BEFORE THE ENVIRONMENTAL PROTECTION AUTHORITY
AT WELLINGTON

IN THE MATTER	of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 ("the Act")
AND	
IN THE MATTER	of the applications by Trans Tasman Resources Limited (TTRL) for marine and discharge consents to recover iron sand under sections 20 and 87B of the Act and
BETWEEN	**Trans- Tasman Resources Limited** Applicant
AND	**The Environmental Protection Authority** EPA
AND	**Kiwis Against Seabed Mining Incorporated (KASM)** Submitter

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STATEMENT OF EVIDENCE BY SHAW TREVOR MEAD
ON BEHALF OF KIWIS AGAINST SEABED MINING INCORPORATED
Dated 23 January 2017

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STATEMENT OF EVIDENCE OF DR SHAW MEAD

INTRODUCTION

1 My name is Shaw Trevor Mead.

2 I hold BSc and MSc (Hons) degrees from the University of Auckland (School of Biological Sciences), and a PhD degree from the University of Waikato (Earth Sciences). I have over 20 years' experience in marine research and consulting, have authored and co-authored 49 peer-reviewed scientific papers, and have solely or jointly produced over 300 technical reports pertaining to coastal oceanography, coastal engineering, marine ecology and aquaculture. I have undertaken over fifteen hundred research and consulting SCUBA dives around the coast of New Zealand and overseas, and have led many comprehensive field investigations that have addressed metocean, biological and chemical components of the coastal environment. I am affiliated to the New Zealand Coastal Society (IPENZ) and am on the editorial board of the Journal of Coastal Conservation, Planning and Management. I am also technical advisor for the Surfbreak Protection Society (NZ) and Save the Waves Coalition. I have a background in environmental science, coastal oceanography, numerical modelling, marine ecology and aquaculture. I studied for my MSc degree at the University of Auckland's Leigh Marine Laboratory, undertaking subtidal research there from 1994 to 1996 directed at the fertilisation success of sea urchins as a basis for the sustainable management and development of the commercial market. As part of my MSc degree in Environmental Science, I also completed a 4th year law paper in Environmental Law focussed on the RMA (1991) (the subject of my dissertation was the quota management system law review which was under way at the time and ended in the Fisheries Act 1996). The marine ecological components of my Doctorate were directed towards subtidal habitat enhancement of marine structures, while the physical oceanography component was focussed on understanding the effects of coastal bathymetry on wave breaking characteristics using field measurements (bathymetry surveys, aerial photography and GPS positioning of in situ data collection) and hydrodynamic numerical modelling.

3 I am currently an environmental scientist and Managing Director at eCoast, which is a marine consulting and research organization, and part-time lecturer and research provider for Unitec. Throughout my career, I have been involved in a wide range of coastal consulting and research projects that have included the design of coastal structures and developments, and assessments and monitoring of physical and ecological effects of marine construction, coastal erosion control, marine reserves (annual monitoring of benthic communities, fish and lobster, inside and outside Goat Island and Hahie Marine Reserves for the past 12 years), dredging, outfalls, oil industry, aquaculture ventures and various other coastal and estuarine projects that have included hydrodynamic (waves and currents), sediment transport and dispersion modelling (including contaminants, suspended sediments, freshwater, hypersaline water, nutrients and petro-chemicals).

4 Further to this, with direct relevance to the present case, I am familiar with the offshore benthic ecology, nearshore marine ecology and physical oceanography of the Southern

Taranaki Bight, and have previously investigated the area in association with the Kupe development (Mead et al., 2004; Mead and McComb, 2004; McComb et al., 2004; Mead et al., 2005b), have undertaken an ecological survey of the North and South Traps (Mead et al., 2005b), and provided expert evidence pertaining to the impacts of offshore seabed-mining on surf breaks in the region (Mead, 2014).

5 Over the past 2 decades I have appeared as an expert witness in Environment Court, High Court and EPA hearings. I was also involved in the Board of Inquiry hearing to consider the NZ King Salmon Co. Ltd's plan change requests in the Marlborough Sounds in 2012, specifically with respect to the ecological significance of the proposed sites, the seabed/benthic effects of the depositional footprints of salmon farms, and the wider ecological impacts and cumulative effects of farm waste deposition. I was also involved in the review of the Chatham Rise Phospate proposal and the East-West Link (independent expert for the EPA).

PURPOSE AND SCOPE OF EVIDENCE

6 I have been asked by KASM to prepare the following evidence. This evidence is based on a review of the benthic ecology component of Tran Tasman Resources Limited TTRL's (TTRLL) 2016 application for marine consents and marine discharge consents to extract and process iron sand in an area of seabed known as "Patea Shoals" within the South Taranaki Bight (STB).

7 In preparing this evidence, I have reviewed the current (2016) and previous TTRL's applications (2013) and the following documents related to the current and/or previous applications:

a. AECOM (2016). Trans-Tasman Resources Ltd Marine Consent Application - Review of benthic ecology. 18 pp.
b. Anderson T.J. (2014). Statement of Evidence in Chief of Dr Tara Anderson on behalf of Trans-Tasman Resources Ltd. 14 February 2014. 28 pp.
c. Anderson T.J., MacDiarmid A., Stewart R. (2013). Benthic habitats, macrobenthos and surficial sediments of the nearshore South Taranaki Bight. NIWA Client Report No: NEL2013-012. 44 pp. Updated November 2015
d. AES (2016). Trans-Tasman Resources Ltd consent application: Ecological assessments. 67 pp.
e. Beaumont J., Anderson T.J., MacDiarmid A.B. (2013). Benthic flora and fauna of the Patea Shoals Region, South Taranaki Bight. NIWA Client Report No: WLG2012-55. 183 pp. Updated November 2015
f. Cahoon L.B. (2016). Expert evidence of Dr. Lawrence Cahoon on behalf of Trans-Tasman Resources Limited. 15 December 2016. 55 pp.
g. Cahoon L.B., Pinkerton M., Hawes I. (2015). Effects on primary production of proposed iron-sand mining in the South Taranaki Bight region. 30 pp.
h. Dearnaley M. (2016). Expert evidence of Michael Dearnaley on behalf of Trans-Tasman Resources Limited. 15 December 2016. 63 pp.

i. DOC (2006). Netting coastal knowledge. A report into what is known about the South Taranaki-Whanganui marine area. 223 pp.

j. EPA (2014). Trans-Tasman Resources Ltd Marine Consent Decision. 197 pp.

k. EPA (2016).Key Issues Report. Trans-Tasman Resources Limited offshore iron sand extraction and processing project – application for marine consents and marine discharge consents. 40 pp.

l. Greer D. (2017). Evidence of Dougal Greer on behalf of Kiwis Against Seabed Mining Incorporated. 23 January 2017.

m. Hadfield M., Macdonald H. (2015). South Taranaki Bight Iron Sand Extraction Sediment Plume Modelling. . NIWA Client Report No: WLG2015-22. 117 pp.

n. Hillock K.A. (2014). Statement of evidence of Kristina Anne Hillock for the Director General of Conservation. 24 February 2014. 17pp.

o. HR Wallingford (2014) Support to Trans-Tasman Resources: Laboratory Testing of Sediments, DDM7316-RT002-R01-00. 54 pp.

p. HR Wallingford (2015) Support to Trans-Tasman Resources: Source Terms and Sediment Properties for Plume Dispersion Modelling, DDM7316-RT004-R01-00. 21 pp.

q. Huber M., Yestes M., Taylor G. (2014). Assessment of effects on benthic ecology from Trans-Tasman Resources marine consent application. SKM review for EPA. 28pp.

r. James M.R. (2016). Expert evidence of Mark Richard James on behalf of Trans-Tasman Resources Limited. 15 December 2016. 65 pp.

s. Joint Statement of experts in the Field of Effects on Benthic Ecology – Part 1 and 2, 26 March 2014

t. MacDiarmid A. (2016). Expert evidence of Alison MacDiarmid on behalf of Trans-Tasman Resources Limited. 15 December 2016. 47 pp.

u. MacDiarmid A., Anderson O., Sturman J. (2013). South Taranaki Bight fish and fisheries. NIWA Client Report No: WLG2012-13. 211 pp.

v. MacDonald I., Budd R., Bremner D., Edhouse S. (2012). South Taranaki Bight Iron Sand Extraction: Oceanographic measurements data report. NIWA Client Report No: HAM2012-147. 106 pp.

w. McClary D.J. (2014). Statement of Evidence in Chief of Dr Dan McClary on behalf of Trans-Tasman Resources Ltd. 24 February 2014. 60 pp.

x. Paavo B.L. (2014). Evidence of Brian Lee Paavo on behalf of Kiwis Against Seabed Mining Incorporated. 24 February 2014. 25 pp.

y. Pinkerton M.H., Gall M. (2015). Optical effects of proposed iron-sand mining in the South Taranaki Bight region. NIWA Client Report No: WLG2015-26. 81 pp.

z. SKM (2013) Review of technical reports relating to TTRL marine consent application – Benthic Ecology. Prepared for the New Zealand Environmental Protection Authority, 13 December 2013 7 pp.

8 I have read the Code of Conduct for Expert Witnesses Environment Court's Consolidated Practice Note (2014). In so far as I express expert opinions, I agree to comply with that Code. In particular, except where I state that I am relying upon the specified evidence of another person as the basis for any expert opinion I have formed, my evidence is within my sphere of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions which I express.

SUMMARY OF EVIDENCE

9 This evidence provides a review of the benthic ecology component of TTRLL's 2016 application, with the aim to assess whether predictions on the potential responses of benthic systems to the proposed activities are based on valid scientific evidence.

10 After having reviewed the current application, all the relevant supporting documentation and compared these to the information provided in the previous application (2013), my opinion is that updated predictions on the impacts of the mining activities on benthic systems are not based on a better understanding of the benthic ecology of the area, but mainly on revised models of sediment dispersion **(Hadfield & Macdonald 2015)**, optical effects **Pinkerton & Gall (2015)** and primary production **(Cahoon et al. 2015)**.

11 For a review of the sediment dispersion, optical affects and flocculation models I refer to the evidence of Dougal **Greer (January, 2017)**. Greer concludes there are such uncertainties in the sediment evidence that reliance on the size of the sediment plume as modelled would not be a conservative approach. Taking a precautionary approach, the plume size is slightly less than that of the previous application.

12 The most significant improvement in the field of benthic ecology compared to the previous application is represented by the inclusion of an extensive monitoring and management framework which would be implemented if the consents are granted. However, no effort has been made to gather more information about benthic habitats and communities of the STB and to combine the modelling information with field observation and experimental data.

13 As a result, many of the uncertainties and knowledge gaps about potential impacts on benthic ecology which affected the previous application still remain. Here below I outline the ones which I consider as the most significant.

14 We know that the benthic organisms in the seabed material to be mined from the 65.76 km^2 will be successively destroyed during the mining operation, that there will be a large plume of suspended sediment generated by the operation and a large area of the seabed that will be covered by fine sediments settling out of suspension, and also that the material being returned to the seabed will be significantly different than that the pre-dredged material. However, due to the many knowledge gaps and lack of comprehensive investigations of the benthic ecology of the South Taranaki Bight (STB) and the various factors that influence it, it is my opinion that the actual impacts on biodiversity, benthic communities (both soft sediment and rocky reef), primary production (especially microphytobenthos (MPB)), and ecosystem services/function are largely unknown and unquantified.

15 The best case scenario is that a large area of the STB will be modified (changed seabed composition, reduced light penetration, increased sediment loads, changed community structure, etc., etc.) throughout the 35 year consent (the continual of 'press' impact of the activity) and sometime after the cessation of seabed mining the area mined will have

recovered (whether or not comprised of the same organisms and benthic communities), and that there will have been, and will be, little significant impacts on the marine environment. The worse-case scenario is that the operations will cause wide-spread ecological change that is disruptive, causes cascade impacts which change community structures and ecosystem function, reduces biodiversity, contributes to cumulative impacts that displace key species (e.g. canopy-forming kelp), and results in a large reduction in productivity over a large area of the STB for the duration of the activity and potentially beyond (e.g. permanent changes to the benthic ecology of the mined area, permanent displacement of some species/communities, etc..).

A. DURATION OF MINING OPERATIONS

16 One of the key aspects determining the impacts of disturbance on natural systems is the duration of the disturbance event. In this case, the impact of mining activities on benthic communities is clearly dependent on the duration of such activities. This information is key to accurately assessing the implications of mining for the benthic systems, but the application documents provide unclear indications about the duration of the mining operations. TTRL is requesting marine consents and marine discharge consents for their maximum allowable duration of 35 years **(TTRL Impact Assessment 2016, page 271)**, but gives no indication about the expected duration of the operations. TTRL also states that the mining operations would occur within an area of 65.76 km^2 **(TTRL Impact Assessment 2016, page 1)** and that sediment will be extracted from an average area of approximately 5 km^2 per annum **(TTRL Impact Assessment 2016, page 30)**. On the base of this, about 13 years would be sufficient to complete the operations in the designated 65.76 km^2 area. However, other documents included or cited in the application indicate that the duration of the operations would be around 20 years **(TTRL Appendices to the Impact Assessment 2016 – Project Description, page 2; AES Report 2016, page 18, 33)**. The 2013 application also anticipated a project duration up to 20 years **(TTRL Supporting Information for Marine Consent Application 2013, page 7)**.

17 This lack of detail about the duration of the operations makes it difficult to predict the impacts of mining. More information about the duration of the activities and also about their temporal patterns (i.e., duration and frequency of interruptions) would be useful for a better assessment of the ecological implications for the benthic communities. Given this lack of clarity, in this evidence I have applied the maximum mining duration that is possible under the proposed consent.

B. SPATIAL ARRANGEMENT OF MINING OPERATIONS

18 The spatial arrangement of mining operations is also unclear and details about the mine planning which were present in the previous application are no longer available. The previous application explained that the extraction lanes would have been parallel to the prevailing wind/wave direction and perpendicular to the prevailing current direction to minimise re-deposition of de-ored sand into un-worked areas. However, Figure 27 of the

impact assessment shows extraction lanes first parallel and next perpendicular to the prevailing current. In addition, the mining area was divided in four blocks which would have been mined in a pre-established sequence **(TTRL Supporting Information for Marine Consent Application 2013, page 8-9)**. This kind of information is not clear in the 2016 application.

19 This lack of detail about the spatial arrangement of the operations also contributes to increase uncertainty around the impacts on the benthic environment. Since no information is provided about how the operations will move through the proposed project area (PPA), it is unclear where the plume will originate at any given time. In addition, it is impossible to establish whether increased sedimentation down-current from the excavation site will keep impacting areas already mined (thereby affecting the recovery process) and/or non-mined areas (which are expected to act as a source of larvae to repopulate the mined areas).

C. INFORMATION AVAILABLE ABOUT BENTHIC HABITATS AND COMMUNITIES IN THE PPA AND THE SURROUNDING AREAS

20 Most of our knowledge about benthic communities in the PPA and in the surrounding regions of the STB is based on two studies done by NIWA which describe the physical and biotic characteristics of the benthic systems found nearshore **(Anderson et al 2013)** and offshore **(Beaumont et al. 2013)** in the broader Patea Shoals region. Both studies are based on extensive benthic samplings using a range of different techniques and provide a large amount of information about benthic habitats and communities in this region of the STB.

21 The two reports make a useful contribution to our knowledge of benthic habitats and communities which were so far poorly known, but also have a number of limitations which should be taken into account when assessing the potential impacts of the mining activities on benthic systems. The key issues which affect the accuracy of the two reports are outlined below.

19.1 Neither report provides any information about the temporal variability in the benthic systems under existing conditions. Despite being spatially extensive, the two reports are based on samplings done over restricted temporal windows: about 8 months (September 2011 – May 2012) in the case of **Beaumont et al. (2013)**, and 3 days (28 February – 2 March 2013) for **Anderson et al. (2013).** Since no sampling was systematically repeated through time, these snapshots do not provide any information about seasonal changes in benthic habitats and communities and about their responses to natural disturbance events.

19.2 The extensive offshore sampling of **Beaumont et al. (2013)**, is affected by a seasonal bias for the core sampling. Cores were a key component of the sampling as they provided all the available data about sediment and infauna composition in the PPA and surrounding areas. Most of the stations closer to the coastline were sampled in spring, between 22 September – 2 December 2011 (Table 1, page 15-16; Figure 2, page 17). These include a number of stations in the eastern side of the PPA and numerous other stations located north, north-east and east of the PPA. Most of the stations further offshore were sampled more than two months later, between summer and autumn (12 February – 21 April 2012; Table 1, page 15-16; Figure 2, page 17). As a consequence, the core samples were not properly spatially randomized through time because replicate cores were not taken from different regions at the same time. Instead, different regions were sampled at different times/seasons. As a result, differences in benthic habitats and communities among regions are potentially confused by natural seasonal changes. As already noted by **Paavo** with regard to the previous application **(2014)**, there can be significant fluctuations in macrofaunal abundances across seasons in similar soft-bottom systems at these latitudes **(Paavo et al. 2011)**. This casts considerable uncertainty over the available information about infauna composition.

19.3 In the two reports, biodiversity was underestimated for a number of reasons:

19.3a In **Beaumont et al. (2013)**, core sampling provided greater information about the infauna inhabiting the top 5 cm of the seabed (331 samples from 103 sites) than about the infauna located 5-10 cm (281 samples from 101 sites) and 10-15 cm (174 samples from 80 sites) inside the seabed. No information is available about the organisms living deeper than 15 cm. In addition, limited information is available about the infauna present at sites with complex substrates such as rocky outcrops and hard ground/biogenic habitats because the corer struggled to penetrate into the seabed.

19.3b The infauna was not sampled in **Anderson et al. (2013)**.

19.3c **Beaumont et al. (2013)** provide very little information about the meiofauna (infaunal organisms between 63-500 μm) of the area, despite the great diversity and abundance of this group of organisms in marine sediments, their importance in the context of marine food webs and their potential value as bioindicators **(e.g., Giere 2008)**. Meiofauna was sampled only from the top 5 cm of sediment of a small subset of cores and identified using coarse taxonomy.

19.3d In **Anderson et al. (2013)** surficial macrobenthos was sampled using dredges, which are scarcely efficient on complex substrates such as rocky reefs. Because of this, sampling efficiency varied from site to site, making comparisons impossible, and no dredge samples could be taken from the most complex reefs. As a result, hard bottom substrates were under-sampled, and comparisons of macrobenthos abundance and composition across sites were based only on photoquadrats (i.e., underwater photographs of areas of the seabed). Estimating the identity and abundance of benthic organisms from photoquadrats relies on good image quality and can be complicated when the organisms are distributed over complex substrates (e.g., with cracks and holes) and when they overlay each other (e.g., algal canopies on top of understory species).

19.3e **Beaumont et al. (2013)**, dredge sampling could not provide any information about the abundance of macroalgae.

19.3f Many of the organisms sampled in the two studies are small and/or poorly known (several newly discovered taxa were recorded in **Beaumont et al. 2013**). As a result, in numerous cases the identification could not be accurate and proceed to species level.

19.4 Rocky reefs areas were not adequately sampled in **Anderson et al. (2013)**, despite supporting highly diverse benthic communities. This is in part because of the sampling techniques which were used and also because an extensive sampling of rock outcrops was beyond the scope of the study. Although patchily distributed, rocky reefs are widespread along the South Taranaki coast **(DOC 2006; MacDiarmid et al. 2013)** and include a number of reef systems (Four Mile Reef, North and South Traps, Waiinu Reef) recognised as ecologically and scientifically significant by the **Taranaki Regional Council (2004)**. Nonetheless, there is very little quantitative information about these habitats in **TTRL Impact Assessment (2016)**. The only relatively recent quantitative data available is represented by the sampling done by **Anderson et al. (2013)** at just five reefs. Further observations of these habitats reported by **McClary (2014)** are only qualitative and achieved with unclear methodology. Independently of the debate around the extent of the sediment plume and the sedimentation levels which these habitats are likely to experience (see **Greer's evidence**), a better understanding of rocky reefs' distribution and of the composition of the associated communities is required. This pivotal information to predict potential impacts and detect changes in response to the mining activities is currently not available.

19.5 The reports do not provide any indication about the distribution and abundance of microphytobenthos (MPB). Although sampling MPB is not easy and was not within the scope of these studies, the lack of information about this group of organisms is an important knowledge gap, given the importance of MPB for benthic productivity and trophic dynamics **(e.g., MacIntyre et al. 1996)** and the potential for impacts due to reduce light intensity as a result of seabed mining.

19.6 Various aspects of experimental design and data analyses are described in very little detail in **Beaumont et al. (2013)**. Because of this, it is sometimes difficult to understand what was done, why and whether it was appropriate. In particular:

19.6a No explanation is provided about the treatment of multivariate data. It is unclear why multivariate data were generally log transformed while the fourth root transformation was used for meiofauna data.

19.6b ANOSIM analyses are used to compare sampling sites located inside the PPA with sites located outside the PPA (Mining vs. Non-Mining; Appendix A).

However, the size of the Non-Mining area is not specified, while the size of the PPA is 65.76 km^2. Because of this, it is unclear whether the sampling effort in the Non-Mining area was comparable to the sampling effort in the PPA.

19.6c All ANOSIM analyses are based on an unbalanced design because fewer sites were sampled in the PPA compared to the surrounding Non-Mining Area. Comparisons across habitat types (wormfields, ripple sands, rubble, etc.) are also based on unbalanced data, because the sampling effort was not equal across habitats. ANOSIM is known to behave unreliably in the analysis of unbalanced designs, particularly for data with heterogeneous multivariate dispersion **(Anderson & Walsh 2013)**. However, the authors do not comment on these limitations and on their implications for the analyses presented.

19.6d In most cases, the outputs of ANOSIM analyses do not include the R value, an important component of this test which indicates the size of the dissimilarity between groups. Unlike p-values, R values are not affected by sample size **(Clark & Gorley 2006)**.

19.6e "Significant differences" and "non-significant differences" in univariate response variables (e.g., the abundance of specific organisms) are mentioned throughout the report, but such statements very rarely include details about the underlying statistics. Therefore, it is hard to understand how significance and non-significance were judged. When ANOVA analyses are mentioned, no indication is provided about the structure of the design (i.e., balanced/unbalanced and number of replicates).

19.6f More information could have been extrapolated from the available data by using a nested design with spatial replication across a series of successively smaller spatial scales nested within the scale above (e.g., replicates within sites, sites within areas, areas within regions; **Morrisey et al. 1992**). This would have provided insights into the heterogeneity in the distribution of habitats and organisms across a range of spatial scales (from a few meters to several 10s of kilometers). Such information would have allowed a better assessment of the differences between Mining and Non-Mining sites in comparison to the natural heterogeneity of this region. With this approach, it would have also been possible to select and arrange the available samples in order to obtain a balanced design.

19.7 I have concerns about the interpretation and discussion of certain results. The following statement is an example (page 130): "*Although the bryozoan, Tubilipora sp., was significantly more abundant in mining than non-mining sites when examining grand means (Figure 7; ANOSIM p<0.05), closer examination by habitat type and zone found that while almost all specimens were collected from wormfield* *habitats (both inside and outside of the PPA, Figure 8a), densities were significantly higher in the non-mining worm-field sites to the north of the PPA than inside the PPA (Figure 8b).*" This statement seems to downplay the abundance of this species in the PPA, but both Figure 8b (page 136) and Table D1 in Appendix E (where the species name is spelled "*Tubulipora"*; page 154) clearly show that the PPA is the region with the second highest densities of this species (lower only compared to the Mid-north area). Once again, it is unclear how significance was judged and it is impossible to assess how informative comparisons across regions are (Inshelf vs. Mid-north vs. PPA vs. Mid-south vs. Offshelf) because we don't know anything about the sampling effort in relation to their spatial extension (with the exception of the PPA).

19.8 Several other technical issues in the two reports which were raised by **Paavo (2014)** with regard to the previous application are still debatable in the current application (e.g., the use of operational taxonomic units, the methods used to extract data from the imagery and the use of a single core sample for both faunal analysis and sediment analyses).

22 In conclusion, considerable knowledge gaps still remain in our understanding of the composition and functioning of benthic communities in this region of the STB. Significant progress has been made in recent years as part of the studies conducted to support TTRL's applications, but the limitations of these studies should be taken into account when making use of the information that they have provided.

D. IMPACTS OF THE MINING ACTIVITIES ON BENTHIC COMMUNITIES

23 The current application predicts lower impacts on benthic systems compared to the previous one mainly on the basis of a revised sediment plume model which predicts reduced sediment dispersion because of increased flocculation rates and reduced resuspension of the finest sediment fractions **(TTRL Impact Assessment 2016).** it is notable that the revised plume model **(Hadfield & Macdonald 2015)** is based on laboratory tests done by **HR Wallingford (2014, 2015)** on three different sediment types with only one sample for each sediment type. In my opinion, this violates basic principles for the design of meaningful tests and the interpretation of their results. This is because:

21.1 since there are no replicates for the three sediment types, it is not possible to establish whether the tested samples are representative of each specific sediment type;

21.2 any test will always confuse the "sediment type effect" with the individual identity of the only replicate available for each sediment type (i.e., pseudoreplication; **Hurlbert 1984**);

21.3 three samples weighing between 2-11 kg and extracted somewhere at a depth greater than 2 m below the seafloor **(HR Wallingford 2014, page 2)** are likely not representative of a 65.76 km^2 area where 50 million tonnes of seabed material per year are proposed to be extracted drilling up to a depth of 11 m **(TTRL Impact Assessment 2016)**.

24 Most of the predictions about potential impacts on the benthos, revolve around the revised sediment plume model, but no significant advancement has been made in the study of benthic habitats and communities of the STB. As a consequence, considerable uncertainties still remain about the impacts of the proposed activities on benthic ecology as outlined below.

25 In **TTRL Impact Assessment (2016)** and in several supporting documents it is repeatedly stated that the STB is a highly dynamic environment where benthic organisms are regularly exposed to various forms of disturbance (e.g., wave, sedimentation) and are therefore likely to be tolerant to stressful conditions. This is plausible, but there is no evidence available about the responses of benthic communities to natural disturbance events in the STB because no study has assessed the temporal variability of these communities. We simply don't know what happens to these communities through time under existing conditions. We only have snapshots of their composition generated by one-off sampling events which already date back to several years ago (the data presented in **Anderson et al. 2013** were collected in 2013 and the **Beaumont et al. 2013** data were collected between 2011-2012). There is no strong ground for any solid inference into the stability, resistance and recovery capacities of these communities, especially in a high-energy, dynamic environment like the STB.

26 In addition, it is important to consider that natural disturbances (e.g., storms, ambient levels of sedimentation) have variable frequency and intensity. They are 'pulse' impacts/events that leave "windows" of favorable conditions which may allow benthic organisms and communities to recover. This is a very different situation from the proposed mining operations. Sediment discharge from the proposed activities will have no downtime 'press' type impact) and will constantly superimpose its effects on natural disturbance. This will result in an altered disturbance regime which could last up to 35 years. Predicting the responses of benthic communities to this unprecedented event is impossible given our lack of understanding of their current dynamics under normal conditions.

27 It also inaccurate to consider the current sediment levels in the STB as natural. Elevated sediment inputs from the rivers are not natural, but result from anthropogenic degradation of freshwater quality through intensive land use (particularly dairy farming; **Dean & Hackwell 2008; Snelder et al. 2010; Haggitt, 2015**). Therefore, the mining activities would increase human disturbance in an area already affected by altered environmental conditions as a result of land-based human activities; it is a cumulative impact. TTRL's claims that project the will not result in adverse cumulative effects are unsubstantiated **(TTRL Impact Assessment 2016, page 122)**, as mine-derived sediment would be added to sediment loads already beyond natural levels. This issue was raised also with regard to a recent application by the Port of Otago for disposal consent, because there was concern about how the resulting sediment plume would have affected the reproduction of macroalgae in coastal waters already affected by poor water quality **(Appendix 4 of the Port of Otago Next**

<u>Generation Environmental Management Plan, 2015)</u>. In the South Taranaki Bight, similar conditions exist and the mining activities would add a further impact occurring 24/7. The resulting cumulative effects would persist for up to 35 years with unclear short- and long-term implications for the benthic environment.

28 In addition, comparisons of sediment discharge and the plume created by seabed mining to coastal SSC's and riverine inputs (often referred to as 'background' levels) have often been presented without considering locations and volumes. For example, the sediment load generated by the proposed seabed mining, although now reduced in the present application is still only slightly less than that delivered by the Manawatu River, with only the Whanganui River having a large sediment load in the region; all other land-use inputs in the region are significantly lower. Similarly, comparing the SSC concentration at the location of the offshore seabed mining to coastal SSC levels does not negate the fact that the SSC generated by the activity will be orders of magnitude greater that the 'natural' levels currently present. For example, MacDonald (2014) found that there was a gradient in SSC extending offshore, with SSC decreasing with increasing distance offshore. Nearshore SSC readings were found to be up to 1.9 gm/l, farther than 2.5 km from the shore the maximum measured SSC was 0.025 mg/l, while out at the proposed seabed mining site, SSC was found to be <0.001 gm/l most of the time. Therefore, when considering impacts on the benthic flora and fauna some 22 km offshore of suddenly discharging a sediment load comparable to the Manawatu River needs to be considered in terms of not only the massive increase in SSC and sediment, but also in terms of the types of organisms and their adaptative capabilities at the site in comparison to those in the nearshore (i.e. the organisms present at the seabed mining site are currently not adapted to high sediment load and decreased light penetration due to SSC).

29 Another recurrent statement is that benthic communities in the PPA and in the surrounding areas most likely to be affected by the sediment plume have low diversity and conservation value and therefore ecological impact can be considered negligible. As previously explained, estimates of biodiversity for the PPA and surrounding areas are not entirely accurate and under-valued. Furthermore, species abundance and composition within the PPA were only compared with the surrounding areas within the STB, but there is no mention of how the PPA biodiversity compares to that of similar systems in New Zealand or elsewhere. Some of the evidence provided by **Beaumont et al. (2013)** is actually at odds with the idea that the PPA may have low diversity and conservation value. For example, the polychaete *Euchone*, which is particularly abundant within the PPA, was previously undescribed and unknown from other areas around New Zealand. **Beaumont et al. (2013)** note that this may reflect the lack of study in similar mid-shelf high energy environments along the west coast of New Zealand. This further emphasizes the fact that this kind of benthic environment is poorly known and may deserve better consideration. Overall, high/low biodiversity and "uniqueness" are hard to define and measure without appropriate standards and are not useful metrics for impact forecast, especially for a system relatively poorly known across New Zealand.

30 TTRL states that the impact of the proposed activities on benthic organisms is expected to be low, aside from in the areas close to the extraction activity. This is because the revised sediment plume model predicts sediment levels indistinguishable from natural variability for most of the modelled area (see **Greer's evidence** for an assessment of these predictions) and because most taxa have been shown to be relatively tolerant of significantly higher levels of suspended sediment than will be experienced as a result of the project operations **(TTRL Impact Assessment 2016, page 116)**. To support this latter claim, TTRL cites a series of New Zealand studies describing the resistance of different benthic organisms to a range of sediment concentrations. These studies are interesting, but not entirely relevant. Data on the development of oyster eggs and larvae **(TTRL Impact Assessment 2016, page 113)**, for example, are inappropriately cited because taken form a study done in the USA **(Davis & Hidu 1969)** using species which are not present in New Zealand (*Ostrea edulis* and *Cassostrea virginica*). In addition, the studies cited provide information only about three species which are found in the Patea Shoals according to **Beaumont et al. (2013)**: the bivalves *Austrovenus stutchburyi*, *Paphies australis* and *Pecten novaezelandiae*. Information about *Austrovenus stutchburyi* and *Paphies australis* is provided by experiments carried out in environments not comparable with the Patea Shoals (i.e., intertidal habitats and laboratory systems; **Hewitt et al. 2001**, **Hewitt & Norkko 2007**; note that Hewitt's surname is misspelled in Table 4.9 at page 114). Only laboratory-based evidence is available for *Pecten novaezelandiae* (**Nicholls et al. 2003**).

31 In summary, the evidence provided about benthic organism sensitivities to suspended sediment relies exclusively on literature values generated by studies done mostly on organisms which are not present in the Patea Shoals. None of the cited studies was carried out in environments comparable with the Patea Shoals. No attempt was made by TTRLL to obtain more detailed information by means of experimental investigations focusing on a broader and more representative range of species and environmental conditions. As a result, the information on New Zealand benthic organism tolerance limits and sensitivities to the effects of suspended sediment is not as comprehensive and as well understood as stated by TTRLL, and only part of the information provided has any relevance in the context of TTRLL's application.

32 As set out above, given the lack of knowledge about the current benthic communities and stresses on them, we cannot predict whether or not the communities are at their natural stress loads already.

33 This limited information is then combined with the guidelines proposed by a single New Zealand study on dredging impacts **(James et al. 2009)** and draws the conclusion that most species in the communities of the STB should be able to tolerate sedimentation levels over 80 mg/l **(TTRL Impact Assessment 2016, page 114)**. James himself in his recent evidence **(2016, paragraph 45, page 17)** contradicts this statement, suggesting a much lower concentration that could be tolerated by most species (35 mg/l); this further demonstrates the range of unknowns that are associated with the proposed activity on the benthic ecology of the STB.

34 Similarly, the evidence provided by TTRLL on the effects of sediment burial on benthic communities is not as comprehensive and as well understood as stated in **TTRL Impact Assessment (2016, page 118)**. An inspection of the cited studies indicates that **Norkko et al. 2002** (referred to as Norkko et al. 2001 by TTRL) seems to be the most relevant evidence in the context of TTRL's application. Most of the other studies cited deal with organisms which are either clearly not present in the STB such as Singaporean coral reef animals **(Doorn-Groen 1998)**, or whose presence is unclear given the information available such as the brown macroalgae *Macrocystis pyrifera* **(Devinny & Volse 1978)**, *Durvillaea antarctica* and *Hormosira banksii* **(Schiel et al. 2006)**. Note that these are macroalgae, not microalgae as indicated in the legend of Table 4.10. I also note that the results of **Schiel et al. (2006)** are not reported accurately, because the germlings of both species examined were able to attach in the presence of a 2 mm deep layer of sediment only when the sediment covered 75% of the available substrate (with a dry weight of 1.3 g/100 cm^2, equivalent to 131 g/m^2). When the sediment was spread over 100% of the available substrate (with a dry weight of 7.3 g/100 cm^2, equivalent to 731 g/m^2) the attachment was impossible for both species.

35 The study of **Norkko et al. (2002)** presents interesting information about the sensitivity of benthic invertebrates to fine sediment sediments (silt/clay) obtained through a large survey of intertidal and shallow subtidal estuarine habitats across the Whitford Embayment (Auckland) and a series of laboratory experiments. The authors also compared their results to those of other studies in New Zealand. Eight of the taxa studied by **Norkko et al. (2002)** are also present in the Patea Shoals region, although the correspondence is often only at family or genus level, not at species level. These are: three bivalve taxa (*Astrovenus* sp., *Nucula* sp., *Paphies* sp.); four polychaete taxa (*Aonides* sp., Glycerids, Nereids, Orbinids); and olygochaete worms. Comparison between **Norkko et al. (2002)** field survey and laboratory experiments and a review of previous studies in New Zealand revealed that consistent, non-contrasting information across multiple studies was available for only four of these taxa. The responses observed across studies were contrasting for the four taxa: the bivalve *Paphies* sp. and the polychaete *Aonides* were negatively affected by fine sediments, Glycerid polychaets were insensitive to fine sediments, and olygochaets worms responded positively to fine sediments **(Norkko et al. 2002, Table 5, page 32)**. This lack of consistency across studies and taxa is an important reminder that we know very little about the responses of individual organisms to sediment deposition, let alone about entire communities. They do suggest that the benthic community will be changed over a large area of the seabed due to the proposed activity, potentially having a negative impact on biodiversity and ecosystem services.

36 Our knowledge of New Zealand benthic organism tolerance limits and sensitivities to the effects of sediment deposition and burial is not as comprehensive and as well understood as stated by TTRLL, and only part of the information provided has any relevance in the context of TTRL's application. None of the studies cited was carried out in environments comparable with the Patea Shoals and STB. No attempt was made by TTRLL to obtain more detailed information by means of experimental investigations focusing on a broader and more

representative range of species and environmental conditions; issues that remain from the 2014 application.

37 Potential impacts on benthic primary production are even more complicated to predict because there is little information about the distribution of both macroalgae and microphytobenthos production (MPB) in the STB. In addition, little is known about MPB productivity dynamics (e.g., *P-E* curves) both in the STB and elsewhere in the world. There are also few estimates of water column (phytoplankton) versus seabed (MPB) primary production (**Cahoon et al. 2015)**. The benthic ecology experts who examined TTRLL's previous application agreed that sediment chlorophyll-a analyses would have helped to distinguish between fresh and decaying photosynthetic pigments and to understand the relative importance of benthic and water column productivity **(Joint Statement 2014 – part 2, page 5)**. However, this recommendation was not followed by TTRLL and this information is still not available.

38 TTRLL states that **Cahoon et al. (2015)** have provided an improved assessment of potential effects on primary production based on revised sediment plume and optical property models, literature searches of relevant information and additional local and international expert input **(TTRL Impact Assessment 2016, page 109)**. I note that the work of **Cahoon et al. (2015)** is exclusively based on literature values, optical modelling results and expert estimates. This is also honestly recognized by the authors, who state that their task was made extremely difficult by the absence of local information about benthic primary producers (particularly MPB) in the STB.

39 It is important to note that, in the absence of field data, **Cahoon et al. (2015)** could not predict changes to absolute production and were only able to estimate proportional changes to the background condition. The estimates of **Cahoon et al. (2015)** are based on both the optical model of **Pinkerton & Gall (2015)** and the plume model of **Hadfield & Macdonald (2015)**. Therefore, all estimates of reduction of benthic productivity rely not on one but on three models whose accuracy must be thoroughly assessed. Despite the clear limitations of the methodology used and of the information available, TTRLL states that the reduction in light and subsequent effects on primary producers at the seabed are likely to be highly variable and episodic, ranging from negligible to moderate, depending on the location, the prevailing wind and current conditions, as well as naturally high levels of suspended sediment input from the rivers inshore **(TTRL Impact Assessment 2016, page 110)**. This statement is not accurate because **Cahoon et al. (2015)** estimates are averaged over time (by year) and space (across the model sediment domain, an area of ocean of ~13,300 km^2). Since no information is provided about smaller spatial and temporal scales, the temporal (e.g., the distribution of the number of days with reduced light availability) and spatial patterns in the predicted impacts (e.g., the responses at specific receptor sites) remain unclear.

40 In conclusion, although some of the greatest impacts of the mining activities would be mediated through effects on productivity and the potential flow on effects on benthic communities, considerable uncertainties remain in our understanding of these key aspects.

Suggestions for improvement recently provided by the EPA (a hydrodynamically driven model of phytoplankton and microphytobenthos production) were rejected by TTRL **(TTRL Impact Assessment 2016, page 117-118)**. Other suggestions included in the EPA Key Issues Report were recently dismissed by **Cahoon (2016)** because they were considered unfeasible.

E. RECOVERY OF BENTHIC COMMUNITIES

41 Benthic habitat and communities are expected to recover over time, but the knowledge gaps in our understanding of these systems and of the ecological implications of the mining activities make it difficult to establish a likely recovery timeframe. Uncertainties about the dispersion of the sediment plume (see **Greer's evidence**) and the duration and spatial arrangement of the mining operations (this evidence) also make this task particularly complicated.

42 A 10-year recovery timeframe is predicted by TTRL **(TTRL Impact Assessment 2016, page 105)** and the experts who examined the previous application found it reasonable **(Joint Statement 2014 – part 2, page 9)**. However, I think that a number of considerations have to be made to interpret this prediction correctly.

38.1 This timeframe may be appropriate only for the soft-bottom communities inhabiting the PPA, but not for more sensitive receptors inshore (e.g., kelp and fucoid canopies) and offshore (bryozoans habitats). If impacts were to occur on these habitats, very different recovery timeframes could be expected depending on the intensity and extension of the disturbance. However, TTRL does not mention these scenarios as they are considered unlikely.

38.2 There is not enough information about the spatial arrangement and temporal pattern of the mining operations (no literature reference is provided either) to predict that recovery will start immediately while mining is still ongoing, thereby producing a gradation in recovery as the activities move to new blocks each year **(TTRL Impact Assessment 2016, page 122)**. Depending on the position of the extraction site, recovery may remain influenced by high sedimentation levels. This may also affect non-mined areas which are expected to act as a source of larvae to repopulate the mined sites.

38.3 The 10-year recovery timeframe is estimated mainly on the basis of literature data **(McClary 2014, Appendix B, TTRL Impact Assessment 2016, page 122)**. Predictions based only on literature information have clear limitations because of differences in locations, biota and activities undertaken across studies. Despite the evidence available worldwide, predicting the time required for full biological recovery remains difficult because of site-specific factors **(Walker et al 2013)**. This is also highlighted in **MacDiarmid**'s recent evidence **(2016, paragraph 51, page 23)**, which states that the recovery time for benthic communities cannot be stated with precision as recovery rates need to be inferred from studies undertaken in more sheltered locations This is a reasonable comment, clearly contrasting with TTRL's vague and unsubstantiated claims about "rapid" and "almost immediate" recovery which dominate the Impact Assessment.

38.4 In the case of TTRL's application, comparisons with other studies are even harder to make because very little is known about the natural dynamics of the communities of the PPA and about the biology of specific organisms. For example, the polychaete *Euchone*, which is particularly abundant within the PPA, was previously undescribed and no research has been done about it in preparation for this new application. TTRL expects the recovery of benthic communities following the mining operations to occur mainly through larval recruitment, but no indication is provided about reproduction and early life history of the organisms which would be expected to recover.

38.5 TTRL states that the recolonisation experiment done by **Beaumont et al. (2013)** in the Wellington Harbour provides some indication of recovery from the mining activities **(TTRL Impact Assessment 2016, page 122)**. I don't agree with this and like **Paavo (2014),** I believe that the experiment provides no indication relevant to the application. This is because of the obvious differences in biota and physical environment between the Wellington Harbour and the STB, in addition to a number of artefacts associated with the experimental procedures, already highlighted by **Paavo (2014, page 15-16;** e.g., the immobilisation of sediment, the intentional prevention of benthic recolonisation, etc…).

43 I would also like to mention two further matters:

39.1 TTRL states that the re-deposited material will be similar to the material extracted in terms of particle size and this will aid recovery of the communities **(TTRL Impact Assessment 2016, page 121)**. However, in reply to a request for further information by the Decision Making Committee, TTRL state that there is a significant difference in the particle size distribution between discharged and extracted sediment. On average, over the particle size distribution range, there is a 6% difference, with the discharged sediment having a higher proportion of very coarse silt and finer sediment **(TTRL response to the DMC further information request, 31 October 2016, page 4)**. How can the two statements be reconciled, and how will these differences impact on benthic community structure?

39.2 Shell debris (also called shell-hash) is present in the seabed of the PPA **(Beaumont et al. 2013, Appendix B)**. Shell debris is an important biogenic habitat which improves biodiversity, substrate stability and biogeochemical processes **(Hewitt et al. 2005)**. Has TTRL taken this into account? Would shell debris be destroyed as part of the mining operations or screened and returned to the surface layer of the seabed as a hash as previous?

F. MONITORING FRAMEWORK

44 Unlike the previous application, the current one includes an extensive monitoring and management framework. This is the most significant improvement in the field of benthic ecology. The proposed framework seems adequate if all components are executed with due diligence. However, there are a number of important issues that the DMC will have to consider in relation to TTRL's proposed adaptive monitoring and management approach, as highlighted by the **EPA Key Issues Report (2016)** and the **AECOM report (2016)**. In particular, the key point is that the entire framework is based on response and compliance limits, equivalent to the 80^{th} and 95^{th} percentile background SSC respectively, for seven sites located east of the PPA. The solidity of this approach must be thoroughly verified. I would also like to highlight a number of areas where improvement or clarifications may be required.

40.1 Due to the many knowledge gaps, both with respect to the existing ecology and potential impacts of the sand mining activity, it is difficult to determine whether or not the most important locations and parameters are being monitored in order to determine the impacts. This is integral to adaptive management; a thorough understanding of the existing environment and the potential impacts is required.

40.2 As part of the monitoring strategy, there are 35 benthic monitoring stations, but only 3 are located inside the PPA. This number is not adequate and a greater sampling effort is required where the biggest impacts would inevitably occur. TTRL states that following the start of iron sand extraction activities, an additional two stations will be added annually for the first five years of extraction activities **(TTRL Appendices to the Impact Assessment 2016 – Environmental Monitoring and Management Plan, page 75)**. However, in my opinion, a larger number of stations should be sampled in the PPA since the start of the monitoring activities (perhaps 6 to 10 depending on the design and rationale according to which they would be distributed across different areas of the PPA). This would provide more detailed information about the benthic communities before mining starts and a better assessment of changes and recovery dynamics.

40.3 Benthic fauna would only be identified to family level. TTRL states that this level of taxonomic resolution is sufficient to identify differences in community structure through multivariate analyses in shallow water benthic assemblages **(TTRL Appendices to the Impact Assessment 2016 – Environmental Monitoring and Management Plan, page 73)**. I do not agree with this. The effectiveness of this approach (known as Taxonomic sufficiency; **Ellis 1985**) is highly debated and TTRL should provide a more detailed explanation of the rationale underlying the decision to use it.

40.4 The methodology for the sampling of intertidal rocky reefs would need to be improved. In particular:

40.3a The aerial photographs to assess the level of sand/fine sediment coverage on intertidal reef areas should be taken at multiple times throughout the year. This would provide a meaningful time series. One single set of photos taken only in summer would not be indicative of any sedimentation trend.

40.3b Because of the vertical zonation typical of intertidal reefs, sampling only along one transect is not an adequate procedure to capture the diversity of intertidal biota. Sampling multiple transects positioned at different tidal elevations would be a more accurate and informative approach **(see Lilley et al. 2006)**.

40.5 The proposed monitoring would generate a large amount of data, but it is not clear how these would be analysed. TTRL vaguely refers to multivariate analyses and "statistically significant interactions", but provides no detailed information about data analyses. Multivariate analyses are just tools and "statistically significant interactions" means nothing without any context (i.e. statistical significance may not relate to ecological significance). A more detailed description of the statistical procedures would help to assess whether these are adequate or not.

CONCLUSION

45 In conclusion, the state of the art in the field of benthic ecology is substantially unchanged compared to the previous application. Considerable effort has been invested in the improvement of models predicting sediment dispersion **(Hadfield & Macdonald 2015)**, optical effects **Pinkerton & Gall (2015)** and primary production **(Cahoon et al. 2015)**. However, much less attention has been dedicated to improve our understanding of the composition and functioning of benthic systems in the STB that will be impacted by the activities.

46 As a result, most of the predictions about the impacts of the proposed activities on the benthic environment relies on modelling, literature data and individual experts 'opinions, but not on a sound understanding of the benthic ecology of this area and scientific investigations to support it.

47 We still know relatively little about the composition and temporal dynamics of the STB benthic communities under the present conditions. Inevitably, considerable uncertainties remain about the potential impacts of the proposed activities.

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