-conduct/notification-and-reporting/) for recording monitoring periods (i.e. time when monitoring started and ended), weather conditions (i.e. Beaufort sea state), location of monitoring (i.e. from the tug or barge), marine mammal detections (i.e. species and location) and methods used to detect them (i.e. binoculars, naked eye, hydrophone or thermal imagine).

Whilst the proposed monitoring measures are satisfactory, the use of more advanced technology would allow more detailed information about the occurrence of marine mammals within the NDA as well as provide more confidence in assessing potential impacts from sediment disposal. Permanent hydrophones (such as a Soundtrap device) could be deployed to record marine mammal activity. A Soundtrap would allow measurement of the seasonal presence of marine mammals within the NDA and would indicate any changes in marine mammal presence before, during or after disposal events. More information on Soundtraps can be found here http://www.oceaninstruments.co.nz/.

3.5 Birds

In his evidence, Simon West notes that while vessel lighting at night has the potential to attract seabirds, the general risk of light attraction and collision would be similar or less than any other large vessel and would not be significant at a population level. This assessment is reasonable. Mr West also refers to proposed condition 24(i) from the evidence of David Hay, which states that 'lighting is to be inward facing and minimised as far as practicable while still complying with any relevant regulations'. This condition should, as Mr West notes in his evidence, minimise the potential effects (of attraction to vessel lighting at night) to nocturnal seabirds.

3.6 Spread of non-indigenous species

MPI has jurisdiction over biosecurity risks both in the entire EEZ, and it considers that there are limited biosecurity risks associated with sediment disposal at the NDA. The most significant risk arises from the potential spread of non-indigenous species through biofouling. To address this risk, Simon West has recommended in his evidence to require vessel operators to comply with MPI's 'clean hull' requirements specified in the Craft Risk Management Standard: Biofouling on Vessels Arriving to New Zealand (MPI, 15 May 2014). He also recommended that CRL provide to MPI biosecurity characterisation of every source site before material dredged from that site is disposed of at the NDA. This will enable MPI to consider whether any additional steps are required to manage biosecurity risks. These measures appear reasonable given the level of risk involved with the dumping of dredge spoil sediments in the NDA.

The Applicant should consider that under the Biosecurity Act, no person can knowingly transport any material or equipment which may contain Unwanted Organisms without undertaking suitable measures to ensure the pest is removed or rendered non-viable. This relates specifically to transfer of dredge spoil from areas where Unwanted Organisms are known to be present.

4 Acknowledgements

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5 Glossary of abbreviations and terms

CRI	Crown Research Institute
CRL	Coastal Resources Limited
DC	Disposal Centre
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
MNZ	Maritime New Zealand
MPI	Ministry for Primary Industries
NDA	Northern Disposal Area

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Appendix A Qualifications and experience of authors

Dr Daniel Leduc obtained his PhD in Marine Science at the University of Otago in 2008, followed by postdoctoral research at NIWA, where he has been employed as Benthic Ecologist since 2013. He has conducted research on sediment animal communities of coastal and deep-sea environments across New Zealand, including studies on the distribution of species and communities and effects of disturbance, and conducted several environmental surveys. He has extensive experience of methodologies used for seabed sampling and data analyses, and published his research in over 65 peer-reviewed scientific articles.

Owen Anderson has been a Biologist at NIWA since 1990. He obtained a BSc Honours degree in Zoology at Victoria University in 1988. He is and experienced statistical modeller, specialising in spatial habitat suitability modelling of deep-sea benthic invertebrates, including threatened and habitat-forming species – particularly in New Zealand and the wider Pacific Ocean. Ha has extensive experience in deep-sea biodiversity survey work, including benthic sled and trawl operations, towed camera transects, identification of benthic invertebrates and taxonomic descriptions, coring and water sampling.

Dr Serena Cox has been employed at NIWA since 2005, where she is manager of the Marine Invasives Taxonomic Service and a Biosecurity Scientist. She obtained her PhD in Biological Science at the University of Auckland in 2004, and currently conducts research on the role of vessel sound in settlement behaviour of biofouling organisms, hull biofouling and inspection protocols, and non-indigenous species invasions.

Dr Krista Hupman has been a Cetacean Biologist at NIWA since 2017. She obtained her PhD in Zoology at Massey University in 2016, and has several years' experience working as marine mammal observer and passive acoustic monitoring operator. She conducts research on the distribution and abundance of cetaceans in New Zealand waters and natural and anthropogenic threats. She has experience with the methodologies used to investigate the distribution and movements of cetaceans.

Dr David Thompson has been a Seabird Ecologist at NIWA since 1998. He obtained his PhD in Zoology at Glasgow University in 1990. He conducts research on seabird biology, ecology/habitat use through tracking technologies, and seabird fisheries interactions. He has published his research in over 80 peer-reviewed scientific articles.

All authors of this report agree to comply with the Code of Conduct for Expert Witnesses in the Environment Court of New Zealand Practice Note (2014).