BEFORE THE ENVIRONMENTAL PROTECTION AUTHORITY

AT WELLINGTON

IN THE MATTER	of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (**EEZ Act**)
AND	
IN THE MATTER	of an application for marine consent under section 38 of the EEZ Act by Trans-Tasman Resources Limited to undertake iron ore and processing operations offshore in the South Taranaki Bight
BETWEEN	**Trans-Tasman Resources Limited** Applicant
AND	**Environmental Protection Authority** EPA
AND	**Fisheries Inshore New Zealand Limited, New Zealand Federation of Commercial Fishermen, Talley's Group Limited, The Southern Inshore Fisheries Management Company Limited and Cloudy Bay Clams Limited** Fisheries Submitters

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PRIMARY EXPERT EVIDENCE OF DR GREGORY MATTHEW BARBARA ON MARINE ECOLOGY FOR FISHERIES SUBMITTERS

DATED: 23rd January 2017

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SUMMARY OF EVIDENCE

1. The bulk of the Impact Assessment (**IA**) is based on the assumptions that the Proposed mining area (**PPA**) is not a unique area within the South Taranaki Bight (**STB**) and that mobile marine fauna would avoid the PPA due to the Suspended Sediment Concentration (**SSC**) and noise levels thereby reducing the risk of direct impacts to fish and marine mammals. It may be that the operations would not necessarily deter animals from entering the area and that the mining operations may act as a focal point for productivity.

2. The Trans-Tasman Resources Limited (**TTR**) SSC modelling undertaken as part of the IA predicts that the SSC plume from the mining operation would not be dissimilar to the existing sand deposition already naturally occurring. This assumes that less than 4% of the sediments redeposited within the PPA will be fines (muds, silts or clays). This assumption if incorrect has wide reaching implications as muds and clays can travel further than sand in the water column and can form anaerobic barriers in even thin layers (<2cm) once settled.

INTRODUCTION

Qualifications and Experience

3. My name is Dr Gregory Matthew Barbara.

4. I am marine technical leader at Jacobs Australia Pty Limited in Adelaide Australia, (part of Jacobs Engineering Group). I hold the qualifications of a Bachelor of Science from Flinders University awarded in 1995, Honours in Marine Microbiology Bachelor of Science from Flinders University awarded in 1996 and a PhD in Marine Ecology from Flinders University awarded in 2002. My PhD was on pelagic marine bacterial interactions with discrete increases in nutrients or stimulates, my thesis drew links between bacterial productivity and the carbon sink in the world's oceans.

5. I have 21 years of professional experience including research experience in marine ecology, aquaculture and consulting. My specialist area is marine ecosystems, particularly foodweb interactions and human impacts on the marine environment.

6. I was employed by Flinders University from 1996 to 2002 as lecturer and marine ecology researcher in the School of Biological focusing on marine microbial foodweb and interactions between fisheries and aquaculture. In 2002 I relocated to the Ocean Research Institute at the University of Tokyo to take up my two year Post-doctoral Research Fellowship sponsored by the Japanese Society for the Promotion of Science, working on bacterial mutualism with fish. My post-doctoral role in Japan was followed in 2005 by a two year Marie Curie Research Fellowship in Scotland through St Andrews University but based on the west coast of Scotland out of the Scottish Association for Marine Science researching marine invertebrate cell culturing. At the end of that post-doctoral fellowship I made the decision to leave research and accept a role to join Scotland's leading aquaculture company Scottish Seafarms in 2007.

7. At Scottish Seafarms I held the role as the Chief Fish Health Biologist with responsibility for managing the impacts of all the company's farms and environmental health as well as the health of the farmed salmon and production up until 2010 when I returned to Adelaide and took up a role as a

senior marine scientist with the professional services and consulting firm Sinclair Knight Merz which serviced clients across Australia, New Zealand and the South Pacific. Since 2010 I have been promoted to Team Leader and Marine Technical Lead for the marine practice. I worked on a range of marine focused projects, including EIS and approvals for offshore oil and gas exploration, major port developments including dredging monitoring projects and discharge fisheries impact monitoring for power stations and desalination plants.

8. In 2013 Sinclair Knight Merz was acquired by Jacobs a global engineering and professional services firm, where I have remained as one of their marine technical leads for the Asia Pacific region, working predominantly with the companies Australian and New Zealand client base. I have a wide range of multi-disciplinary skills specialising in coastal, benthic and pelagic systems with broad experience in marine biodiversity, marine ecosystems, and the state of the marine environment and human impacts on marine ecosystems.

9. Since joining Jacobs (SKM) I have led many marine investigations for clients across Australia and authored 54 consultancy reports including matters related to water quality, discharge impacts, fish monitoring, invasive marine specie surveys, benthic habitat mapping and health, dredging impacts, port EIS/EIA, biogeochemical modelling and threatened species assessments. I have also assisted on over 40 other projects as the marine lead or reviewer including independent reviews of EISA for the New Zealand Environmental Protection Authority.

Code of Conduct

10. I have read the Environment Court Code of Conduct for expert witnesses and agree to comply with it.

11. I confirm that the topics and opinions addressed in this statement are within my area of expertise except where I state that I have relied on the evidence of other persons. I have not omitted to consider materials or facts known to me that might alter or detract from the opinions I have expressed.

Background to Evidence Preparation

12. I have been I have been retained by the Fisheries Submitters to prepare a statement of evidence on an assessment of the overall ecological effects and the significance of, and context for, the effects of the proposed TTR activities on fisheries and the supportive ecosystem in the STB. This includes an assessment of the effects on:

(a) Marine Mammals as indicators for over health of the region as a fishery;

(b) Underwater noise impacts on marine organisms;

(c) Particle Size Distribution of sediments and suspended sediments;

(d) Sediment redeposition and physico-chemical effects on benthic species;

(e) Effects on pelagic primary productivity and the foodweb;

(f) Non-indigenous species or invasive marine species; and

(g) Interactions with fisheries.

13. I have attached a list of references I refer to under **annexure** "**A**".

14. I am familiar with site of the application and surrounding environment having been involved in assessing the previous TTR application for the New Zealand Environmental Protection Authority.

15. In preparing this evidence I have read the following documents:

(a) TTRL (2016) South Taranaki Bight Offshore Iron Sand Extraction and Processing Project Impact Assessment;

(b) NIWA (2015) Report 1 South Taranaki Bight Factual Baseline Environmental Report NIWA Client Report: WLG2011-43 (updated report);

(c) NIWA (2015) Report 2 Benthic habitats, macrobenthos and surficial sediments of the nearshore South Taranaki Bight NIWA Client Report No: NEL2013-012;

(d) NIWA (2015) Report 3 Benthic Flora and Fauna of the Patea Shoals Region, South Taranaki Bight NIWA Client Report: WLG2012-55 (updated report);

(e) NIWA (2015) Report 4 Habitat models of southern right whales, Hector's dolphin, and killer whales in New Zealand NIWA Client Report No: WLG2012-28;

(f) HRW (2014) Support to Trans-Tasman Resources Laboratory testing of sediments report full version. Client Report No: DDM7316-RT002-R01-00; and

(g) Vopel K, Robertson J and PS Wilson (2013) Support to Trans-Tasman Resources Report 42 - Auckland University of Technology – Iron Sand extraction in the South Taranaki Bight: effects on trace metal contents of sediment and seawater.

(h) TTRL evidence: Project overview and consultation witness statements from Shawn Thompson – Operational description and Project description;

(i) TTRL evidence: Fish and commercial fishing. Expert witness statement Alison MacDiarmid – Marine effects and benthic ecology;

(j) TTRL evidence: Ecology. Expert witness statement Lawrence Cahoon – Primary Production and optical effects;

(k) TTRL evidence: Ecology. Expert witness statement Mark James – Overall ecological effects;

(l) TTRL evidence: Ecology. Expert witness statement Iain MacDonald – Existing environment;

(m) TTRL evidence: Ecology. Expert witness statement David Thompson – Seabirds;

(n) TTRL evidence: Ecology. Expert witness statement Simon Childerhouse – Marine mammals;

(o) TTRL evidence: Ecology. Expert witness statement Barrie Forrest – Biosecurity; and

(p) TRRL evidence: Expert witness statement Daniel Govier – Monitoring of effects and management plan.

REBUTTAL OF TTR'S EVIDENCE

Marine Mammals

16. I concur with the evidence of Simon Childerhouse where he states that while NIWA Reports 1 and 4 of the TTR application are overall good studies given available data at the time they are now a little out of date and would benefit from an update to include more recent survey data including fisheries bycatch data of marine mammals. Data from the MacDiarmid et al. (2015 – NIWA Report 1) and Torres et al. (2015 NIWA Report 4) reports:

(a) has been collected from outside the proposed mining area;

(b) are from non- systematic surveys; and

(c) it is therefore unknown if these data are likely to be representative of the proposed mining area (PPA).

17. Childerhouse goes on to state that Torres et al.'s (2015 NIWA Report 4) conclusion from the modelling that habitat suitability for Hector's dolphins (as a surrogate for Maui dolphins) in PPA was low but that coastal areas inshore of the PPA were predicted to have average to above average suitability as habitat for Hector's dolphin. While the inshore habitat may be suitable, it does not mean that dolphins will necessarily be found there and, in fact, aerial surveys of this region found no evidence of Maui or Hector's dolphins in either the PPA or inshore waters (Childerhouse 2016).

18. Torres et al.'s (2015) model uses dated data up to 2011, but since this time Childerhouse (2016) points out in paragraph [18] of his evidence extensive aerial surveys of New Zealand have shown Hectors dolphin have a more offshore distribution than previously thought. Since the model was developed based on the historical understanding of species habitat preferences and presence absence data, in my opinion this new information about habitat use

by Hectors dolphin could change the predictions of habitat suitability in the PPA.

19. Childerhouse (2016) states in paragraph [22] of his evidence that there are now a number of new research findings and sightings data that confirms the presence of Maui and Hectors dolphins in North and South Taranaki.

20. Childerhouse (2016) also provides a useful Figure 1, which depicts the bandwidths and peak energy of anthropogenic underwater noise sources and marine hearing and vocalisations. It shows that Hectors/Maui dolphins hearing ranges generally falls outside of the sound frequencies associated with dredging operations. This indicates that if present in the PPA Hectors/Maui dolphins may not be deterred from the area by underwater noise associated with the TTR operation. Likewise given the species utilisation of nearshore areas for foraging which natural experience elevated SSC sediment plumes, the TTR operations sediment plumes may not deter the species from entering the PPA.

21. The TTR IA and Baseline Environmental Monitoring Plans (**BEMP**) propose the primary methods that will be employed to gather baseline data for marine mammals are aerial surveys and acoustic surveys. I agree that acoustic surveys are a superior method for gathering baseline and monitoring data for marine mammals as it avoids the limitations of visual spotters from either vessel based or aerial surveys, which are subject to influences of poor weather, sea states and visual acuity or training of the observer. Acoustic monitoring for marine mammals during the TTR operations would also be of benefit.

22. Goiver states acoustic surveys will be used to understand how marine mammal distribution and density changes through time. Multiple autonomous sea noise loggers and/or echolocation click detectors will be deployed to assess habitat use by Hector’s/Maui’s dolphins and blue whales in the STB. Each device will be selectively programmed and located to target vocalisations from each of these species. By targeting only these two species this specifically excludes the other Nationally Endangered or vulnerable marine mammals. Due to the limitations of visual monitoring changes in the

distribution or density of southern right whales, bottlenose dolphins or orcas may be missed if they are left out of the acoustic monitoring programme.

23. As per Dr Childerhouse's recommendations, bottlenose dolphins should be included in the assessment of marine mammal monitoring as they are now listed as Nationally Endangered. Bottlenose dolphins, along with all the Nationally Endangered or Vulnerable marine mammals, should therefore be included in the passive acoustic monitoring programme not just blue whales and Hector's/Maui dolphins as stated in paragraph [158] of Goiver (2016) and Childerhouse (2016).

24. The IA proposes to station acoustic loggers only to the south and east towards inshore of the PPA. Sightings for marine mammals, particularly blue whales have been to the west and north of the PPA (MacDiarmid 2015). It would be more prudent to station the acoustic loggers closer to areas where targeted marine mammal species are most likely to approach the PPA. Due to more than just blue whales and Hector's/Maui dolphins being present in the STB, it would be better to increase the number of acoustic loggers to surround all sides of the PPA and monitor for all Nationally Endangered or Vulnerable marine mammals.

25. Goiver (2016) states all cetacean sightings will be recorded during TTR operations (including sightings from the IMV, FSO, other support vessels and helicopters). Data collected during pre-start observations will be useful to calculate sighting rates; and all other cetacean sightings will assist with the state of knowledge for species presence in and around the PPA. Currently the proposed Conditions, specifically proposed Condition 11 and Environmental Monitoring and Management Plan (**EMMP**) specifically exclude monitoring of fur seals.

26. Of all marine mammals documented in the STB and PPA, New Zealand fur seals have been the most frequently sighted species in the PPA (Childerhouse 2016, MacDiarmid 2015). Seals are an indicator species of the health of a fishery; they are also known to be opportunistic exploiters of human activities. Therefore, in my opinion it would be prudent to require monitoring of the numbers of seals in and around the TTR operations in STB as well as include them in the BEMP and EMMP as they are the most likely of all marine

mammals to be encountered and therefore be impacted upon. Currently the exclusion of seals from the proposed Conditions may imply that they are not an important indicator for habitat health.

27. The assumptions made are that marine mammals rarely use the PPA and would avoid the operation due to SSC and underwater noise, and would not, therefore, be impacted by TTR's proposed operation. However, the marine mammals present in the area may be habituated to noise of other impacts due to the existing oil and gas development industry and vessel movements throughout STB. Therefore, the argument that marine mammals are unlikely to be impacted based on avoidance behaviours is not strictly valid. Species such as fur seals are also capable of swimming at the surface with their heads above water and can avoid underwater noise impacts if they are determined to investigate an area. This type of behaviour has been observed for seals around aquaculture fish farms in Scotland which use "seal screamers" as underwater acoustic deterrents.

28. Goiver states in paragraph [162] of his evidence *"[s]hut-downs in response to cetacean sightings are limited to the duration of the soft-start; hence once full operations are under way, no shut-downs for cetaceans will occur."* This implies that any cetaceans that enter the PPA will encounter impacts as operations will not cease. There should be a procedure in place to shut down if a marine mammal is observed in the PPA undergoing stress or erratic behaviours.

Underwater Noise Impacts

29. I question the appropriateness of the applied noise levels for developing the underwater noise modelling. Hegley (2015) notes that *"no specific information is available on the noise level from the suction dredge"*, but that some empirical information is available from a similar unit in two reports by the Institute for Maritime Technology (1994, 1995). While noting that the proposed TTR crawler units are significantly more modern pieces of equipment, they are also 20% larger than the units described in Institute for Maritime Technology Reports (1994, 1995). Assumptions on ambient noise masking are also based on data from 1995 from Lyttelton Harbour.

30. Based on previously recorded Sound Pressure Levels, dredging is likely to be audible to most marine mammals over considerable distances (depending on conditions) of up to several kilometres from the source. Given the lack of direct measurements of equivalent crawler equipment noise impact predictions on other marine fauna including fish species may not be appropriate.

31. MacDiarmid reports commercial fishing demersal and pelagic fish species with predicted distributions in the STB that particularly coincide with the TTR PPA (i.e. those species with an occurrence > 50%) include barracouta, blue cod, carpet shark, eagle rays, john dory, golden mackerel, kahawai, leather jacket, lemon sole, red cod, red gurnard, rig, school shark, snapper, spiny dogfish, tarakihi, trevally, common warehou, and witch. Species that are predicted to be particularly abundant (> 50 kg per hour standard trawling) in the PPA include barracouta. While many fisheries species are considered the focus is on the resident species, and no discussion is given to effects on migratory fisheries such as tuna. I discuss the importance of the migratory tuna fishery in paragraph [82].

32. MacDiarmid also states that red gurnard are likely to be sensitive to sounds within the range predicted to be produced by the TTR operations and juvenile snapper are susceptible to desensitisation of lower frequency sounds when exposed to ongoing underwater noise. They assume that these species, along with other fish that may be impacted by underwater noise, would move away from the area due to SSC above 2 mg/l thereby reducing the risk of damaging sound levels. This does not take into account that fish can become acclimatised to both increases in background noise and SSC, particularly if there is stimulus such as increased food sources or habitat enrichment. The TTR operations potentially provide both as discussed in paragraphs [55] to [57] of my evidence.

Particle Size Distribution of sediments

33. One of the main focuses of potential impacts from the TTR sand mining in STB is the SSC plume generated by the iron sand processing. A high-level technical review and high quality modelling have been undertaken to model the SSC plume and predict potential impact areas. This modelling, however, has been based on the assumption that the mined sands contain less than

4% clay and silts. In the event the concentrations of clays and silts are greater than 4%, then deposition of clays and silts is likely to travel further distances and these would therefore have greater impacts than the modelled sand deposition.

34. In 2013 SKM's (now Jacobs) independent review of the previous TTR submission identified that disturbance and discharge of sediments with a mud content above the 3.12% assumed in the sediment plume modelling could result in the generation of sediment plumes that are significantly more intense and spatially widespread than predicted by the modelling. The uncertainty regarding the reliability of the sediment plume modelling could be addressed by clarifying how the assumed sediment particle size distribution (**PSD**s) were derived and whether they are representative of the actual PSDs in the sand layers.

35. SKM (2013) noted the PSDs used for modelling de-ored sediment discharge are broadly consistent with measured PSDs in sandy layers of two sediment cores collected using reverse circulation drilling (Orpin, 2012; note that Orpin (2012) also refers to a third core (STH004) analysed in 2011 but the results are not included in the application). These layers have a low (<4%) content of fine particles (mud). Both cores, however, show significant layers with much higher (>80%) mud content, and report that the third core showed similar results. Results from five other cores also show intervals with mud content >10%, and up to 79% depending on the sampling method (Orpin 2013).

36. This is significant information that does not appear to have been updated in the re-submitted IA or given adequate discussion, assessment or further description in the context of the IA. Given that sand extraction is proposed to a depth of 11 metres below the seabed, defining the spatial distribution, depth and thickness of the mud layer is important, from both an operational and environmental perspective. The number of cores used to describe the mud layer (two, with a third unreported) is inadequate to give sufficiently detailed description of the distribution of the mud layer throughout the project area.

37. In 2014 TTR commissioned HR Wallingford (**HRW**) to undertake a series of laboratory tests to investigate the behaviour of the tailings under both saline and freshwater conditions. Tests were carried out to look at settling velocity,

flocculation and critical stress for deposition and erosion. As part of the tests, PSD analysis of test cores supplied by TTR to HRW was also undertaken. While these laboratory tests showed that flocculation rates and settling times of de-ored sediments may be higher in seawater than previously anticipated they also indicated that the PSD of the three sediment samples contained significant percentages of fines <0.063 mm (HRW 2014).

38. Figures 3.1-3.3 of the HRW (2014) report show post-grind tailings of up to 45% fines (<0.063 mm) up to 97% pre-grind ultra-fines and 50% fines in bulk tailings for samples 1, 2 and 3 respectively. These levels of fines are consistent with those reported by Orpin (2012) in the previous TTR submission (SKM 2013). This, however, does not fit with the sediment plume modelling for percentage fines expected to be discharged. Neither the HRW (2014) nor the previous Orpin (2012) reports clarify whether the PSD analyses and/or the PSDs used in sediment transport modelling are based on whole samples or spear samples from polyweave sacks; if so, they are likely to underestimate the contribution of fines.

39. This uncertainty regarding the PSD percentages of fines demonstrate that there is a potentially considerable underestimate of the mud content if the samples are collected as spear samples from polyweave sacks on the geotechnical vessel, compared to grab samples from the cyclone slurry of the crawler.

40. James (2016) states in paragraph [76] of his evidence that deposition of muds and clays would have the greatest impact on benthic fauna, with only 3.8 cm of mud to kill some benthic communities of gastropods, or 2 cm of clay, compared to up to 17 cm of sand. Thin films of as little as 2mm of clay can prevent settlement and recruitment of macroalgal species such as Macrocystis pyrifera known to occur on reef areas in the STB. If mud deposition or clay exceeds 4 cm in areas fisheries species such as surf clams would also suffer.

41. The macroalgal reefs within the STB are important areas for productivity within the region providing habitat and foraging areas for a wide number of species. Impacts to these areas would have significant impacts on the productivity of the STB as a whole. Given the SSC modelling is based on > 63 µm and does

not account for particles less than 20 µm or potential higher percentages of muds than 4% there is some uncertainty around the full extent of the potential impacts from the mining plume. Sediment fines tend to have the lowest densities and longest settling times. It is my opinion that clays and silts would travel much greater distances than 5 km and remain in suspension far longer than the modelled SSC, and therefore pose a threat to macroalgal reefs outside of the PPA in the wider STB. Without modelling of fines it is difficult to know the full extent of a plume, but it would be expected to be larger than the current TTR sediment plume.

42. The quality of the sediments in particular the percentage of mud in the sediments to be mined appears to be uncertain at this stage. I consider a condition is required which restricts the mining of sediments which contain mud(s) above a certain percentage so to avoid the release of fine material into the marine environment. I understand that the geotechnical sampling will be undertaken approximately up to two years ahead of the mining operations. A condition should be imposed that requires where sediments are encountered which have a mud concentration above the consent limit these areas should be avoided.

Sediment Redeposition and Physio-Chemical Effects on Benthic Fauna

43. Proposed Condition 14 states - Prior to the commencement of any iron sand extraction activities, the Consent Holder shall ensure that a minimum of two (2) years of baseline monitoring has been undertaken and shall, as a minimum, include monitoring of:

- Suspended sediment concentrations;
- Sediment quality;
- Subtidal and intertidal biology;
- Optical water quality;
- Physio-chemical parameters;
- Seafood resources;

- Marine mammals;
- Underwater noise;
- Seabirds;
- Commercial fishing; and
- Recreational fishing.

44. However, in Goiver's (2016) witness statement for the BEMP (and EMMP) physio-chemical parameters, sediment quality and commercial fishing appear to have been omitted from the monitoring programme as outlined in Appendix 1 of his evidence. There is also no specific quantitative compliance limits for water quality other than for SSC.

45. TTR has proposed procedures that would be implemented if a Response Limit, Compliance Limit or the Interim Sediment Quality Guideline-High (ISQG-High) value for "*meals, metalloids, organometallic and organic compounds*" in the ANZECC guidelines is exceeded. Should an exceedance occur, the Technical Review Group and EPA will assist to select the most appropriate Operational Response in order to rapidly return SSC levels to below the Response Limit or ISQG-High below the threshold.

46. I assume Goiver means 'metals' instead of 'meals' in paragraph [217] of his evidence. In my opinion, clarification is required in terms of which metals, metalloids and organometallic compounds will be tested for. Goiver states in paragraph [60] that cadmium (cd) mercury (Hg), copper (Cu) and nickel (Ni) are to be tested for in water but he does not specify which contaminants are to be tested for in sediments – Appendix 1 of his evidence does not specifically state testing of sediments or water for contaminants or which suite of contaminants will be screened for. This is a gap linking effects of sediment resuspension with changes in water quality.

47. Hg, Cd, Cu and Ni are now to be screened for in Water Quality testing. Lead (Pb), chromium (Cr VI & CrIII) and zinc (Zn) along with tributyl tin (TBT) and in my opinion arsenic (As) should also be screened for. While As does not have an ANZECC trigger for marine waters, it does have ISQG triggers for marine sediments and it would make sense to develop a baseline for As and

the other toxicants in both water and sediments in order to determine if sand mining is having any influence on the ambient concentrations in the PPA and surrounding areas.

48. The de-ored sand is anticipated to be readily recolonised by benthic organisms from outside of the PPA due to organisms within the STB being already highly adapted to sediment disturbance. It is expected that sediments would be recolonised within weeks to months post disturbance. However, this is based on limited trials in Wellington Harbour and Taranaki of low iron (Fe) sand from Lyall Bay and literature reviews (TTR Report 3). No direct trials of the sediments from the PPA that have undergone similar processes to the mineral extraction process have been undertaken.

49. The TTR mining will remove sediments down to 11m and return them de-ored to the within 4m of the seabed. The extracted sediment would not only have Fe removed. The mining process would also alter the pH and redox potential of the sediments, particularly the sediments from below 1m which are more likely to be anoxic. These changes in the sediment chemistry would alter the ability for organisms to recolonise the redeposited sediments.

50. Vopel et al. 2013 indicate that copper levels in elutriates from unprocessed ore would be elevated, indicating the potential for formation of a permanent zone of elevated copper concentrations in the water around the de-ored sediment discharge. The formation of a turbid bottom layer from the returned de-ored sand to the seabed has the potential to impede the near-bottom dilution of the elutriates (including copper). It is therefore possible for benthic organisms near the mine site to undergo long-term exposures to copper concentrations above the ANZECC/ARMCANZ trigger value for 99% species protection (though note that the ANZECC/ARMCANZ guidelines specify the use of the 95% species protection trigger value in slightly-moderately disturbed systems). The elutriate results also imply that dilution would be required for nickel concentrations to comply with the relevant trigger value (i.e., 99% species protection), however it appears that the parameter requiring the highest dilution would be copper.

51. Copper is a known inhibitor of settlement and growth of marine organisms and therefore elevated concentrations of copper associated with the de-ored sand could impede the recolonization of the area by benthic organisms. Longer or wider than predicted loss of benthic fauna including worm fields may have implications for demersal fisheries, and this is discussed in paragraph [75].

Effects on Pelagic Primary Productivity and Higher Trophic Levels

52. The STB is known to be a nutrient poor area that responds rapidly to seasonal upwelling events of relatively nutrient rich waters that stimulates phytoplankton growth and in turn zooplankton grazers that exploit the increasingly abundant phytoplankton biomass. These zooplankton community increases are important for the pelagic food chain, as they provide a food source for species such as fish and squid as well as the baleen whales such as blue whale known to forage in the offshore waters of STB (Childerhouse 2016). These planktonic increases are also important for migratory fish species including tuna which prey upon squid and smaller fish.

53. Little is known about the seasonal cycle on inter-annual variability of plankton in the STB as historical data collection has focused on summer surveys (MacDiarmid 2016). What is known is that phytoplankton blooms are highly responsive to the relatively nutrient rich upwelling events that occur in the STB off the Kahurangi Shoal, Cape Farewell and the D'Urville current (TTR Report 1) and appear to peak during spring throughout the STB and offshore in deeper waters (TTR IA). These upwelling events are also thought to be important for the squid and fish aggregations. To date studies of the STB phytoplankton biomass have focussed on satellite imagery with some field surveys. Due to the size of the STB it is not possible to sample the whole region. What surveys have shown is that the interannual and seasonal dynamics of the STB are best understood around these larger upwelling events.

54. Recent surveys by NIWA found phytoplankton and chlorophyll a concentrations greater than 1 µg/l immediately to the east of the project area, which is an indication of localised algal blooms (TTR IA). Without detailed phytoplankton surveys across the STB it is difficult to determine the prevalence of these more localised algal blooms. It is possible these transient

localised areas of productivity may heavily influence the distribution of pelagic species such as fish and squid during times of low productivity elsewhere in the STB.

55. Cahoon (2016) stated that microplankton and bacteria along with some smaller polychaetes (James 2016) could escape the mine processing, and these could in turn scavenge organic matter and capitalise on the anticipated increase in nutrients released (4 µM). Since nutrients, rather than light, are the main limiting factor for primary production in the STB, this enrichment of primary productivity and microbial activity, Cahoon (2016) suggests, would be a potential benefit of the mining process to the area by increasing productivity in the food chain in a localised area of the PPA. Knowing how responsive the marine organisms are to opportunistic events due to the dynamic nature of the STB, the mining operation could become a localised hotspot for enhanced productivity.

56. Given the potential for the sand mining to stimulate primary productivity or encourage scavenging of pulverised benthic fauna redeposited to the seabed, the assumption that fish would avoid the area is not necessarily valid. It is already known that many of the fish species in the STB already forage in areas where SSC levels regularly exceed 10 mg/l therefore it is unlikely the SSC levels predicted to be less than 10 mg/l in the PPA would deter fish from entering the area. It is my opinion that stimulation of productivity in the PPA would act as an attractant for pelagic and demersal fish species.

57. The IA assumes most mobile organisms would avoid the PPA but increases in fish and squid numbers would also lead to attraction of predators such as larger pelagic fish, seabirds and marine mammals including seals and dolphins. By creating a focal point, albeit very localised for productivity the mining discharges could lead to changes in the distribution or behaviours of some animals and the EMMP would need to monitor for this.

Non-indigenous Species or Invasive Marine Species

58. The potential for the TTR mining operation to remobilise or increase nutrients in the water column to stimulate algal productivity has other implications. To date, TTR has not conducted detailed surveys for invasive marine species or

non-indigenous species (Forrest 2016). This includes screening for harmful algal species or their cysts that can lie dormant in sediments for decades (Miyazono et al. 2012). Algal cysts respond to resuspension and nutrient conditions and can rapidly increase in numbers to create blooms. Some species of algae form harmful (toxic) algal blooms and if any of these species are present in the PPA or introduced through ballast water or TTR operations they would be almost impossible to contain (Forrest 2016).

59. Invasive marine species (**IMS**) are marine biota that are translocated into waters outside their natural geographic range and subsequently settle, survive and spread. Translocation and survival of these species in new areas can cause irreversible impacts to the local ecosystem by competing with and/or predating on native species, as well as introducing disease. The consequences include a combination of environmental, social and economic impacts. Most at risk are aquaculture industries due to the high-density stocking of farmed organisms, settling surfaces on infrastructure and often increased nutrients or decreased competition or predation due to farm practises. IMS such as European crabs can destroy entire mussel farms and parasitic diseases such mudworms (already in New Zealand) that effect mussels and oysters or prawn white spot currently effecting Queensland prawn farmers lead to industry closures during outbreaks.

60. Forrest (2016) states that ballast water conditions are too hostile for most marine organisms to survive. However, the extremes of temperature, pH and salinity changes along with low oxygen and lack of light are ideal conditions for selecting for algal cysts as well as more robust marine organisms capable of exploiting new areas.

61. It is an accepted best practice that international vessels discharge ballast water in open waters outside of territorial waters in order to minimise the risk of ballast water borne organisms reaching suitable settlement locations in ports or coastal waters. TTR propose to discharge ballast water from the bulk carrier within the PPA which lies within New Zealand waters at a rate of 1.7 and 5.4 million tonnes of ballast water annually. TTR propose to use vessels with ballast water treatment, however few ships in the world currently have ship-board ballast water treatment systems and onboard treatment of ballast water would not kill all organisms or algal cysts.

62. Forrest (2016) assumes this is acceptable because open and exposed marine environments are significantly less vulnerable than sheltered ports. However, the TTR operation will potentially provide localised nutrient enrichment and settlement locations along vessel hulls and mining infrastructure that would not ordinarily be available in Open Ocean or exposed environments.

63. While Forrest (2016) does not directly consider harmful algal species, he does state that ballast water has the potential to introduce species that inhabit the water column and the possibility of introducing non-indigenous species (**NIS**) establishing in the natural habitats of the sand extraction area cannot be disregarded (Forrest 2016).

64. The introduction and establishment of harmful algal blooms (**HAB**) within the STB would have far wider effects than the PPA. The effects would depend on the type of HAB, some species produce toxins that directly kill fish while others produce toxins that bio-accumulate. Shellfish and crustaceans can both accumulate high levels of toxins through either filter feeding of harmful algae from the water column or ingestion of filter feeders that have accumulated the toxins. The accumulation of these toxins can remain in the tissues of shellfish and some crustaceans for weeks which has implications for human consumption as the toxins of some harmful algal species are lethal to humans. Shellfish industries across the globe are now regularly subject to closures when HABs or toxin levels in shellfish tissues are detected.

65. While there is a risk of introducing a harmful algal species, I do not consider the risk of introduction of a harmful algal species any more likely than the introduction of any other algal species by the TTR operations. Effective treatment of ballast water and discharge practices to minimise the risk of introduction of HABs or any other IMS are the only mitigation measures available. Environmental sampling of water and sediments within the PPA for harmful algal species and other NIS will provide an early warning for whether NIS have been introduced and should form part of the EMMP.

Interactions with Fisheries

66. Apart from the potential impacts on fisheries species noted in paragraphs [51], [56] and [57], there is the direct impact on commercial fisheries of spatial displacement of fisheries that currently fish waters within the PPA.

67. TTR and its witnesses state that this displacement or loss of fishing areas are minor or inconsequential when the entire area of the STB is considered and that the PPA does not represent any unique habitat. However, this conclusion is based on the benthic habitat surveys conducted on behalf of TTR which note their own limitations due to the sampling methods and extents of surveys (Report 2 and 3).

68. MacDiarmid et al. (2015 TTR Report 1) comment that there is a gap or disconnect in the high pelagic and demersal fishery productivity and the apparent lack of benthic productivity which it would be expected to support.

69. The Waitotora estuary, Waiinu reef, Waverly Beach, North and South Traps, Whenuakura estuary and Whanganui river estuary are all described as being outstanding natural resources by the Department of Conservation (TTR Report 1, 2 and 3). However, due to difficulties in dredge trawling of reefs and the water depths around the PPA, no direct reef surveys were conducted during the NIWA surveys and instead data was extrapolated from other reefs. MacDiarmid et al. notes that the benthic communities of algae and bryozoans within their survey area may be distinct (TTR Report 1, 2 and 3).

70. Much of the benthic fauna data for STB was based on presence or absence of species and not densities, because of the lack of sampling data available, and historical data commonly reported only new or novel vouchered specimens (TTR Report 1, 2 and 3). This type of sampling approach can bias records and lead to conclusions of low benthic macrofaunal diversity.

71. The nearshore surveys' dredge trawl surveys used a mesh of 4mm and the sediment grabs collected were only screened for grain size not infauna (TTR Report 2). These sampling methods would miss most macro fauna less than 4mm and potential some larger elongated fauna. The survey also did not search for benthic diatoms which apart from being important primary producers and food sources for benthic species, also exude polymeric

substances that bind and stabilise sediments. This sample bias makes it difficult to determine if the nearshore habitats support similar species to the wider STB.

72. Fifty-one demersal species are known to inhabit the STB based on 26 years of research trawls (TTR Report 1). MacDiarmid et al. (NIWA 2015 TTR Report 1) report a few species that are very widespread and abundant but most species are only common within a restricted depth range with a few species having very restricted distribution within the region. Barracouta, blue cod, carpet shark, eagle rays, john dory, golden mackerel, kahawai, leather jacket, lemon sole, red cod, red gurnard, rig, school shark, snapper, spiny dogfish, tarakihi, trevally, common warehou, and witch all have greater than 50% usage of the PPA (TTR Report 1). From examination of the TTR Report 1, sand flounder, spotted stargazer, spotty, elephant fish, New Zealand sole, porcupine fish, red mullet, hake, horse mackerel, king fish, anchovy and eagle ray all have a preference for waters in depths similar to the PPA with many of their predicted higher probabilities of occurrence overlapping with the PPA (Appendix 3 of TTR Report 1). This has implications for where these fish species can be caught and whether exclusion of fishers from the PPA will have an impact on fisheries.

73. Commercial bottom trawling and set netting have the greatest overlap of effort and catch within the PPA, with bottom trawling occurring year-round with no obvious seasonality in effort (TTR Report 10 and IA). The catch for these fisheries is not evenly distributed and centres around specific areas in the STB often related to higher benthic productivity. Despite the higher effort in the southernmost and coastal areas of the STB for bottom trawling, the highest catch numbers as reported appear to be in waters within and adjacent the PPA. This implies that these waters are highly productive compared to other areas of the STB.

74. The TTR reports do not directly overlay the catch effort maps with the plume modelling or the PPA, so it is difficult to determine the actual level of overlap. It is my opinion that this uncertainty with the amount of high productivity fishing area to be impacted should be more clearly depicted and discussed.

75. Based on the findings of the NIWA 2015 reports for TTR, the benthic areas within the PPA directly adjacent and to the north west are classified as worm fields with relatively high densities of tube worms. Given the apparent lack of benthic infauna and epifauna within loose sands of the STB these worm fields are potentially important areas for demersal fish species. The location of the worm fields also aligns with where the greater catch return for some demersal fisheries also occur (TTR IA and TTR Report 10). The NIWA (2015) reports do not show any extensive worm fields in the south or nearshore areas of the STB. If the worm fields are important benthic habitats for fisheries species this may explain the distribution of fishing catch return being higher around areas of worm fields.

76. Little is known about the foodweb of the STB and the importance of specific habitats, therefore the noted gap between the fisheries productivity and apparent depauperate benthic fauna is an area that should be further investigated.

77. It is my opinion that without a better understanding of the extent of overlap with the PPA, plume impacts and high return fishing areas it is not possible to state that the spatial displacement of the PPA would be minor or not.

78. NIWA have produced statistical distribution models for demersal fish species throughout the STB in order to determine the most likely areas (commercial) fish would be caught and therefore enable a prediction of impacts to fisheries by TTR operations. However, there is a lack of survey data available for most species and rather than use commercial catch records to develop the models, which would impose some bias due to catch effort, NIWA used catch data recorded from research bottom trawls from only three vessels along with expected habitat preferences (TTR Report 10). There are, however, some problems with basing species distribution or catch models on this research trawl data as it is not evenly distributed across the STB and not all areas of the STB have been mapped and classified for habitat types, particularly around reef areas. Therefore, much of the model outputs are based on extrapolated data and assumptions around habitat types across the region. Based on these outputs it is not possible to assume fishers can relocate to other areas that have been modelled to have similar or better expected catches, particularly when the importance of worm fields are not examined or

the limitations of weather conditions sea state and presence/absence of bottom snags or reefs for safe fishing areas are not considered. Fishing effort is often dictated by the cost, especially the cost of fuel. Therefore, fishers who usually target areas around the PPA may be reluctant or unable to relocate operations to the southern extents of the STB, even if fishing areas are expected to be similar or better than the PPA.

79. Apart from the effects discussed in the paragraphs [55], and [58] above, the sand mining operation will also use freshwater produced by reverse osmosis (RO) to extract the ore and operate night time lighting for all of their operations for safe navigation. RO produce concentrated brine with higher salinities in order to extract freshwater from seawater, this brine must be discharged back into the sea. The brine discharge along with the de-ored slurry will have localised effects on water quality including changes in salinity, temperature, oxygen and nutrient levels. While these parameters will not lead to region wide changes due to the scale of TTR operations there will be localised effects that dissipate with distance from the PPA. Dependent on the sensitivity of organisms to changes in water quality, some species may alter their distribution around and within the PPA. These effects on their own are anticipated to be minor but coupled with effects discussed in paragraph [57] and night time lighting would increase the presence of some fisheries species such as squid or mackerel around the mining operations.

80. Thompson (2016) notes in paragraph [26] of his witness statement that the night time lighting of the TTR operations are likely to attract fish and squid. I concur with Thompson that the night time lighting alone would be unlikely to significantly displace the distribution of entire populations of mobile species when the entire STB is considered. However, as I have discussed in previous paragraphs the effects of night time lighting would not be the only potential fish attracting feature of the TTR operations.

81. As mentioned the STB is highly dynamic and most species within the region are adapted to exploit the dynamic changes either through rapid succession of benthic species after sediment disturbances or planktonic blooms (phytoplankton and zooplankton) triggered by nutrient enriched upwelling events. Therefore, mobile species in particular are adept at either avoiding detrimental areas or seeking out and exploiting areas of increased productivity

even on small temporal and geographical scales. Changes in food resources and water quality have implications for migratory fish species within the STB such as tuna and mackerel.

82. In New Zealand, there are several species of tuna that are commercially fished the albacore (Thunnus alalunga), bigeye (T. obesus), skipjack (Katsuwonus pelamis) yellowfin tuna (T. albacares) and southern bluefin tuna (T. maccoyii). In recent years' landings of northern bluefin tuna have also been recorded due to the acquired ability to distinguish southern and northern bluefin tunas. Only southern bluefin tuna (Thunnus maccoyii), managed by the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), is subject to catch restrictions (Murray & Griggs 2001). According to Murray & Griggs in 2001 tuna represented an important and valuable seasonal fisheries worth more than $NZ 20 million. Tuna catches across New Zealand are dependent on species habitat preferences and catch methods; albacore form the basis of a summer troll fishery, primarily on the west coasts of the North and South Island (albacore are also caught throughout the year by longline in these areas), bigeye, the second most valuable tuna (per kg), are caught by longline around the northern half of the North Island throughout the spring – autumn period with skipjack caught in small numbers by trolling with most of the catch taken by purse seine during summer months. Southern bluefin tuna traditionally have been caught during autumn - winter months off the West Coast of the South Island. Tuna feed on smaller pelagic fish such as mackerel as well as squid and therefore their distribution is subject to the distribution of their prey.

83. The common jack mackerel is a migratory species that is commercially targeted within the STB. The species shows a preference for water temperatures less than 17°C and entire schools will move to stay below this temperature (I&I NSW 2010). Jack mackerel generally have a depth range of 0-500m and grow to around 65 cm with smaller fish usually occurring in shallower depths, being a planktivore they feed primarily upon planktonic crustaceans forming large schools of uniformly sized individuals (Bray 2017). Jack mackerel are in turn are preyed upon by larger fish such as gemfish, barracoota and tuna (I&I NSW 2010). Dependent on the extent of increases in primary productivity or temperature changes around the TTR mining

operations movement patterns of jack mackerel may be affected, which in turn lead to changes in southern bluefin tuna distribution.

84. It is unlikely that the scale of the TTR operation would significantly alter water quality to the extent that migratory patterns of fish would be significantly altered across the entire region. What is likely to happen is that commercial fish species attracted to this area would have decrease catch return in around the PPA as fishers are excluded from the PPA.

85. Each of these factors when considered alone: benthic habitat loss, sediment quality and benthic morphology changes, water quality changes, SSC, underwater noise, nutrient enrichment, biofouling and night time lighting are not enough to significantly change the distribution of fisheries species across the region. However, the cumulative effect of all of these would be enough to change the distribution of some species. The extent of these changes in distribution is difficult to predict without ecosystem modelling for fish distributions that includes the effects of all of these parameters in the STB

CONCLUSION

86. In summary, I conclude that:

(a) The current BEMP and EMMP should be updated to include acoustic monitoring for all Nationally threatened marine mammals along with blue whales. Seals should also be included in the BEMP and EMMP as key indicators of habitat health.

(b) The uncertainty regarding the PSD percentages of fines expected to be produced by the mining operation needs to be resolved. The potential considerable underestimate of the mud content could lead to far wider sediment plume impacts, including direct impacts on macroalgal reefs which are important productivity areas within the STB. The SSC model should be updated to include a greater percentage of fines in order to better align with the PSD of de-ored sediments to be returned to the PPA.

(c) In addition to Cd, Cu, Hg and Ni the contaminants Pb, Cr VI, CrIII, Zn, TBT and As should also be screened for in both the water and sediment monitoring programme. While As does not have an ANZECC trigger for marine waters it does have ISQG triggers for marine sediments and it would make sense to develop a baseline for As and the other toxicants in both water and sediments in order to determine if sand mining is having any influence on the ambient concentrations in the PPA and surrounding areas.

(d) Given the potential for the sand mining to stimulate primary productivity or encourage scavenging of pulverised benthic fauna redeposited to the seabed it would act as an attractant for pelagic and demersal fish species. The EMMP would need to monitor for changes in the distribution of fisheries species as well as predators such as seals which would provide a broad indicator on the health of the area.

(e) Currently there is no baseline for NIS within the PPA or the STB. A targeted NIS survey including sediment and water sample screening for algal cysts and NIS larvae should be included as part of the BEMMP, this will also provide TTR with an understanding of any existing risks. Environmental sampling of water and sediments within the PPA for harmful algal species and other NIS will provide an early warning for whether NIS have been introduced and should form part of the EMMP.

(f) The worm fields identified during NIWA's surveys with and surrounding the PPA does not appear to occur elsewhere within the STB. The importance of these worm fields for demersal fisheries needs to be investigated and determined if there is a link between the higher catch returns in these areas and the presence of the worm fields. At this time, it is unknown whether the worm fields exist in other areas of the STB and if they do not the worm fields surrounding the PPA may represent unique habitat within the STB.

(g) Considering that the TTR operations in STB will run for 20 years, it is not possible to assume the cumulative effects of changes within the PPA and impacted adjacent areas in the STB will sit within the natural perturbations of the region. The paucity of long term ecosystem monitoring data in the STB means that it may not be possible to determine if changes observed during the EMMP were a result of the TTR operations or natural cyclic shifts in the ecosystem. As the TTR expert witness MacDiarmid states in paragraph [110] of her evidence, larger scale changes due to climate change may overshadow the small-scale changes detected in the EMMP. It is my opinion that due to the lack of a long-term baseline dataset and the questions I have raised throughout my evidence an ecosystem model for fisheries in the STB would be of benefit for determining potential impacts from the PPA.

Dated this 23rd day of January 2017

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Gregory Matthew Barbara

ANNEXURE "A"

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