IN THE MATTER of application U190438 by The New Zealand King Salmon Company Limited for Coastal Permit (Marine Farm) – North of Cape Lambert, North Marlborough

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STATEMENT OF EVIDENCE OF BRYONY MILLER

ON BEHALF OF FRIENDS OF NELSON HAVEN AND TASMAN BAY INCORPORATED INC., GUARDIANS OF THE SOUNDS, KENEPURU & CENTRAL SOUNDS RESIDENTS ASSOCIATION AND MARLBOROUGH ENVIRONMENT CENTRE.

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7 October 2021

INTRODUCTION

1. My full name is Bryony Miller.
2. I am a Principal Marine and Freshwater Ecologist at e3Scientific Limited.
3. I am a professional marine and freshwater ecologist and the Technical Director of Marine and Freshwater Ecology at e3Scientific Ltd. I am a member of the New Zealand Marine Sciences Society, the New Zealand Freshwater Science Society, a committee member of NZ Science Divers and a regional representative for the New Zealand Coastal Society.
4. I hold the following tertiary qualifications; a Bachelor of Applied Science in Environmental Science from AUT and a Diploma in Marine Science from Toi Ohomai Institute of Technology.
5. I have over 12 years' experience working in the marine science industry in Australia and New Zealand. My experience includes providing ecological impact assessments in the marine and freshwater environments predominantly within the Otago, Southland (including Fiordland) and Bay of Plenty Regions and providing technical input and review for Fisheries New Zealand (FNZ) and Regional Councils within Marlborough, Chatham Islands, Southland and Otago. Prior to working for e3Scientific I was employed by Fisheries New Zealand (FNZ) under The Ministry for Primary Industries (MPI), NZ Marine Science Centre, Antarctica NZ and the Institute of Geological and Nuclear Sciences (GNS Science).
6. I have a strong understanding of benthic dynamics and habitat function based on numerous subtidal marine investigations, benthic marine assessments for capital dredging and blasting works in Bluff Harbour, compliance seabed and wharf surveys for ports, benthic infaunal and epifaunal investigations to support coastal activities within marine protected areas, the classification of cockle (*Austrovenus stutchburyi*) suspended sediment threshold levels with regard to dredging and shellfish stock assessments for FNZ. I have also provided ecological impact assessments for aquaculture facilities that include a range of marine and freshwater species, including salmon. Whilst employed by MPI I worked on special projects assessing national and international dredging and trawling methods, and the flatfish fisheries plan which included benthic habitat assessments. Technical audits completed on behalf of regional and central government include hydro dam coastal discharge applications, Marlborough Sounds scallop fishery (SCA7) benthic investigations and fishery issues, cockle stock assessments for Otago (COC3) and Marlborough and Nelson Bays (COC7A), port activities, water abstractions and stormwater discharges. I have prepared ecological evidence for hearings and provided expert technical evidence at Environment Court.

7. I confirm that I have read and agree to comply with the Environment Court Code of Conduct for Expert Witnesses (Consolidated Practice Note 2014). This evidence is within my area of expertise, except where I state that I am relying on the evidence or information provided by other parties. I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

SCOPE OF EVIDENCE

8. I have been engaged by a coalition of community groups, Friends of Nelson Haven and Tasman Bay Incorporated Inc., Guardians of the Sounds, Kenepuru & Central Sounds Residents Association and Marlborough Environment Centre, together called in this evidence ’the coalition’ to provide a brief of evidence regarding the potential for benthic effects from the proposed 1,000 hectare (ha) ‘Blue Endeavour’ salmon farm consent application U190438. Please note; the applicants’ titled ‘Blue Endeavour site’ is interchangeably referred to as the ‘Cape Lambert site’ in this statement of evidence, to assist with geographical reference.
9. The coalition has asked me to address five main questions in considering the information provided in the application. The questions I address in my evidence are provided as follows:

   Question 1 – Is the characterisation of the benthic habitats likely to be affected by the proposal robust and appropriate for this size of application?

   Question 2 – Does the depositional modelling accurately reflect the environmental conditions and the proposed activity?

   Question 3 – Is the marine ecological effects assessment robust given the characterisation of the existing environment and the depositional modelling undertaken?

   Question 4 – Is Enrichment State (ES) utilised appropriately within the application and is it a sufficient measure to rely on to assess the impact of the proposed activity?

   Question 5 – Is an adaptive management approach appropriate for this application?

10. To address the questions asked of me by the coalition, I have read the following reports provided by the applicant, NZ King Salmon Ltd (NZKS):
    - “Assessment of seabed effects from an open ocean salmon farm proposal in the Marlborough coastal area”. Cawthron Report No. 3317 (Elvines et al., 2019);
    - The updated “Assessment of seabed effects for proposed 'blue endeavour' (revised) open ocean salmon farm”. Cawthron Report No. 3489 (Elvines et al., 2021a);

- “Blue Endeavour Seabed Investigation Broad-Scale Mapping of Biogenic Horse Mussel Reef” (Robertson, 2020);
- “Relating 'VenOM' depositional model outputs to ecological response: a case study using high-flow salmon farms in tory channel”. Cawthron Report No. 3521 (Elvines et al., 2021b); and
- “A comparison of three depositional models: DEPOMOD, SMTOMOD and VenOM”. Cawthron Report No. 3336A, (Smeaton & Vennell, 2021).
- Benthic Workshop Additional Information.

11. I have also read a series of reports commissioned by the Marlborough District Council in drafting the S42a report, including:
    - Mr Oldman - regarding benthic modelling;
    - Mr Davidson - regarding benthic effects;
    - Dr Lohrer - regarding sampling and habitat characterisation;
    - Dr Morrison - regarding benthic biogenic habitats and demersal fish (2019 report); and
    - Dr Giles - regarding benthic effects monitoring and management.
12. I have also read the following briefs of evidence on behalf of the applicant:
    - Dr Keeley
    - Dr Morrisey
    - Dr Robertson
13. Please note; the applicants’ proposed benthic effects monitoring and management plans have not been reviewed as part of this scope of evidence.
14. There are a number of key points regarding the proposed 1,000 ha Cape Lambert salmon farm that are of concern to local scientists and community groups who have been actively involved in aquaculture development within the Marlborough Sounds for the past few decades. This statement of evidence provides an independent review of the application and council documents to enable me to respond to the questions asked of me by the coalition.
15. I attach an appendix to this statement of evidence (Appendix BM1) which is ROV footage of the Ecologically Significant Marine Site (ESMS) McManaway Rock, taken on 10 June 2020.

Question 1 – Is the characterisation of the benthic habitats likely to be affected by the proposal robust and appropriate for this size of application?

16. It is understood that the benthic habitat under the proposed Cape Lambert farm is complex and has logistical challenges when attempting to classify and characterise. Generally, the methods utilised within Elvines et al. (2019 & 2021a) to assess the benthic habitats in situ are considered suitable. However, it is also apparent from the methods and results that there are significant limitations to both the data collected and the interpretation of the data which are not clearly outlined throughout the report but rather commented on briefly within the methods or results section. This is an important distinguishing point as within the concluding commentary these limitations are omitted, and previously qualitative components are being utilised in quantitative manners to state that the habitat is not significant and/or effects are less then minor.
17. Elvines et al., (2021a) appear to have put substantial effort into characterising the current environment via Multi-Beam Echo-Sounder (MBES) data and complementary observational data. However, the observational data coverage to validate MBES data is considered insufficient, particularly within the footprint of the proposed activity. I note that Elvines et al. (2019 and 2021a) adopts qualitative methods which are then restructured to provide quantitative statements based on numbers or percentages about whether a habitat is considered 'significant' or not in terms of habitat provision and ecosystem services. For example, Elvines et al. (2021a) state; "Occurrence of taxa and other seabed characteristics present was based on qualitative density estimates" "Abundance categories used by Elvines et al. (2019) were: rare = present in < 5% of the video frames, occasional = present in 5-20%, uncommon = present in 20-50%, common = present in 50-80%, abundant = present in 80-100%. Percent cover was assessed as an average across several video frames from different points of progression along a given transect". This is not an appropriate use of qualitative video data, which is largely uncorroborated by observational data, and the respective limitations to the findings are omitted within the concluding statements. This also should be put in the context of the camera reportedly leaving the seabed for unspecified sections of the transect "*Often, the sled was intentionally towed faster in order to cover more ground in the general area, resulting in long segments where no seabed is captured*" (Elvines et al. 2021a). As such I do not consider Elvines et al. (2021a) findings robust with respect to the characterisation of the area that is predicted to be affected by the proposed activity and the likelihood of significant habitats being adversely affected.

18. Benthic communities within the proposed farm footprint include "ecologically important" and "sensitive" habitats including horse mussels (*Atrina zelandica*), bryozoans, and brachiopods which are likely to be impacted even by the predicted low levels of deposition which are associated with 'mild enrichment' ranging from 3-12 g/m^2 (Elvines et al., 2021b). Elvines et al. (2021a) states that "*Live horse mussels were patchily distributed across the horse mussel/ brachiopod beds in Area A, with relatively barren areas of seabed (often 10s of metres) in between. Within this habitat, cover of 'beds supporting primarily intact horse mussels' varied between < 5% and 70% of the surface and was usually between 30 and 60%*"... "*Atrina-like forms', and 'potentially-living Atrina' were rare (see Appendix 5; Table A5.1). Therefore no 'beds' of living horse mussels are likely to exist within the farm footprint of either of the blocks of pens*". These statements should be considered in light of the qualitative nature of the benthic assessment, the stated "low quality" video footage and the low volume of verified observational data to accompany the MBES mapping. Given the limitations of the methodology I consider it possible that the conclusions drawn may not accurately represent the ecological values underlying the proposed farm sites.
19. There are no systemic maps of horse mussel distributions nor accurate estimates of their abundance around New Zealand. However, Anderson et al., (2019) estimated that nationally, areas of horse mussel beds had reduced by 25-75% and would continue to decline in the future. A point also identified by Dr Morrisey in his evidence dated 30 September 2021. Furthermore, their general habitat condition and ecosystem services were described as 'poor', which was noted to mainly refer to shelf beds due to damage and loss from bottom fishing activities (Anderson et al., 2019). Approximately 41 shelf bed locations were identified nationwide as part of Local Ecological Knowledge (LEK) interviews with commercial fishers regarding the "Continental shelf biogenic habitats" programme, which identified the Marlborough Sounds as one such habitat (Jones et al., 2016). Fishery evidence points to historical losses of horse mussels across New Zealand, both in assemblages where they tend to dominate, and as part of mixed biogenic habitat assemblages (Morrison et al., 2014), as does more localised assessments in the Outer Sounds and Cook Straight completed by Morrisey & Fletcher (2019). Although they are a fisheries QMS species this is predominantly to allow for bycatch reporting rather than due to their sustainable fishery characteristics. They are long-lived and recruitment appears to be highly variable between years meaning beds may appear or disappear over decadal scales (Hayward et al 1997). Therefore, although horse mussels are not considered 'Threatened' or 'At Risk' their nationwide distribution and abundance is not well described. Their known continental shelf

communities are often highly modified by bottom-contact fishing methods and as an ecologically important species they should not be assessed in Elvines et al. (2021a) by their threat classification but rather as Dr Morrison states in his S42A report by their ecological function; "*Species that are classified as threatened or at-risk by default do not exist in large numbers, or biomass/spatial coverage; and therefore, will not fundamentally affect other species. Ecologically important species, in contrast, are present in high relative numbers / large biomass, which allows them to act as influential species through mechanisms such as being keystone predators or providing habitat that supports many other associated species assemblages ('foundation species')*."

Field methods

20. The data quality of video transects in Appendix 4 of Elvines et al. (2021a) indicate 50% of the footage was of sub-optimal quality and the video sled was reported to lift from the benthos for long periods, therefore the benthic area indicated as assessed through GPS tow lines is unlikely to accurately represent the benthic area surveyed.
21. The video sled method used to assess brachiopod beds within the benthic characterisation is not considered appropriate by MacDiarmid et al. (2013) and is not a robust approach to determine the absence of brachiopod bed habitat, however this has been solely relied on when identifying this habitat type. Although these method limitations are acknowledged in footnote 17 (pg. 18 of Elvines et al. 2021a) and the accuracy is indicated to be improved by the 1 m distance from bed, the limitations of this method are omitted from the overall confidence in the benthic characterisation findings. Elvines et al (2021a) identify brachiopods as being present in the low density epifauna habitat which makes up a substantial area within the proposed effects footprint "*Brachiopods were rare-occasional (but densities were < 1 per* m^2*)*." Note, rare-occasional is an abundance category, indicating observations of brachiopods may be present in up to 20% of video frames.
22. The habitat classification video tows have also been undertaken during a tidal flow which promotes high turbidity and could have been avoided to increase the video footage quality and improve classification. Furthermore, it appears this issue may have occurred across all benthic tows indicating field data may not support robust classification of benthic habitat. No quality of data is indicated for ROV footage captured to inform Robertson (2020) or Elvines et al. (2019) studies.
23. Accurate habitat characterisation is critical to support the assessment of ecological effects, avoid sensitive environments and mitigate the effects of the activity. The field data collection component in this instance should have targeted slack tides to improve data

quality for classifications and should have also looked to supplement the substantial uncertainties in habitat characterisations. Laboratory tank-based experiments could also have been utilised to more accurately understand the potential effects. Without any site-specific species or habitat effects assessment, the assessment of effects relies heavily on robust classification and characterisation which, based on the limitations discussed within Elvines et al. (2019 & 2021a), has not occurred: "*obtaining quality visual imagery at this site is challenging due to the often-difficult working conditions associated with the high currents. Visual seabed surveys at this site should therefore target calm weather (~10 kts or less), neap, and ideally slack tidal conditions for best results. Outside of slack-water conditions at this site, we caution that it can be challenging to obtain high-precision, repeatable seabed visual imaging fit for quantitative analysis in routine monitoring*" (Elvines et al., 2021a).

24. Sediment and infauna grabs were initially taken as part of the Elvines et al. (2019) study prior to NZKS placement of the pens at the Cape Lambert Site. These were to assist in the characterisation of benthic substrate and infauna communities. However, only 3 sediment/infauna grabs were taken beneath the two proposed pen sites (1 under the northern pen and 2 under the southern pen) and a total of only 5 sediment/infauna grabs lie within the proposed depositional footprint (PD-PEF & RF-PEF) (an area of approximately 714 hectares; 539 ha in the northern block and 355 ha in the southern block) (Figure 1). It is my opinion this is an insufficient amount of data to adequately characterise the benthic substrate and infaunal communities. A revised sediment/infauna sampling plan should have been completed upon the placement of the pens to enable targeted data collection.
25. In Dr Keeley's evidence Point 31 he summarises "*All horse mussel and brachiopod <u>beds</u> (*my underline*) recorded during the collective surveys were found outside of the Blue Endeavour modelled footprint. It can be assumed that if those beds are exposed to any farm waste (it is possible they won't be at all), then it is expected to be at a very low level. Therefore, in my opinion it is unlikely that any measurable effects will be observed*". Horse mussels and brachiopods were found within the Cape Lambert modelled footprint, however, based on the captured video footage the percent viewed was not considered representative of a 'bed'. Given that the video sled methodology utilised is not considered best practice for assessing brachiopod beds (MacDiarmid, et al., 2013), and the classification of a 'bed' is based on a quantitative percentage, as well as the other aforementioned limitations to the Cape Lambert seabed surveys, this statement does not appear to be accurate.

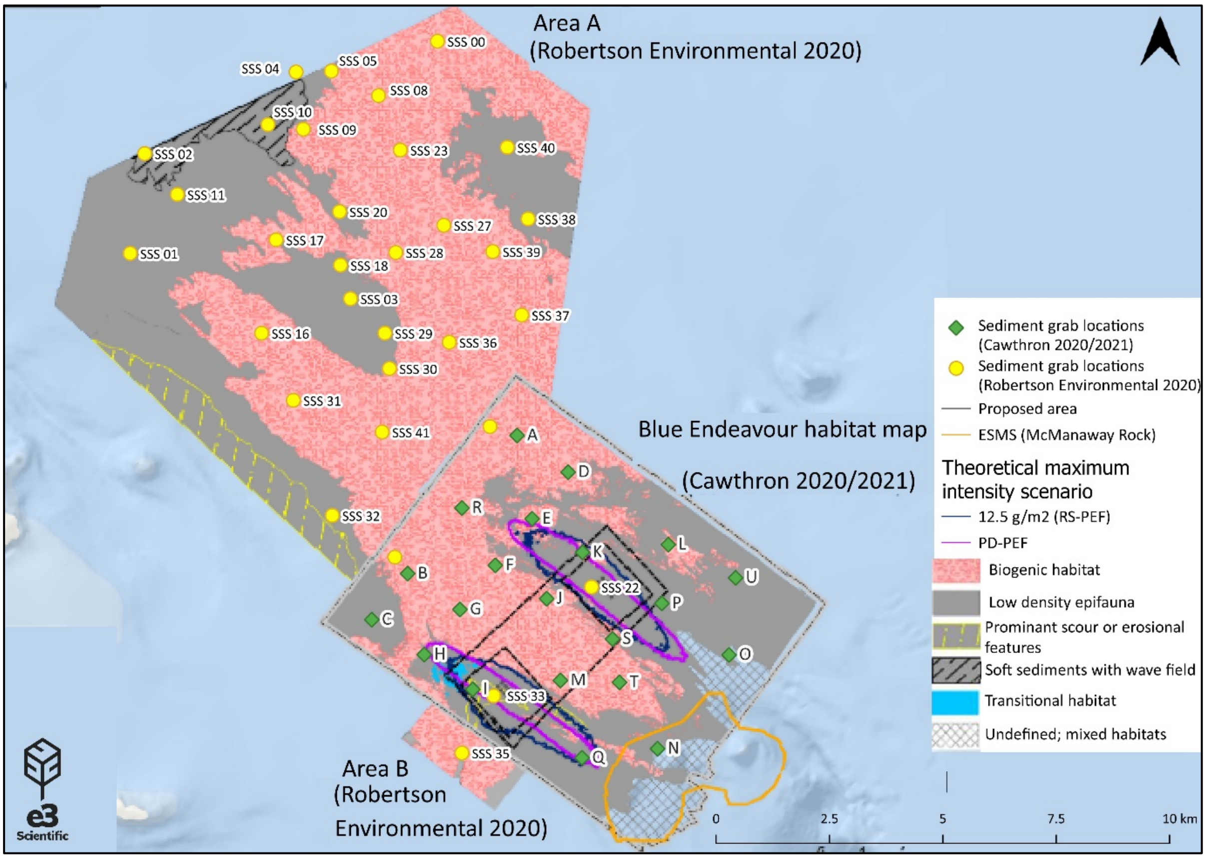

Figure 1: Modified benthic habitat figure with sediment and infauna grab locations georeferenced from Elvines et al. (2021a) and Robertson (2020).

Classification of Habitats

26. The broad-scale habitat maps provided are based on epifaunal characteristics. Relative abundance estimates were assigned for notable taxa, based on qualitative density estimates averaged across the entire video transect. Abundance categories used were: rare = present in < 5% of the video frames, occasional = present in 5-20%, uncommon = present in 20-50%, common = present in 50-80%, abundant = present in 80-100%. Percent cover was assessed as an average across several video frames from different points of progression along a given transect. The poor quality of 50% of video transects collected in the field does not appear to have been taken into consideration when assigning abundance estimates. The video sled left the sea floor for long periods of time and was reported to often have poor visibility which likely resulted in epifauna to be underrepresented and small epifauna such as brachiopods to be missed. In my opinion the poor quality of 50% of the video transects is likely to have underestimated the abundance of the epifaunal community. This community may be more abundant and consist of more vulnerable species than reported and therefore the resulting

ecological adverse effects in a relatively pristine environment may be greater than asserted by the applicant.

27. Density estimates, although useful, have not been found to be the best explanatory variable for the beneficial effects of horse mussels for benthic epifauna (Hewitt et al., 2002). Generally, the most useful variable is either found to be the minimum distance between small-scale clusters of *A. zelandica* within high density beds and the distance between individual *A. zelandica* in sparse beds. This suggests that *A. zelandica* may be as important in creating a habitat while also as in directly interacting with other species. Therefore, it is appropriate to consider organism interactions on the basis of dynamics within environments such as is frequently undertaken for habitat-organism interactions (McIntyre & Wiens, 2000; Bowers & Dooley, 1999) rather than just density-to-density comparisons.
28. Further to this, juvenile *A. zelandica* grow completely buried and only protrude above the surface sediments as they mature (Hay, 1990), as such horse mussel nursery beds are not readily identified via video tows. Therefore, the assumption that patchy individual horse mussels do not represent a significant habitat may considerably underestimate the beneficial ecosystem effects of this species and important nursery areas.
29. The benthic classifications within the applications' technical reports are inconsistent. Robertson (2020) classify areas of 'low-density epifauna' of the sub class "*coarser sediments; sand and shell material predominate*" following the area that is classified by Elvines et al. (2019) as 'bryozoan fields'. Low density epifauna is a habitat type described by Elvines et al. (2021a) to contain 'solid branching and bushy types' of bryozoans but apparently no brachiopods beds despite the previous classification in the 2019 assessment and the limitations in identifying the absence of brachiopods due to the video methodology used.
30. The benthic habitat reclassified from 'bryozoan fields' in Elvines et al (2019) to 'low-density epifauna' in Elvines et al. (2021a) sits directly below the proposed pen sites and is stated to have "low ecological value" and "no special ecological significance" (Section 2.3.3; Elvines et al, 2021a). The executive summary concludes the farm will have no effect on biogenic habitat, and it can only be assumed from this statement that the class "low density epifauna" is not considered to be biogenic habitat. However, of importance here is that this habitat type meets the ecological significance criteria of Appendix 3 ecological significance criteria under Diversity and Pattern (Medium) within the proposed Marlborough Environment Plan (pMEP); and the significance criteria for National Environmental Standards – Marine Aquaculture (NES-MA) as it has areas of shell hash >40%. At the very least this

requires that installation and operation of a farm closer than 50 m shall not have an adverse effect on the habitat.

31. The habitat class 'Undefined; mixed habitats' includes McManaway Rocks and the adjacent benthic area stretching just beyond the significant habitat area identified in the pMEP. This habitat class is noted to include erosional seabed features and highly variable sediment types dominated by coarse material (shell, gravel, rock). No ground-truthing has been undertaken in this habitat class to describe the epifaunal assemblages present. It appears this lack of characterisation is based on the assumption that the depositional model is 100% accurate and this area will not be within the primary depositional farm footprint. This is of significant ecological concern as not only are the VenOM depositional model inputs not locally calibrated, but it also appears to utilise the same inputs as DEPOMOD which has been assessed in other NZKS 'dispersive' farms (Waitata and Tory Channel) to have underestimated the depositional footprint by between 40-58% (Hearing evidence from Rob Schuckard re Application U190357, November 2019). This could have substantial implications for this significant habitat as McManaway Rocks and could sit within the actual primary footprint of the Cape Lambert farm, but the potential effects on the rock formation have not been addressed in the application.
32. Even if it is assumed that Elvines et al.'s (2021b) proposed depositional modelling has accurately captured the extent of the deposition footprint activity, and cites attributes utilising Norwegian, Scottish and non-locally calibrated parameters; McManaway Rocks significant marine habitat remains within the area that is stated to have some accumulation of depositional material arising from the Cape Lambert site. In my view, the lack of assessment of effects on the McManaway Rocks is an oversight of the application and further information is required to support an accurate assessment of risk to this significant marine habitat.
33. Local ecological knowledge is another tool to assist in characterising an area, which along with observational data can assist in delineating sizeable habitat types quickly. Local commercial fishermen often have a comprehensive knowledge of benthic marine habitats from generations of fishing an area. Protection from trawling is proposed as a potential benefit to benthic communities within the site location, however trawl records indicate this location has low annual trawl intensity. Elvines et al. (2021a) discuss the role of anchor blocks, pen and warp structures "*Once established, the presence of farm structures may also be beneficial for some organisms, due to the protection they provide from destructive activities such as use of towed fishing gear*." Conclusions such as this are meaningless for

this location as trawl records indicate this location has low annual trawl intensity, as Elvines et al. (2021a) acknowledges. Benthic trawl fishers target areas appropriate to their catch species to reduce the likelihood of gear entanglement and lost fishing productivity (Michael, 2010), which often includes areas with substantial biogenic habitat. The apparent avoidance of trawl fishing in the proposed Cape Lambert location could indicate local fishermen are aware of greater biogenic habitat than this application has characterised. Furthermore, the low level of bottom contact fishing in this area further supports the high natural character and ecological significance of this location (Clark et al., 2019; Cryer et al., 2002).

Question 2 – Does the depositional modelling accurately reflect the environmental conditions and the proposed activity?

34. The proposed depositional footprint is based on inputs that appear to have inherent differences from the proposed sites' characteristics and utilises species parameters that are not the species proposed to be farmed. It is appreciated that this is a complex site to model however, the outputs of a model that is not locally calibrated nor species specific should not be utilised as it has been in this application to discount the possibility of adverse effects on the benthos outside of the footprint. For example, "*(I)mpacts to McManaway Rocks are not expected to occur, even if maximum monthly feed discharges are realised at the northern and southern blocks concurrently*", despite the McManaway Rocks ESMS boundary lying approx. 250 m from the southern edge of the primary depositional footprint.
35. Mr Oldman states in his s42a report that the "*Overall the modelling approach in the application cannot be considered best practice*". I concur with this statement based on the following points.
36. Appendix 2 of Elvines et al. 2021a note that VenOM model input parameters use a pen circumference of 200 m for all Cape Lambert simulations. The impact of this on the model outputs are not discussed. The model input parameters should reflect the full net circumference proposed of 240 m.
37. The field validation using data collected in Tory Channel (Elvines et al. 2021b) does not clarify how reliable VenOM is in the context of this application. Wave and current environment differ significantly between Tory Channel (average 15-22 cm/sec water current) and Cook Straight (mid-depth average 40 cm/sec water current), but these differences are not referred to and their implications for the validation of VenOM not addressed. The Tory Channel case study is mentioned throughout the report as the only point of reference to validate the VenOM results. This limitation should then be given greater consideration in the

final outputs and the proposed footprint as it is not calibrated to the fast-flow environment and depths which it is attempting to model.

38. There is uncertainty about the accuracy of the residual solid modelling, which had a weak correlation with enrichment state when validated against the Tory Channel field data. Residual solids should help to describe more accurately the accumulation of biodeposits on the seabed accounting for the effects of particle resuspension and decay. This is one of the main points of difference between VenOM and other models used historically, and a particularly important point of difference for a highly dispersive site like Cape Lambert.
39. VenOM uses the same input parameters as DEPOMOD. Several model parameters (Table A2.1, Elvines et al. 2021b) come from Cromey et al. 2002, who developed them for Scottish Atlantic salmon under conditions not comparable to those of the Cape Lambert site. Therefore, despite a new model being developed, the input parameters appear to be largely the same as for DEPOMOD, which has proven unreliable in predicting the impacts of other fast-flow farms in the Marlborough Sounds, where currents are slower than at the proposed site, such as the NZKS Waitata farm. This reduces confidence in the VenOM model being superior to DEPOMOD as it is characterised by the same input parameters.
40. The Clay Point Salmon Farm in Tory Channel has a similar water current compared to the Waitata Farm and is used as a case study for the testing of the VenOM model. Clay Point has been operating since 2009 with feed levels between 3160-4531 tonnes per annum. The predicted footprint for this farm (ES≥3) was to be 9.4 ha (Keeley et al., 2013). The observed footprint was 13.2 ha, a difference of about 40%. This difference is comparable with the 58% difference between the predicted and footprint assessed at the Waitata Farm (R. Schuckard; U190357 Hearing Evidence, November 2019). This comparison between the two farms shows the uncertainty of DEPOMOD modelling at dispersive farms. Although VenOM is offered by NZKS in the Cape Lambert application as a more robust alternative to DEPOMOD with the inclusion of resuspension, the parameter inputs are largely the same and it is unverified in practice. If the discrepancy between the observed and the modelled footprint of the Cape Lambert site is similar to the 40 or 58% difference assessed at the two ‘high flow’ NZKS farms (Clay Point and Waitata) currently operating, the depositional footprint could extend from the predicted ~714 ha to between ~1,000 ha and 1,130 ha. This then has implications for a considerable footprint overlap of the McManaway Rocks ESMS.
41. No assessment has been provided for how parameters developed for Atlantic salmon have been calibrated for Chinook salmon. In September 2021, following the Cape Lambert benthic workshop, NZKS attempted to justify the 85% digestibility coefficient (Malcolm Smeaton

Memo, 9th September 2021), however these parameters should be qualified by their limitations to represent the model they are being utilised for. This then raises the question of why, after 30 years of Chinook salmon farming in New Zealand by the applicant, are there not more reliable and relevant parameters available for the model regarding Chinook salmon digestibility. Utilising the parameter inputs from a study carried out almost 20 years ago by Cromey et al. (2002), that has been assessed via DEPOMOD observed footprints at NZKS high flow farms to misrepresent the deposition area by up to 58%, does not appear to be a robust approach and is not likely to provide a true reflection of the outer benthic limits.

42. The decay constant, K, was estimated from infaunal respiration rates reported in a single study carried out at a single farm in Norway (Keeley et al. 2019). There is no explanation as to why the decay constant is unable to be calculated using local data. Elvines et al. (2021b) never discusses this and does not provide a justification for using only data from Norway, nor discusses their applicability to the Outer Sounds context.
43. The Keeley et al. (2019) study utilised for the decay constant in the VenOM model (Elvines et al. 2021b) was also regarding an Atlantic salmon farm, not Chinook salmon, which will be grown at the Cape Lambert salmon farm. Other significant differences in the two studies are latitudinal (63.7° North vs 41° South), water depths (31-40 m depth vs 60-70 m depth), and significantly different current speeds (average of 3-8 cm/sec vs. 30-35 cm/sec). It is also unclear how food volumes between the Norwegian farm and the Cape Lambert site differ as no information is provided.
44. VenOM does not account for the influence of benthic topography on particle retention. This casts further doubt on the accuracy of VenOM given the presence of extensive areas colonized by habitat-modifying organisms, such as horse mussels, which increase substrate complexity and promote the accumulation of biodeposits.
45. Salmon are fed different size pellets at different size classes. Pellet size, along with the feeding efficiency of the different size classes, can affect the amount of food wasted. The model input for pellet settling speed (0.095 m/s) would apply to a feed pellet of approx. 5 mm diameter according to the relationship reported by Cromey et al. (2002). This is an average value used in the absence of NZ-specific peer-reviewed data. It is unclear how it was calculated (i.e., average of what?) and whether it accounts for the range of pellet sizes that would be used for different size classes of fish.
46. It is unclear how the wave environment may affect the proposed operations and the amount of material discharged to the benthos. Waves over 2 m occur every 3 to 5 weeks and can last up to 5 days at this site as highlighted in the water column report (Newcombe et al., 2020).

Assuming that feeding operations will not be suspended during periods of high waves, the implications for the deposition modelling under these conditions are not stated. It is possible that in high-wave conditions the percentage of food waste may be higher than 3%, however, it is unclear from the modelling methods whether these components have been accounted for.

47. Another effect of farming, observed by Keeley et al., (2013) is "*associated with the continual rain of organic material, which results in a situation where the sediment is enriched even though there is no net accumulation because material is constantly being advected away. Therefore, using non-resuspension scenarios to predict effects for such high-flow sites is potentially more appropriate on the basis that it represents the 'primary footprint', defined as where the particles may fall on initial settlement and where effects are most pronounced*". Subsequently, particles are likely redistributed by re-suspension and horizontal transportation, resulting in alterations to the overall size or shape of the footprint. DEPOMOD 2.2 modelling for fast flow farm Waitata in the Marlborough Sounds (U140294) showed that even with no resuspension, the model was significantly underestimating the size of the footprint. With resuspension, it was predicted that there was no accumulation of deposits for feed loadings modelled for 2000-8000 t yr^{-1} (Ellis et al. 2011).

48. When interpreting model results, it is also important to keep in mind that a series of studies have shown significant farm deposition effects in high energy habitats despite dilution due to exposed conditions (Lee et al., 2006; Hall-Spencer et al., 2006; Sarà et al., 2006; Mayor et al., 2010; Sweetman et al., 2014). For dispersive systems, enrichment effects have been observed also in the absence of significant organic accumulation on the seabed (i.e., simply as a result of the continual rain of organic material). Keeley et al., (2013) found that the conventionally held view that benthic effects are proportional to depositional flux (Cromey et al., 2002), is not always the case and that the resultant effects were not negligible. A similar observation was made by Chamberlain & Stucchi (2007) at a moderately dispersive site in Canada, where DEPOMOD predicted that virtually all of the material would be exported from the site, yet localised seabed enrichment was evident. This suggests that either the resuspension component of the model is overpredicting how much material is being exported, or the model is correct, and the common understanding of how ecological effects are induced at dispersive sites is incomplete. Therefore, a precautionary approach to the results is required even when model inputs are stated to represent 'worst case scenarios'.

49. I have examined the model and it appears that some of the inputs utilised are more representative of 'low-flow' sites rather than the proposed 'high-flow' environment. Also, the calibration of the relatively unvalidated VenOM model has been with a slower flow environment in the Sounds which does not experience the same environmental variables nor depth ranges.
50. It should also be noted that the suggested positive 'dilution effect' from high-flow sites has been shown to not reduce the depositional impacts on benthic ecosystems in any significant manner (Hall-Spencer et al. 2006; Lee et al., 2006; Sarà et al., 2006; Sweetman et al., 2014).
51. In summary, I consider the modelling undertaken to support an assessment of the extent of the organic depositional footprint has a number of flaws that undermine the accuracy of the model. Given the size of the proposed salmon farm, inaccuracy of the model could increase the size of the depositional footprint by hundreds of hectares. If this is the case, the ecological effects could be far greater than those anticipated under the modelled scenario.

Question 3 – Is the marine ecological effects assessment robust given the characterisation of the existing environment and the depositional modelling undertaken?

52. It appears that, due to the largely unsubstantiated findings that "*no 'beds' of living horse mussels are likely to exist within the farm footprint of either of the blocks of pens*", among other such statements and the reclassification of 'bryozoan fields' to 'low density epifauna', no attempt has been made to assess the benthic responses of this species within an open water habitat to the proposed activity. Elvines et al (2021a) have not included any form of assessment of how sensitive and ecologically important species and communities within the Outer Sounds will adapt or survive to the proposed depositional inputs from the Cape Lambert farm. It is not evident why this component of high uncertainty within the assessment of effects has not been addressed. There are substantial differences between shallow coastal (i.e. Inner Sounds) and deep coastal or shelf communities (i.e. Outer Sounds) and species adaptations (as discussed earlier; Gage, 1996; Holmer, 2010) therefore, assumptions regarding survivorship to the proposed organic loadings are not considered suitable when based on coastal habitats. In order to understand the effects of the salmon farm I believe the applicant should have results based on suitably designed tank-based experiments with live horse mussels and brachiopods (collected from the proposed farm area; i.e deep coastal habitat). This would have allowed controlled assessment of the effect

of assessing how salmon waste (mimicking the proposed farm activities) affects species feeding and survival.

53. The application assumes that due to its dispersive high flow nature the Cape Lambert site can cope with salmon feed volumes which, put in context, at the lowest predicted farm scale are of a similar volume of all the current operational farms in New Zealand added together (i.e., a total of ~15,000 greenweight tonnes per annum versus potentially ~11,000[1]). However, Sweetman et al., (2014) found that fish farming can dramatically alter benthic ecosystem functioning, and significant effects can occur around fish farms irrespective of the water-flow regime the farms are moored in. Whilst some theoretical models predict this type of scenario (Findlay & Watling 1997; Kalantzi & Karakassis 2006), some studies have shown that water flow has little effect in reducing disturbance (Carroll et al. 2003; Lee et al. 2006). For example, Mayor et al. (2010) found that the magnitude of effects under some net pens located in high current speed areas can be greater than at similarly sized fish farms situated in more quiescent waters. In addition, higher flushing rates through fish farms will likely increase the area over which particulate organic waste products are deposited and areal extent to which seafloor ecosystems are affected (Sarà et al., 2006).
54. There is also more localised evidence that deposition from farms in high flow environments will not be mitigated by local high flow dynamics and detrimental effects to the structure and organisation on the local benthos are measurable, such as has been observed at Waitata farm. Areas with diverse communities indicative of fast flow habitats identified from the Waitata site (Ellis et al., 2011), tended to have a wider range of ecological functions and such communities are known to be more quickly degraded and take longer to recover from salmon farm practices than those where diversity is low and the communities are simple (Thrush & Whitlatch, 2001; Hall-Spencer et al. 2006). The fauna at more sheltered locations where organic-rich sediments accumulate may have a more natural resilience to organic loading, being ecologically and functionally pre-adapted to cope with an increased level of organic enrichment. Consequently, impacts will be more significant in areas with inherently high diversity and the assumption that developing farms in more exposed locations thereby reducing the environmental impact of organic enrichment by spreading the effects, may in fact be unfounded (MacLeod et al. 2006).
55. Although an area adjacent to the proposed site has been assessed, no effort seems to have been made to characterise species abundance at the proposed site nor to assess the ability

[1] It is unclear from the Cape Lambert application what the total proposed volume of fish annually produced will be (in greenweight tonnes); however, based on the 1.8 times production conversion ratio (PCR) and 20,000 t of feed it is assumed to be ~11,000 t per annum.

of these organisms to recover from a similar disturbance. Subsequent surveys beyond the farm location by Robertson (2020), have identified a transition from biogenic habitat to soft sediment habitat which may have been more suitable to placement of a salmon farm. These sites are also further from the McManaway Rocks significant ecological area. However, the extent of this habitat was not investigated further.

56. In general, there is very limited information available on the response of benthic shelf and deep coastal communities (i.e., 50-100 m depths) to organic enrichment. A certain capacity to consume (fauna) and decompose (microbial) organic matter can be expected, although it is important to take into account the high quality of organic matter settling from fish farms compared to allochthonous material (Holmer, 2010). Fish farm waste is enriched in proteins and lipids, and even low sedimentation rates add relatively large amounts of organic matter to the benthic compartment (Holmer et al., 2007; Pusceddu et al., 2007). Where coastal sediments host a diverse benthic fauna community, some of which are tolerant to organic pollution, deep coastal and shelf fauna are adapted to lower food conditions, oxic or oxidized sediments and are most likely less tolerant to organic enrichment (Lee et al., 2006; Kutti et al., 2007). Such a benthic community may rapidly be significantly altered due to organic inputs from farms, with limited potential of reestablishment due to low recruitment and slow growth rates (Gage, 1996). Low recruitment also affects the potential for regeneration of the sediments after fallowing. If no pollution-tolerant fauna are present to colonize the enriched sediments, the stimulatory effect of benthic fauna in regenerating sediments is less, increasing the duration of the recovery period (Lin & Bailey-Brock, 2008; Macleod et al., 2007).

57. The impact of biodeposits to the seafloor is provided in the context of Enrichment State (ES), a metric calculated for inshore soft-sediment infaunal communities. The applicant has indicated similarities between infauna at the Cape Lambert Site and the three salmon farms (Clay Point, Te Pangu and Ngamahau) in Tory Channel and attempts to relate deposition rates to the monitored effects on rocky reef communities found in the Tory Channel. These rocky reef communities contain, in general, various hydroids, sponges, ascidians and macroalgae (Dunmore, 2019). Whether these communities can be compared with horse mussel beds, brachiopods and bryozoan communities and have a similar sensitivity to the effect from the proposed Cape Lambert activity has not been assessed. There appears to be poor consideration made for epifaunal community and sensitive habitats at the Cape Lambert site.

58. The 12.5 g/m^2 threshold of residual solids is heavily relied on to inform the primary deposition footprint and anticipated area of effect (Figure 2). However, 12.5 g/m^2 was the midpoint of the modelled range when validating the model. In this validation, moderate effects could be expected for deposition ranging from 7–18 g/m^2. "*Soft sediment stations showing 'mild enrichment' (n = 7) (i.e., enhanced infauna with increased numbers of taxa and/or total abundances) had variable residual solids values (between 3 and 12 g·m$_{-2}$; mid-point 7.5 g·m$_{-2}$*)." Given that these depositional effects are based on enrichment state calculated for soft sediment infauna and much of the Outer Sound area provides habitat for vulnerable epifauna, a more precautionary approach should be taken. A more precautionary approach may be to use 7 g/m^2 as a threshold of effect for soft sediment habitats. Elvines et al. (2021b) indicate the lower range for potential mild enrichment is 3 g/m^2, a lower threshold of residual solids such as this may be appropriate to inform a preliminary boundary of potential effects for epifauna until the impacts of depositional material on these species is better understood. Residual solids up to 9 g/m^2 were cited as having no effect on rocky reef near a salmon farm in the Marlborough Sounds (Elvines et al., 2021b) and is utilised within Elvines et al. (2021a) to assess what consitutes "no or low effects". This finding within Elvines et al. (2021b) appears to have come from a validation/model using one year of data from 14 rocky reef sites, of which only 6 sites had predicted residual solids

above 3 g/m^2 and is not considered a directly applicable correlation to the current proposal.

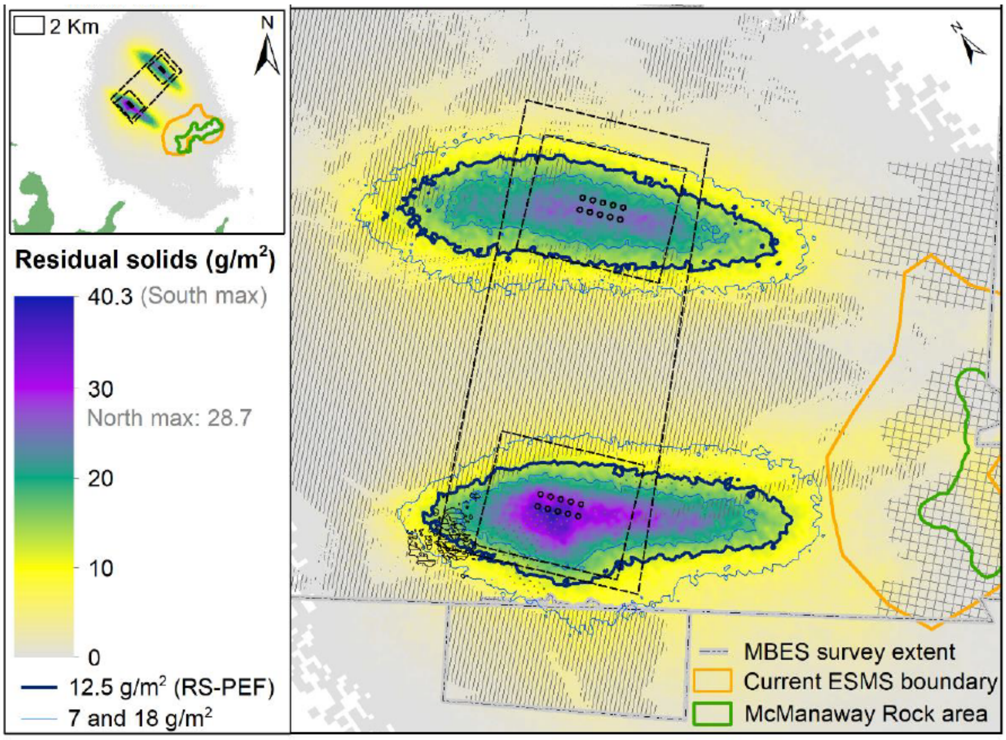

Figure 12. Modelled solids flux and residual solids concentrations from depositional modelling based on a **maximum permissible <u>periodic</u> feed discharge** simulation for both farm blocks (2,286 tonnes/block/month). The pink line indicates the primary deposition predicted effects footprint (PD-PEF) area where solids flux is > 0.5 kg/m^2/yr (41.7 g/m^2/month), while the residual solids contours (7, 12.5, and 18 g/m^2 residual solids) are shown as blue lines. The residual solids predicted effects footprint (RS-PEF) is shown as a dark blue line. The background delineates the seabed habitats as described in Section 3.1.3.

Figure 2: Modelled solids flux and residual solids concentrations from Elvines et al. (2021b).

59. Accumulation of organic material is most likely to occur in seafloor depressions, and in areas with higher surface rugosity such as provided by patch reefs and biogenic habitat. In these areas, lower shear velocities encourage deposition of particles, and the variable seabed relief can protect them from resuspension (Keeley et al., 2018). Therefore, there are significant concerns that the Enrichment State (ES) and modelled deposition rates will not be uniform across the seabed as is assumed within Elvines et al. (2021b) but will have a greater impact on the biogenic habitats with increased rugosity and biodiversity.

60. The tolerance of ecologically important and/or sensitive epifauna such as horse mussels, bryozoans, and brachiopods to deposition of farm waste are not well studied in a New Zealand context. *A. zealandica* are well known for their habitat modifying characteristics which can facilitate increases in biodiversity of surrounding communities via refuge from predation and the accumulation of biodeposits (Hewitt et al., 2006; Miller et al., 2002; Norkko et al., 2006; Anderson et al., 2019; MacDiarmid et al., 2013). However, it has also

been found that the beneficial macrofaunal facilitations created by *A. zealandica* are conditional and that facilitation decreased with increased suspended sediment concentrations (SSC) (Norkko et al., 2006). Therefore, although impacts on these sensitive benthic species are not well studied with regards to farm waste, in the absence of this information, correlations could be drawn between the predicted increases in SSC and the potential responses of these species which appear likely to cause adverse effects.

61. It is stated in Elvines et al. (2021a) that benthic impacts are not predicted beyond the farm deposition footprint. However, SSC as low as 80 mg/L, which are commonly recorded during storms, can depress the feeding rate of *A. zelandica* (Thrush et al., 2004). Combined laboratory and field experiments and surveys on *A. zelandica* have demonstrated the strong negative effect on its physiological condition, resulting in a natural distribution limit controlled by suspended sediment load (Ellis et al., 2002). In addition, the response of *A. zelandica* to elevated suspended sediment concentration is thought to be partly dependent on environmental history (Hewitt & Pilditch, 2004; Lohrer et al., 2006). The *A. zelandica* beds at the proposed site may be acclimatized to relatively pristine conditions and be particularly sensitive to the faming impacts. Horse mussels have also recently been identified as an important nursery habitat for juvenile blue cod in the Marlborough Sounds (Anderson et al. 2019) and horse mussels and bryozoan colonies have been shown to be important modifiers of habitat of soft sediment communities increasing biodiversity and recycling nutrients (Cummings et al., 1998; Grange et al., 2003; Norkko et al., 2001). Only sparse horse mussels occur throughout the Inner Sounds following significant damage as a result of scallop dredge fishing and nationally horse mussel beds are in decline mainly due to bottom contact fishing (Anderson et al. 2019). Large-scale losses of horse mussel beds from across the outer Marlborough Sounds in association with declines in water quality, increased sedimentation and resuspension of sediments have been described by long-time fishers and residents (Anderson et al. 2019). Due to these issues, it is considered highly unlikely that effects from the Cape Lambert farm will have less than minor impacts on this species and its habitat. Further to this, based on the significant concerns regarding the extent of the actual versus predicted footprint of ‘moderate enrichment’ underpinning the proposal it is expected that the detrimental effects on this species and associated benthos will be much higher and widespread than is predicted.

62. Bryozoan are important habitat forming species and provide a range of ecosystem services (MacDiarmid et al., 2013; Anderson et al., 2019). There is information suggesting that bryozoan fields exposed to bottom fishing activity have undergone physical removal and

damage possibly over extensive areas, such as kilometers of seafloor (e.g. Otago shelf, Separation Point and Patea Shoals (MacDiarmid et al. 2013; Anderson et al. 2019). Bryozoan reefs at Separation Point, have been slow to recover after being protected from fishing following benthic degradation (Anderson et al. 2019). The most common type of bryozoans within the proposed Cape Lambert site were soft, flexible branching or bushy forms (likely Candidae and Catenicellidae) which would not be expected to recover quickly. Due to the cited low dredge and trawl intensity this site currently experiences it may be one of the few remaining bryozoan habitats that have not been degraded by bottom contact fishing.

63. Epifauna, even more mobile species, are vulnerable to farm enrichment. In 1988, salmon farms were temporarily moved to sit over unmodified brachiopod beds in Paterson Inlet and the effects were well documented by Hare (1992) (Figure 3). Although this study was not within an open ocean environment, it provides an observation of the response of an unmodified seafloor community and the relative sensitivity of benthic epifauna to smothering with farm waste. After one month, a layer of farm deposition covered the seafloor beneath the farms completely. Dead heart urchins *Echinocardium cordatum* and holothurians, which live below the sediment surface, were commonly observed. Additionally, several dead holothurians *Chirodota nigra* and brachiopods *Terebratella sanguinea* and *Neothyris lenticularis* were documented. After less than three months of deposition, mortality of mobile species such as scallops *Pecten novae-zelandiae* and *Talochlamys gemmulata* was observed. As discussed earlier, high flow sites do not necessarily facilitate high dilution and reduced deposition (evidenced by depositional results from Waitata and Tory Channel farms; Keeley et al., 2013) therefore it is important to consider the potential for this type of impact at the Cape Lambert site, particularly in the absence of locally calibrated depositional modellling.

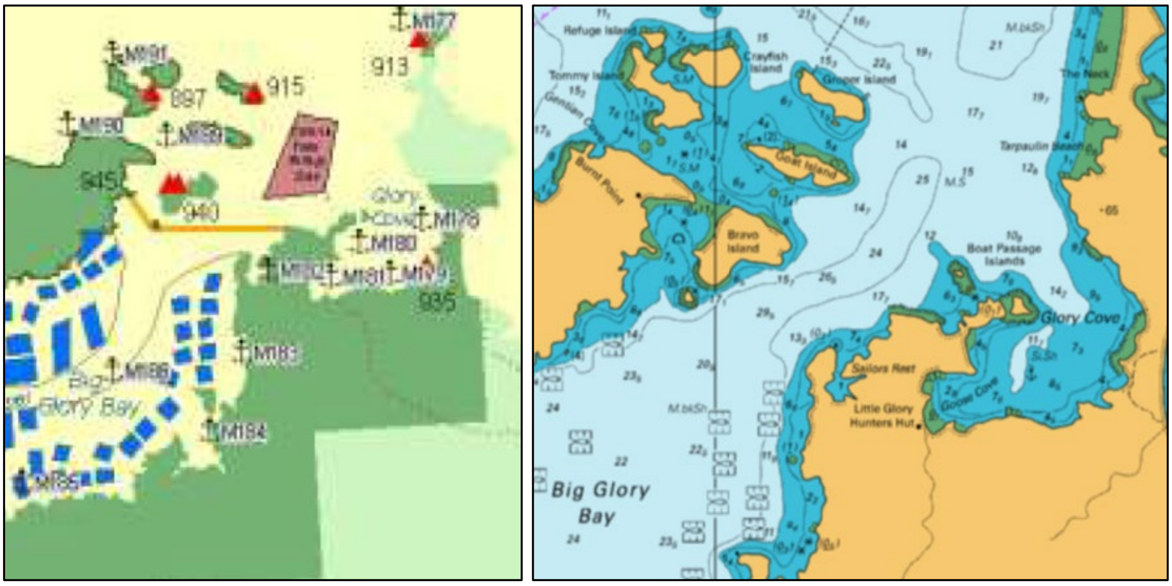

Figure 3: Salmon refuge site monitored and reported on by Hare, 1992, and bathymetry.

64. Robertson (2020) noted it was difficult to distinguish live from intact dead horse mussel shells in videos and, therefore, to assess the ecological value of the beds. However, the ecological significance of habitat classification, particularly regarding horse mussel beds, should not be reduced due to presence of dead shell. The NZCPS guidance elaborates that biogenic systems are natural marine habitats and communities that are created by the physical structure of living or dead organisms or by their interaction with the substrate. Horse mussels retain function as biogenic habitat even when dead due to their large shell structure providing ecological services such as habitat for attachment, reproduction and refuge which would otherwise be absent for a range of species (Figure 4). The difficulty in differentiating between alive and dead shellfish, due to their rich encrusting communities and continued upright position in the sediment, further supports the ecological role of these structures.

Figure 4: Horse mussel shell 'habitat' from Marlborough Sounds (S. O'Connell-Milne, 2017).

65. Robertson (2020) observed horse mussels to be covered in a layer of fine sediment. Fine sediments were considered to have a potential role in horse mussel mortality and concluded that these bivalves represented a degraded example of this ecosystem. Based on Robertson's (2020) assumption of fine sediments coming from the Pelorus Sound and potentially causing or having a role in mortality of horse mussels, the far field effects of the proposed farm should be considered as an additional stressor which may cause further mortality on any horse mussel beds. The cumulative effect of farm waste has not been considered for existing or potential stressors on horse mussel beds i.e. terrigenous sediment migrating from inner sound activities.
66. Further to species specific effects, this application should be considered in the context of a region in which the marine environment is experiencing unprecedented degradation (Urlich & Handley, 2020). With benthic communities and the whole marine ecosystem already under extreme pressure within the inner Sounds, the potential effects of the proposed Cape Lambert site may have significant unforeseen regional ecological impacts.
67. Cumulative effects of fishing, aquaculture, forestry and shipping within the adjacent environment are not considered despite some evidence that terrigenous sediment (classified within Elvines et al. 2021 as mud) is already encroaching on this site. Furthermore, Robertson (2020) cites this layer of fine sediments as rationale for classifying it as 'degraded'

rather than assessing that this deep coastal shelf habitat previously thought to be pristine is now experiencing anthropogenic degradation.

68. The implications of this terrigenous mud encroaching on the edges of the proposed site from the inner sounds may create a tipping point for benthos already experiencing levels of stress from land, fisheries and aquaculture activities within the sounds. Therefore, it is necessary to assess the potential for cumulative effects on these significant benthic habitats.

McManaway Rock

69. The McManaway Rock is an offshore rock stack which meets pMEP significance criteria for rarity, diversity and pattern and distinctiveness. The proposal suggests reducing the boundary for the McManaway Rocks Ecological Significant Marine Site (ESMS) area to 100 m from the rock structure. This reduction would remove the extent of the ESMS to be outside of the area considered ‘affected’ by the Cape Lambert farm deposition. It appears that Elvines et al. (2021a) only consider the rock itself to be of value and disregards the significant body of work that has gone into completing the ESMS assessment to delineate the existing boundary which incorporates benthic habitat with ecological values, which also meet the pMEP significance criteria.
70. The application indicates “there are no substantial accumulations (or hot-spots; > 12.5 g/m^2) of residual solids beyond the combined PD-PEF and RS-PEF. However, a slight accumulation of residual solids is indicated within the McManaway Rock ESMS, and along the side of the McManaway Rocks where the seabed drops away. The applicant classes residual solids of <7 g/m^2 to have no effect however there has been no investigation into the ability of this habitat to process deposition of organic matter, or consideration for chronic effects (either lethal or sub-lethal) on this significant ecological area. Although links have been made to deposition rates in Tory Channel and resilience of rocky reef habitat in this system, there is no robust evidence that this is relevant to the community at this location as no ground-truthing has been carried out to describe the epifaunal assemblages present. As this is a significant site and organic material is modelled to reach this habitat via resuspension, it should be fully quantified, and a precautionary approach should be taken to avoid adverse effect. The benthic sled imagery recorded at the McManaway Rocks ESMS via our own ROV indicates a diverse and sensitive community with kelp, ascidians, hydroids and sponges as shown in Figure 5.

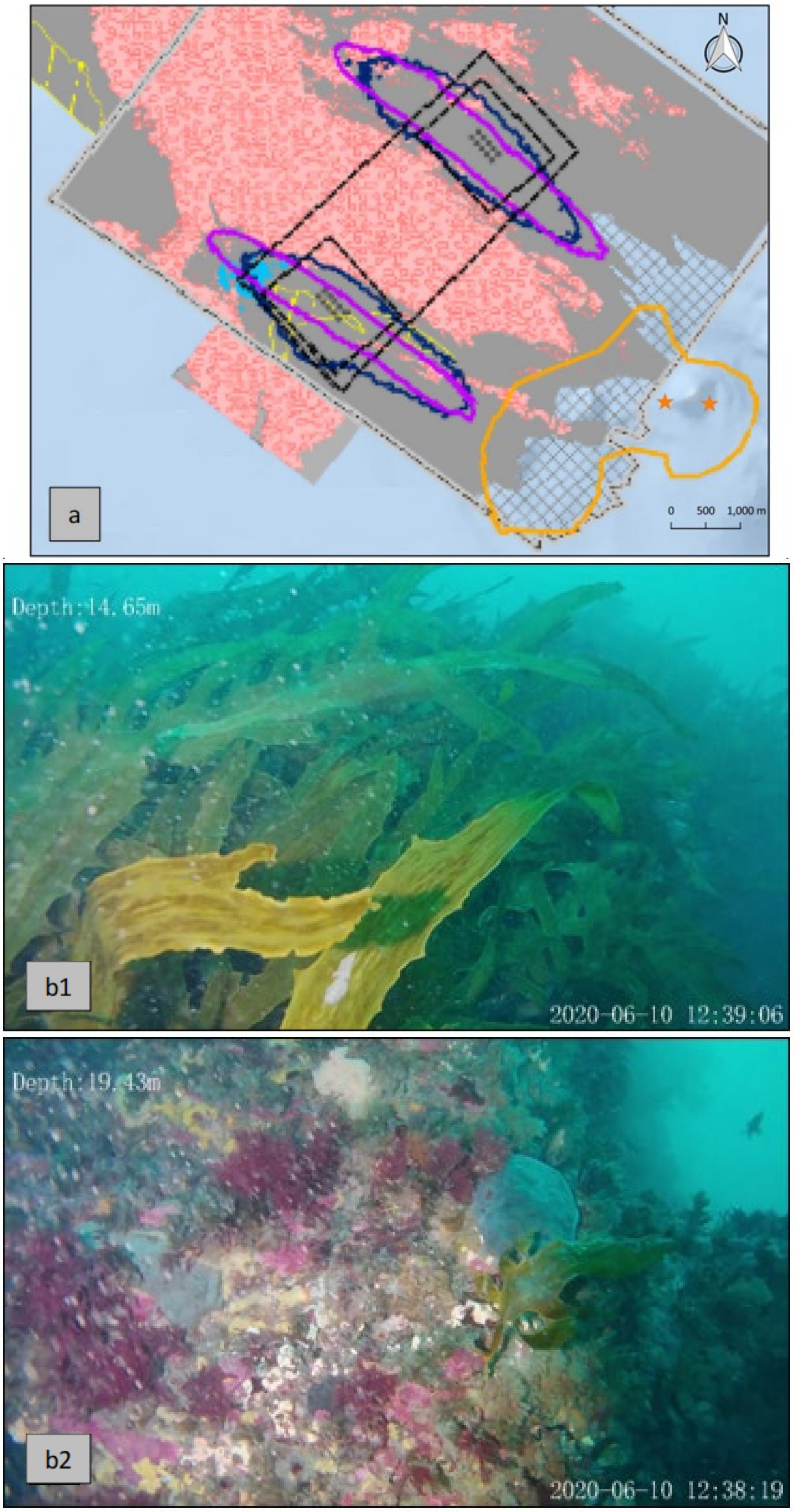

Figure 5: a) Map of ROV Imagery sites near McManaway Rocks (orange stars) over "low density epifauna" habitat as classified by Elvines et al. (2021a). b1&b2) ROV imagery capturing diverse benthic assemblages at McManaway Rocks: b1 - Kelp forest; b2 -Combination of hydroids, sponges, ascidians and macroalgae.

Question 4 – Is Enrichment State (ES) utilised appropriately within the application and is it a sufficient measure to rely on to assess the impact of the proposed activity?

71. The effect of residual solids is calculated based on a benthic infauna health measure of Enrichment State (ES). Enrichment state is calculated for soft substrates from a subset of variables, focussing on those that best discern the enrichment gradient, are the most versatile and provide complimentary information i.e. sediment organic content, sediment chemistry (sulphides and redox) and infauna composition (species richness, infauna abundance). The scores for the different variables can then be combined quantitatively (by weighted averaging) to arrive at an overall ES' that has an associated statistical variance and as such provides an assessment of the environmental condition and the level of certainty associated with that assessment. Hence, it is a multi-variable, 'weight-of-evidence' type approach. Applicability and/or adaptation for biogenic habitats has been considered as a tool to be developed during the consent period of the farm (N. Keeley – Benthic Workshop). However, the board of inquiry for NZKS requests for plan changes and applications for resource consents decision (dated 13 February 2013) required the baseline to be set prior to the establishment of a farm.
72. The relationship between deposition and ES to identify indicative thresholds of effect was assessed from one year of data from a Tory Channel farm and correlations were cross checked using one further year of data. This was then used to determine the appropriate depositional footprint where "moderate effect" (predicted to occur over 12.5 g/m) will be observed at the BE site. The effect of this deposition of farm waste is considered in the context of impacts for benthic soft sediment infauna. However, the proposed BE site is a relatively pristine mixed bed habitat consisting not only of soft sediment but large areas of high energy sand waves and shell material. Sediment types were not clearly distinguished, and areas of soft versus coarse sediment were not delineated as there was a gradual transition which was difficult to show on maps and in back scatter. It is unclear how any changes to the ES state will be assessed post-operation within areas that have not had adequate baseline characterisation.
73. The primary deposition predicted effects footprint for the Cape Lambert farm was assessed as PD-PEF; flux > 41.7 g/m^2/month [> 0.5 kg/m^2/year] and the residual solids predicted effects footprint was assessed to be RS-PEF: 12.5 g/m^2. Modelled deposition of residual solids up to 9.04 g/m^2 on reefs near to existing farms in the Marlborough Sounds was reported by Dunmore (2019) as unlikely to have a measurable community-level effect as

informed by reef monitoring stations in Tory Channel. However, even if there is a similar sensitivity for hydroids, sponges, ascidians and macroalgae communities in the Outer Sounds, the effects on brachiopods, horse mussels and bryozoan communities is still not addressed. Based on Dunmore (2019) findings, NZKS assumes modelled deposition will have no effect beyond the 12.5 g/m^2 residual solids deposition footprint. This is a largely unsubstantiated assumption and there are numerous studies which illustrate the vulnerability of deep coastal and shelf habitats and fauna compared to shallow coastal habitats (i.e., 0-50 m depths) that are more tolerant of terrigenous inputs (Lee et al., 2006; Kutti et al., 2007; Holmer 2010).

74. The parameters assessed by Elvines et al. (2021a) utilised redox only to predict ES, omitting sediment sulphide analysis which is identified as one of the key environmental variables to utilise in this assessment. Sulfide toxicity is a substantially greater issue than previously reported, and it is recommended that sediment quality status thresholds for benthic macroinfauna should be reduced (Cranford et al., 2020). Cranford et al., (2020) also warn against underestimating sulfide toxicity and that trigger levels that are set too high. Furthermore, it is worth noting that Elvines was a co-author of this paper regarding the importance of sulfides as part of assessing ecological quality status, however this component has been omitted from Elvines et al. (2019 & 2021a) surveys and reports. As mentioned earlier only 3 sediment/infauna grabs were taken under the two pens and a total of 5 sediment/infauna grabs taken were actually located within the predicted depositional footprint (Figure 1). When only a subset of variables are utilised so scarcely across a large and diverse area, the robustness of a multi-variable, ‘weight-of-evidence’ type approach is diminished and renders it less meaningful as an indicator for adaptive management of effects.

75. The benthic enrichment stages and effects were developed for inshore soft sediment environments and are not considered to be directly applicable to open ocean aquaculture environments and biogenic habitat. While effects are generally considered to be less intense in open ocean environments because of the greater scope for dispersal and dilution, there is also evidence to the contrary specifically regarding the response of open ocean environments to organic enrichment because of the lower natural rates of organic input to some systems (Holmer, 2010). The area-specific capacity of the receiving oceanic environment to process the inputs from finfish farms may be lower because oceanic waters and sediments are not always pre-adapted to receiving large, localised inputs of nutrient and organic matter in the way that some inshore waters are.

76. Further to the point above, the numerical relationships developed by Keeley et al. (2013) and Elvines et al. (2021b) to relate solids flux and residual solids to ecological changes in infaunal soft-sediment communities (expressed through the 7-stage Enrichment Stage scale) do not appear to be appropriate for the Cape Lambert site. These relationships were developed using data about infauna community composition from farms located in more sheltered environments within the Sounds, which do not have depths and current speeds comparable to the Cape Lambert site. A detailed comparison of depth and currents at the sites used by Keeley et al. (2013) and Elvines et al. (2021b) and at the Cape Lambert site is missing in the application. The correspondingly low number of infauna grabs within the predicted depositional footprint at the Cape Lambert site also provides significant limitations when attempting to compare ecological changes with soft sediment communities found within the inner Sounds.
77. In point 83 of Dr Morrisey's evidence he discusses the impact of ES 4 and 3.5 levels on 11.5 ha of biogenic habitat with regard to Mr Davidson's concerns that this level of enrichment for some species, may mean that they die or move away. Dr Morrisey responds to this with "*I consider that an impact on 11.5 ha of biogenic habitat within the footprint will have a minor effect on the quality, diversity, and ecological function of biogenic habitat in the wider area around the proposed farm and is, therefore, not significant*". This statement relies heavily on two main components which, in my opinion, do not have sufficient scientific rigour to base RMA significance criteria nor effects-based responses on. The first assumption is that the VenOM model, which is based on DEPOMOD parameters, uncalibrated data and little to no validation, has accurately estimated the size of the area to receive ES 4 and 3.5 levels. It is unclear from Dr Morrisey's statement what size, in hectares, of ES 4 and 3.5 would, in his opinion, constitute a 'greater than minor effect'. The second assumption then relies on the numerical relationships developed by Keeley et al. (2013) and Elvines et al. (2021a) relating to the Inner Sounds having any meaningful correlation with ES states and infaunal or epifaunal responses in an open ocean Outer Sounds context. The levels of uncertainty surrounding both of these assumptions undermine the conclusions made regarding "minor effects" on the biogenic habitats near to the Cape Lambert site.
78. ES considers response of the infauna to enrichment however does not allow response of epifauna to be captured. As a result, it paints an incomplete picture of environmental impacts. This is particularly concerning in the case of the Cape Lambert site, which supports a rich and diverse epifauna expected to be impacted by the farm waste. Interpretations of

model results based on the Enrichment Stage scale seem to ignore potential impacts on this important component of the ecosystem.

Question 5 - Is an adaptive management approach appropriate for this application?

79. Adaptive management of large-scale activities particularly in the marine environment is becoming an increasingly utilised method to provide flexibility to both the applicant and the regulatory authority. Adaptive management effectively is an ongoing process that combines assessment with management actions in order to learn about the complexities of system dynamics where knowledge is incomplete (Allen & Garmestani, 2015). Where uncertainties exist that can only be verified by the activity itself, adaptive management provides a good framework to put in place a series of safeguards for the regulatory authority to intervene or have confidence that further management protocols can be implemented in the case of adverse effects being identified. However, for adaptive management to be successfully implemented, the receiving environment must be robustly characterised and the potential effects on the habitats and species must be accurately identified. This ensures scientific rigour when establishing baseline conditions and creating a monitoring programme that will capture any changes from the baseline in a quantifiable manner.
80. In this application there has been substantial effort to provide a broad-scale characterisation of an extensive area of seabed surrounding the proposed activity. However, in order to accurately assess changes under an adaptive management framework, a detailed characterisation of species diversity and populations is required to establish the baseline environment from which monitoring can be compared against. In my view the current level of detail is not sufficient to characterise the applied area to set a baseline nor enable the establishment of a robust adaptive management plan.
81. The scale of the proposed infrastructure referred to by Elvines et al. (2021a), refer to pens of up to 240 m circumference and 35 m deep, to support a stocking density of 2.2% of the pen area, a density recommended for animal welfare by NZKS. This indicates the proposed infrastructure has capability for an increase in feed levels significantly greater than currently proposed. Elvines et al. (2019) indicated NZKS have future aspirations to increase feed from an initial 10,000 T per block to 40,000 T (80,000 T across both blocks). However, this has been omitted from the updated benthic report (Elvines et al. 2021a).
82. When assessing the appropriateness of adaptive management in this proposal, the full potential scale of the operations and its effects should be considered. Furthermore, NZKS

sets out no clear plan about where cages would be moved to allow fallowing if adverse effects are observed, and the proposed consent conditions do not outline if destocking would be required.

83. In summary, it is my view that adaptive management is not a viable option for this activity as it currently exists with the level of uncertainties both from the benthic characterisation and the effects on the benthic environment, delineated by the predicted modelling footprint. Greater certainty regarding one or both of these components would be necessary as well as transparency regarding the proposed operational capacity and activity to support the design of an appropriate monitoring programme that could accurately track the effects of the activity.

Bryony Miller

7 October 2021

References

Allen, C. R., & Garmestani, A. J. (2015). *Adaptive Management of Social-Ecological Systems* (Vol. 148).

Anderson, T. J., Morrison, M., Macdiarmid, A. B., Clark, M. R., Archino, R. D., Tracey, D. M., Gordon, D. P., Read, G. B., Kettles, H., Morrisey, D., Wood, A., Smith, A. M., Page, M., Paul-burke, K., Schnabel, K., & Wadhwa, S. (2019). Review of New Zealand's Key Biogenic Habitats. *NIWA Client Report*, *January*, 190.

Chamberlain J, & Stucchi D. (2007). Simulating the effects of parameter uncertainty on waste model predictions of marine finfish aquaculture. *Aquaculture*, *272*(1–4), 296–311.

Cranford, P., Brager, L., Elvines, D., Wong, D., & Law, B. (2020). A revised classification system describing the ecological quality status of organically enriched marine sediments based on total dissolved sulfides. *Marine Pollution Bulletin*, *154*.

Cromey, C. J., Nickell, T. D., & Black, K. D. (2002). DEPOMOD-modelling the deposition and biological effects of waste solids from marine cage farms. *Aquaculture*, *214*(1–4), 211–239. https://doi.org/10.1016/S0044-8486(02)00368-X

Cummings, V. J., Thrush, S., Hewitt, J., & Turner, S. (1998). The influence of the pinnid bivalve Atrina zelandica (Gray) on benthic macroinvertebrate communities in soft-sediment habitats. *Journal of Experimental Marine Biology and Ecology*, *228*, 227–240.

Dunmore, R. (2019). *Reef environmental monitoring results for the New Zealand King Salmon Company Ltd salmon farms: 2018.*

Ellis, J., Cummings, V., Hewitt, J., Thrush, S., & Norkko, A. (2002). Determining effects of suspended sediment on condition of a suspension feeding bivalve (Atrina zelandica): Results of a survey, a laboratory experiment and a field transplant experiment. *Journal of Experimental Marine Biology and Ecology*, *267*(2), 147–174. https://doi.org/10.1016/S0022-0981(01)00355-0

Ellis J, Clark, D. ., Keeley, N., Taylor, D., Atalah, J., Forrest, R., & Goodwin, E. (2011). *Assessment of effects of farming salmon at Waitata Bay, Pelorus Sound: deposition and benthic effects.*

Elvines, D., Morrisey, D., Smeaton, M., Floerl, L., & Keeley, N. (2021a). *Assessment of seabed effects for proposed "blue endeavour" (revised) open ocean salmon farm*. Cawthron Report 3489. Prepared for The New Zealand King Salmon Co. Limited.

Elvines D, Smeaton M, & Bennett H. (2021b). *Relating "VenOM" depositional model outputs to ecological response: a case study using high-flow salmon farms in Tory Channel.* Cawthron Report 3521. Prepared for The New Zealand King Salmon Co. Limited.

Gage J.D. (1996). Why are there so many species in deep-sea sediments? . *Journal of Experimental Marine Biology and Ecology*, *200*, 257–286.

Grange, K. R., Tovey, A., Hill, A. F., Lohrer, A. M., Thrush, S. F., Gibbs, M. M., Hewitt, J. E., Cummings, V. J., Dayton, P. K., Cryer, M., Turner, S. J., Funnell, G. A., Budd, R. G., Milburn, C. J., & Wilkinson, M. R. (2003). Bioturbators enhance ecosystem function through complex biogeochemical interactions. In *Nature* (Vol. 17, Issue 2). www.niwa.co.nz

Hall-Spencer, J., White, N., Gillespie, E., Gillham, K., & Foggo, A. (2006). Impact of fish farms on maerl beds in strongly tidal areas. *Marine Ecology Progress Series*, *326*, 1–9.

Hare, J., & New Zealand. Department of Conservation. Southland Conservancy. (1992). *Paterson Inlet marine benthic assemblages : report of coastal investigations*. Southland Conservancy, Department of Conservation.

Hay, C. H. (1990). *The ecological importance of the horse mussel Atrina zelandica with special reference to the Marlborough Sounds.*

Hewitt, J., Thrush, S., Gibbs, M., Lohrer, D., & Norkko, A. (2006). Indirect effects of Atrina zelandica on water column nitrogen and oxygen fluxes: The role of benthic macrofauna and microphytes. *Journal of Experimental Marine Biology and Ecology*, *330*(1), 261–273. https://doi.org/10.1016/j.jembe.2005.12.032

Hewitt J, & Pilditch C. (2004). Environmental history and physiological state influence feeding responses of Atrina zelandica to suspended sediment concentrations. *Journal of Experimental Marine Biology and Ecology*, *306*(1), 95–112.

Holmer, M. (2010). Environmental issues of fish farming in offshore waters: Perspectives, concerns and research needs. In *Aquaculture Environment Interactions* (Vol. 1, Issue 1, pp. 57–70). Inter-Research. https://doi.org/10.3354/aei00007

Jones, E. G., Morrison, M., Davey, N. K., Hartill, B., Sutton, C. P., & New Zealand. Ministry for Primary Industries. (2016). *Biogenic habitats on New Zealand's continental shelf. Part I : Local ecological knowledge*.

Keeley, N. B., Cromey, C. J., Goodwin, E. O., Gibbs, M. T., & Macleod, C. M. (2013). Predictive depositional modelling (DEPOMOD) of the interactive effect of current flow and resuspension on ecological impacts beneath salmon farms. *Aquaculture Environment Interactions*, *3*(3), 275–291. https://doi.org/10.3354/aei00068

Keeley, N., Gillard, M., Broekhuizen, N. (Niall), Ford, R. B. (Richard B., Schuckard, R., Urlich, S. C., & Fisheries New Zealand (Government agency). (2018). *Best management practice guidelines for salmon farms in the Marlborough Sounds. Part 1, Benthic environmental quality standards and monitoring protocol (Version 1.1 January 2018) / prepared for Fisheries New Zealand by the Benthic Standards Working Group* .

Keeley, Nigel B., Forrest, B. M., & Macleod, C. K. (2013). Novel observations of benthic enrichment in contrasting flow regimes with implications for marine farm monitoring and management. *Marine Pollution Bulletin*, *66*(1–2), 105–116. https://doi.org/10.1016/j.marpolbul.2012.10.024

Kutti, T., Hansen, P., Ervik, A., Hoisaeter, T., & Johannessen, P. (2007). Effects of organic effluents from a salmon farm on a fjord system. II. Temporal and spatial patterns in infauna community composition. *Aquaculture*, *262*, 355–366.

Lee, H. W., Bailey-Brock, J. H., & McGurr, M. M. (2006). Temporal changes in the polychaete infaunal community surrounding a Hawaiian mariculture operation. *Marine Ecology Progress Series*, *307*, 175–185. https://doi.org/10.3354/meps307175

Lin D., & Bailey-Brock J. (2008). Partial recovery of infaunal communities during a fallow period at an open-ocean aquaculture. . *Marine Ecology Progress Series*, *371*, 65–72.

Lohrer, A. M., Hewitt, J. E., & Thrush, S. F. (2006). Assessing far-field effects of terrigenous sediment loading in the coastal marine environment. *Marine Ecology Progress Series*, *315*(December 2014), 13–18. https://doi.org/10.3354/meps315013

MacDiarmid, A. B., Bowden, D. A., Cummings, V. J., Jones, E., Morrison, M., Rowden, A. A., Kelly, M., Neil, H., & Nelson, W. A. (2013). Sensitive marine benthic habitats defined. Prepared for Ministry for the Environment. *NIWA Client Report*, *April*, 72.

MacDiarmid, A. B., Law, C. S., Pinkerton, M., & Zeldis, J. (2013). New Zealand Marine Ecosystem Services. *Ecosystem Services in New Zealand: Conditions and Trends*, *2005*, 539.

Macleod C K, Moltschaniwskyj N A, Crawford CM, & Forbes S E. (2007). Biological recovery from organic enrichment: Some systems cope better than others. *Marine Ecology Progress Series*, *342*, 41–53.

Mayor, D. J., Zuur, A. F., Solan, M., Paton, G. I., & Killham, K. (2010). Factors affecting benthic impacts at Scottish fish farms. . *Environmental Science & Technology*, *44*, 2079–2084.

Miller, D. C., Norkko, A., & Pilditch, C. A. (2002). Influence of diet on dispersal of horse mussel Atrina zelandica biodeposits. *Marine Ecology Progress Series*, *242*, 153–167. https://doi.org/10.3354/meps242153

Morrisey, D., & Fletcher, L. (2019). *Biology and ecology of horse mussels (Atrina zelandica) with reference to the outer Marlborough Sounds area*.

Newcombe, E., Knight, B., Smeaton, M., Bennett, H., Mackenzie, L., Scheel, M., Vennell, R., & Campos, C. (2020). *Water column assessment for a proposed salmon farm offshore of the marlborough sounds*. Cawthron Report 3313. Prepared for The New Zealand King Salmon Co. Limited.

Norkko, A., Hewitt, J. E., Thrush, S. F., & Funnell, G. A. (2006). Conditional outcomes of facilitation by a habitat-modifying subtidal bivalve. *Ecology*, *87*(1), 226–234. https://doi.org/10.1890/05-0176

Norkko A,, Hewitt J. E, Thrush S. F., & Funnell G. A. (2001). Benthic-pelagic coupling and suspension feeding bivalves: linking site-specific sediment flux and biodeposition to benthic community structure . *Limnology and Oceanography*, *46*, 2067–2072.

Pusceddu, A., Fraschetti, S., Mirto, S., Holmer, M., & Danovaro, R. (2007). Effects of intensive mariculture on sediment biochemistry. *Ecological Applications*, *17*(5), 1366–1378.

Sarà, G., Scilipoti, D., Milazzo, M., & Modica, A. (2006). Use of stable isotopes to investigate dispersal of waste from fish farms as a function of hydrodynamics. *Marine Ecology Progress Series*, *313*(Alongi 1996), 261–270. https://doi.org/10.3354/meps313261

Sweetman, A. K., Norling, K., Gunderstad, C., Haugland, B. T., & Dale, T. (2014). Benthic ecosystem functioning beneath fish farms in different hydrodynamic environments. *Limnology and Oceanography*, *59*(4), 1139–1151. https://doi.org/10.4319/lo.2014.59.4.1139

Thrush, S. F., Hewitt, J. E., Cummings, V. J., Ellis, J. I., Hatton, C., Lohrer, A. M., & Norkko, A. (2004). Muddy waters: elevating sediment input to coastal and estuarine habitats. *Frontiers in Ecology and the Environment*, *2*, 299–306.

Thrush, S., & Whitlatch, R. (2001). *Recovery Dynamics in Benthic Communities: Balancing Detail with Simplification.* https://doi.org/10.1007/978-3-642-56557-1_15.

Urlich, S. C., & Handley, S. J. (2020). From 'clean and green' to 'brown and down': A synthesis of historical changes to biodiversity and marine ecosystems in the Marlborough Sounds, New Zealand. *Ocean and Coastal Management*, *198*. https://doi.org/10.1016/j.ocecoaman.2020.105349

APPENDIX BM1 – ROV FOOTAGE OF MCMANAWAY ROCK ESMS (recorded 10 June 2020).