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25 February 2021

Trevor Offen and Andrew Caddie
Kenepuru and Central Sounds Residents Association Inc (KCSRA)

Dear Trevor and Andrew,

Re: Mussel Farm impacts on the Marlborough Sounds Marine Environment.

Here, I present my expert opinion with respect to the current understanding of the effects of mussel farming on the Marlborough Sounds marine environment. Firstly, I consider the existing situation with respect to understanding the impacts of mussel farming in the Marlborough Sounds. Next, based on the current understanding, I provide an opinion on how mussel farming should be managed going forwards. I also attach and reference several documents that go into details of what I describe below and support my opinion. These documents include exhaustive literature and data reviews that consider the impacts of mussel aquaculture in the Marlborough Sounds (mostly in the Clova/Crail/Beatrix Bay enclosed embayment), field studies around and under mussel farms in the Marlborough Sounds, and expert witness evidence.

I have been involved in investigating the impacts of intensive mussel farming in the Marlborough Sounds (and also salmon farming) for over 20 years, and from any objective scientific point of view, it is very clear that there are areas of the Sounds that are being negatively impacted by an 'over-subscription' of mussel farms. This in terms of negative impacts on the wider and indigenous species/ecosystems (exceeding the ecological carrying capacity) and also on the productivity of the cultured mussels themselves (exceeding the production carrying capacity).

The following references are some of the work I have done in this area (aquaculture); a brief summary of my expertise and experience can be found at the end of this letter report, and my CV is also attached:

- S. T. Mead and D. J, Phillips, 1999. *Mahai Paua Farm: Description of Site Ecology.* Report prepared for Environmental Management Services Ltd., May 1999.
- Mead, S. T., K. P. Black and A. Longmore, 2001. *The Sustainability of Marine Farming in Beatrix Bay, Marlborough Sounds.* For the Marlborough Sounds Trust, March 2001.
- Mead, S. T., 2002. *Ecological Survey of Beatrix Bay, Marlborough Sounds.* Report prepared for the Marlborough Sounds Trust, July, 2002.
- S. T., Mead, 2002. *Expert Evidence on the Biological Impacts of Additional Aquaculture Farms in Beatrix Bay.* Prepared for the Marlborough Sounds Trust, Environment Court Hearing, October, 2002
- Mead, S. T., K. P., Black and J. Mathew, 2002. *Aquaculture Development and Training: Ekas Bay, Lombok, Indonesian – Second Progress Report.* Report prepared for the Ministry of Foreign Affairs and Trade, November 2002.
- Mead, S. T., D. J. Phillips and K. P. Black, 2002. *An Assessment of Aquaculture Potential for Southern Poverty Bay.* Report prepared for Port of Gisborne Ltd, June 2002.

- S. T. Mead, 2002. *Supplementary Expert Evidence on the Biological Impacts of Additional Aquaculture Farms in Beatrix Bay.* Prepared for the Marlborough Sounds Trust, Environment Court Hearing, November 2002
- Haggitt, T., and S. T. Mead, 2004. *Northland Aquaculture Management Area (AMA) study: Literature review and Field Studies of: Environmental impacts of aquaculture and biological information within proposed Northland Aquaculture Management Areas.* Report prepared for the Northland Regional Council, August 2004.
- Longdill, P.C., Black, K.P., Healy, T.R., Mead, S.T., and Beamsly, B., 2005. *Bay of Plenty Sediment Characteristics: Aquaculture Management Areas.* Report for Environment Bay of Plenty, ASR Ltd and the University of Waikato. 59p. March 2005.
- Mead, S.T., Longdill, P.C., Moores, A., Beamsly, B., and Black, K.P., 2005. *Bay of Plenty Biological Survey: Aquaculture Management Areas.* Report for Environment Bay of Plenty, ASR Ltd, 35p. June 2005.
- Longdill, P., K. P. Black S. T. Mead, T. R. Healy and S. Park, 2005. *The Bay of Plenty Benthic Environment: Preliminary Investigations for the Zoning of Aquaculture Management Areas.* New Zealand Marine Science Conference, Victoria University, Wellington, New Zealand, August 23-26 2005.
- Mead S. T., C. Boserrelle, K. Black and D. Anderson. *Mossel Bay Currents and Fish Farm Dispersal Study.* Prepared for CCA Environmental (Pty) Ltd, September, 2008
- Longdill, P.C., Black, K.P., Haggitt, T. and Mead, S. T., 2006. *Primary Production Modelling, and Assessment of Large Scale Impacts of Aquaculture Management Areas on the Productivity within the Bay of Plenty.* Report for Environment Bay of Plenty, July 2006.
- Mead, S. T., 2012. *New Zealand King Salmon Plan Change – Review of Benthic AEE.* Prepared for the Nelson Underwater Club, May 2012.
- Mead, S. T., 2012. *Expert Witness Statement for the EPA Proceedings of Proposed NZ King Salmon Farms in the Marlborough Sounds – Benthic Impacts.* Prepared for SOS/NUC, EPA Hearing, July 2012.
- Mead, S. T., and T. Haggitt, 2014. *Desktop Summary of Current Level of the Science and Understanding of the Cumulative Ecological Impacts of Mussel Farms Ring-Fencing Coastlines such as Beatrix Bay, Marlborough Sounds.* Expert report prepared for PBC and KCSRA in relation to and Application for Resource Consent – Coastal Permit – Beatrix Bay, Central Pelorus Sounds – U130797, May 2014
- Mead, S. T., 2014. *Review of Evidence with Regard to the Application for Resource Consent for a Coastal Permit in Beatrix Bay.* Expert opinion prepared for Commissioner Kenderdine, May 2014.
- Mead, S. T., 2014. *Review of Mr Davidson's and Mr Forrest's Evidence Dated 21st May 2014 with Regard to the Application for Resource Consent for a Coastal Permit in Beatrix Bay*. Expert report prepared for PBC and KCSRA in relation to and Application for Resource Consent – Coastal Permit – Beatrix Bay, Central Pelorus Sounds – U130797, May 2014
- Mead, S. T., 2015. *Statement of Evidence in Chief.* Prepared for the Respondent, PBC and KCSRA in relation to and Application for Resource Consent – Coastal Permit – Beatrix Bay, Central Pelorus Sounds – Env-2014-env-Chc-34, March 2015.
- Mead, S. T., 2018. *Statement of Evidence of Dr Shaw Mead (Surfbreak Impacts) – Western Firth of Thames Mussel Farm.* Prepared for the Surfbreak Protection Society Inc., May 2018.
- Atkin, E., S. T. Mead and J. Davies-Campbell, 2019. *A Review of the Assessment of Environmental Effects for a Commercial Marine Farm (Mussel Spat) at Mercury Bay*. Prepared for H. Vivian, November 2019.
- Mead, S. T., 2019. *Evidence Summary and Rebuttal of Shaw Trevor Mead.* Whauwhau Bay Spat Farm Application. Prepared for H. Vivian. Waikato Regional Council Hearing, December 2019.

Lack of Monitoring Data

As NIWA point out with regard to aquaculture-environment interactions[1], sustainable development of marine farming requires providing opportunities for investors while *maintaining coastal ecosystem health and integrity*, and so, when considering a marine farm application, regulators require information that will enable them to satisfy themselves that the:

a) environmental changes arising from the proposed activity (in concert with those of pre-existing farms) are likely to remain within acceptable bounds;
b) environmental monitoring regimes can detect changes that would be unacceptable large, and;
c) the monitoring data (in concert with other tools and appropriate follow-up studies) will enable them to determine the cause(s) of any changes that have deemed to be too large to be acceptable.

NIWA states that both farmers and regulators seek monitoring methods that yield reliable results without imposing excessively onerous costs upon either party. However, despite concerns over the management of mussel farm applications in the late 1990's due to greatly increased growth times before harvest (i.e. an indication of potential impacts on production carrying capacity) (e.g. see Attachment 1), there are still *no monitoring data to consider the impacts of mussel farming on the Marlborough Sounds marine environment*. This notwithstanding the calls made for ecological monitoring to be put in place for the Sounds and marine farms, and the widespread recognition of the importance of monitoring for environmental management as described in NIWA's 2009 publication. As a result, the number and area of mussel farms in the Marlborough Sounds has continued to expand without correctly considering the impacts. Modelling in recent years has indicated that these impacts are now very large in some areas of the Marlborough Sounds (discussed below).

Lack of Regard to Cumulative Effects

The poorly-managed and unconstrained expansion of mussel farms in the Sounds has also been exacerbated by an almost complete lack of consideration of the cumulative effects of mussel farming. That is, marine farming applications have not considered the impacts of the existing farms in an area, only the farm being applied for. This has led to situations such as in Beatrix Bay, where in 2001 the area covered by mussel farms was 160 ha and there were concerns that the decreased growth rates were due to too many farms in the area (i.e. production carrying capacity might be exceeded). By 2014, new permits had been granted and many farms had been significantly extended seawards, resulting in a total of 297 ha (~15% of the Bay's surface area) being allocated to aquaculture. That is, the number of farms had almost doubled (~100% increase in the area farmed) since carrying capacity issues were first signalled in the 1990's.

Today I understand that lines on the inside of farms have effectively been abandoned because there is insufficient plankton left in the water after passing through the outer lines of the farms to grow mussels to a harvestable size. This suggests production carrying capacity is exceeded. As discussed below, it follows that ecological carrying capacity is also well exceeded.

The cumulative ecological impacts of mussel farms in areas with limited flushing are well known (as has been detailed in many NIWA and Cawthron reports), and are detailed in Attachment 2, "Desktop Summary of Current Level of Science and Understanding of the Cumulative Ecological Impacts of Mussel Farms Ring-Fencing Coastlines such as Beatrix Bay, Marlborough Sounds".

[1] https://niwa.co.nz/aquaculture/research-projects/aquaculture-environment-interactions

Unfortunately, it seems that regulators are only now beginning to come to terms with the adverse ecological impacts of intensive mussel culturing in low flush environments, in particular the need to have regard to cumulative effects.

Food Web and Carrying Capacity

Figures 1 and 2 present the schematic diagrams depicting the impacts of mussel farming, and how these impacts effect on the Marlborough Sounds food-web and biodiversity. Figure 1 summarises the actual and potential environmental and ecological effects of mussel farming. As can be seen, some effects are contradictory, and not all effects will be seen at every site. For example, the potentially positive effects of bedload transport to other areas cannot occur in many areas of the Marlborough Sounds since tidal current velocities are too low and waves are locally wind-generated and so do not penetrate to the bottom and move sediment; the Clova/Crail/Beatrix Bay enclosed embayment is such an area. As a result, the impacts on the benthos due to the increased organic loading to the benthos leads to anaerobic conditions, reduction in biodiversity and denitrification (see Attachment 1 and 3).

As can be seen, many of the actual and potential impacts of intensive mussel farming are detrimental to the wider environment and food-web. These are exacerbated when extremely large areas of mussels are farmed in low flush sheltered locations (as in many areas of the Marlborough Sounds). As discussed below, this is clearly shown in the NIWA biophysical model (NIWA, 2014).

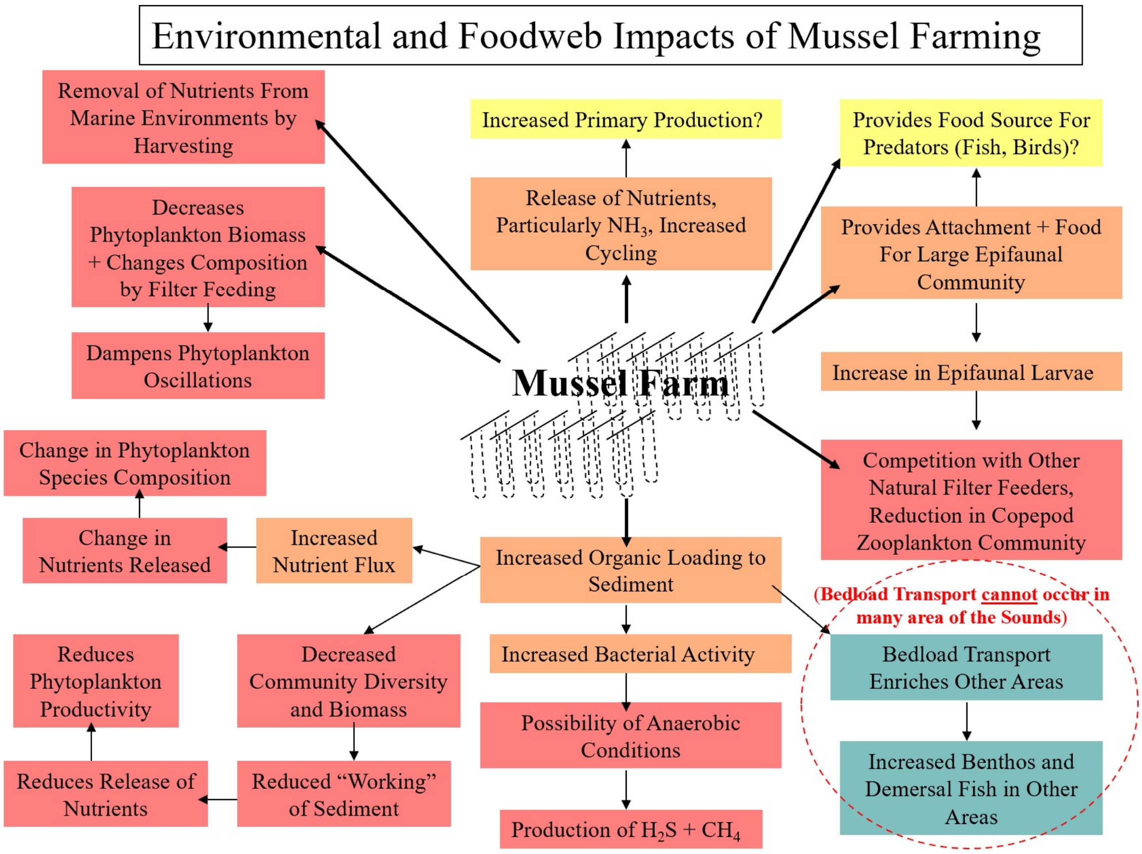

Figure 1. Summary of the actual and potential environmental and ecological effects of mussel farming. Note, some effects are contradictory, and not all effects will be seen at every site (adapted from Barg, 1992). Of note, the potentially positive effects of bedload transport to other areas (right hand bottom) cannot occur in many areas of the Marlborough Sounds since current velocities are too low and waves are locally wind-generated and so do not penetrate to the bottom and move sediment. As can be seen, many of the actual and potential impacts of intensive mussel farming are detrimental to the wider environment and foodweb.

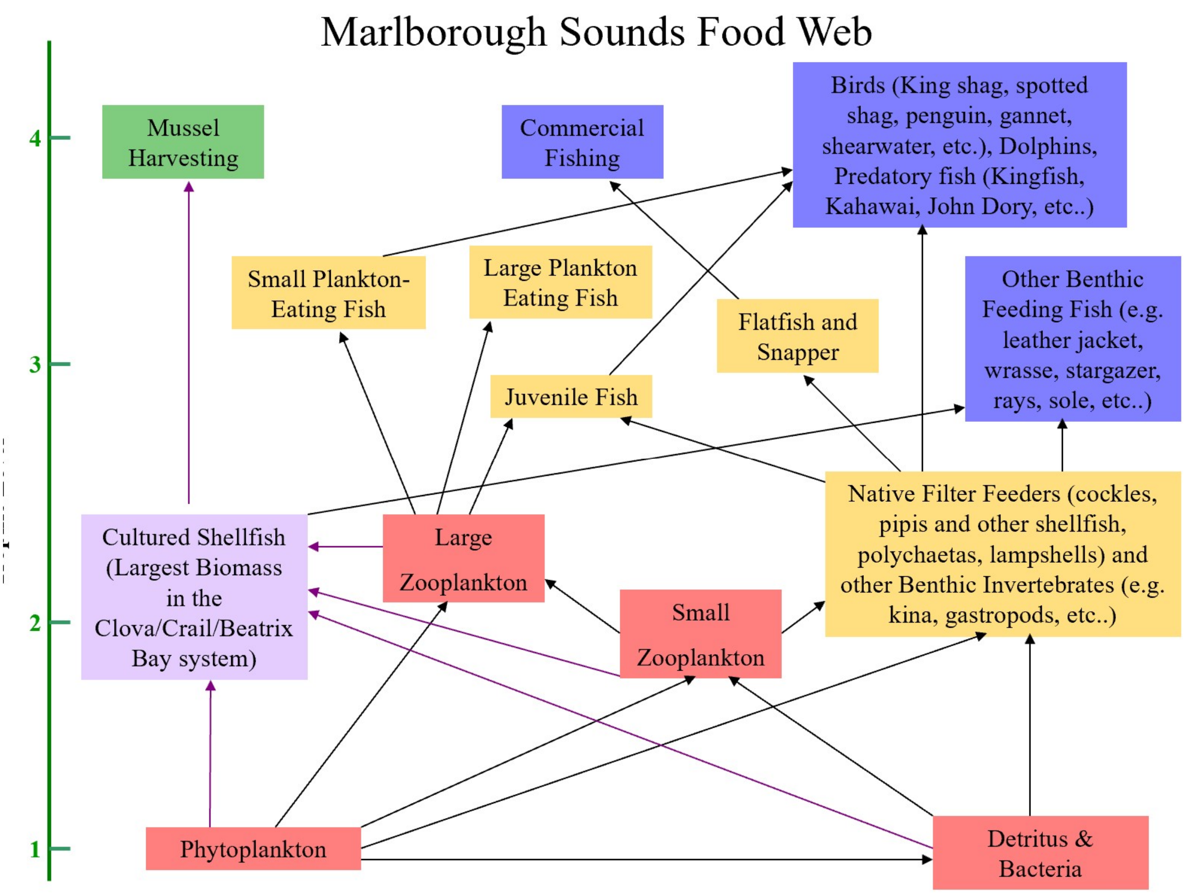

Figure 2. Marlborough Sounds marine food web (adapted from Bradford-Grieve, 2002). Note the range of food linkages between cultured mussels and the lower trophic levels that lead to the potential to impact on higher trophic levels.

The marine ecosystem and the interactions such as those depicted by the food-web in Figure 2 are complex and have multiple trophic pathways rather than linear food-chains. Even so, there is a general trend from the primary producers/bacteria-detritus up through the trophic levels to larger species. As can be seen in Figure 2, mussels are feeding and extracting energy from a range of lower trophic levels, which has the potential to impact on the higher trophic levels and the structure of the food-web (as shown in Figure 1).

Empirical Studies on Marine Farming in Low Flush Environments

Studies in the Marlborough Sounds and internationally indicate that mussel farms have a range of impacts on the food-web and it is clear that the carrying capacity of a system for cultured mussels is lower when the marine system has limitations (e.g. low nutrients and/or low flushing/exchange of new water), such as areas in the Marlborough Sounds. These studies are discussed with supporting scientific references in detail in Attachment 3. More recently I refer to Karuza *et al.*, 2016's study of an area with similar attributes as the Clova/Crail/Beatrix bay complex and which demonstrates the negative food-web impacts of intensive mussel farms.

Attachments 1 and 3 provide detailed discussions supported by cited scientific literature (a significant fraction of which are studies within the Sounds) that clearly demonstrate that mussel farming in Beatrix Bay had already greatly exceeded carrying capacity by the late 1990's and potentially even earlier (e.g., Gibbs *et al*., 1992). Dr Andy Longmore (2002) comes to the same conclusion (Attachment 4). Dr Longmore goes on to point out that Dr Mark James (then at NIWA) suggests that the mussels being farmed are indicators of bay health, and asserted that "*if mussels are doing well, other biota should also be doing well*". Dr Longmore's analysis concluded that "*By James' definition*, *the Beatrix Bay ecosystem has been unhealthy for considerable periods*." (paragraph 22, Attachment 4). As noted above, over a decade later the area covered by mussel farms in Beatrix Bay has basically doubled (Attachment 2), inshore lines have effectively been abandoned and mussels are now taking several years to reach harvestable size (which in the early 1990's occurred within 9 months). This all strongly indicates that mussels are not doing well, and so nor is the other biota in the area.

Production and Ecological Carrying Capacities

Production carrying capacity is about how much mari-culture an area is capable of carrying. Ecological carrying capacity is about the how much mari-culture an area is capable of carrying without significantly changing the major energy fluxes or structure of the food web (Jiang and Gibbs, 2005). The issues of impacts on the wider environment associated with carrying capacity were re-visited in 2015 and are detailed in Attachment 5. Here it is established that production carrying capacity is not relevant to sustainability and the RMA (1991) – it is ecological carrying capacity that must be considered. Ecological carrying capacity is likely to be approximately 20% of production carrying capacity.

As noted above, there is good existing evidence that potentially significant adverse effects on the ecosystem and biodiversity are already occurring due to the intensive level of mussel farming activity in areas of the Sounds where tidal flushing is low such as the Clova/Crail/Beatrix bay complex. However, it is important to note that the recent report that considers "Measuring mussel farming effects on plankton inthe Marlborough Sounds" (Newcombe and Broekhuizen, 2020) should not be considered in any way an assessment of carry capacity, ecological or production, in the Marlborough Sounds; neither is referred to in the text, the report is directed at changes to plankton. Similarly, the conclusions of this report do not provide scientific evidence that there are potentially no issues with over-stocked areas of the Sounds, such as the Clova/Crail/Beatrix bay complex.

The Newcombe and Broekhuizen (2020) report yet again points out the need for more monitoring and modelling in order to ascertain the extent of changes to plankton in the Marlborough Sounds. However, due to lack of data and short datasets there are mostly conclusions that the impacts are unknown; e.g. "Consequently, these data do not allow us to confidently determine whether there is any evidence that the mussel farms are (or are not) inducing depletion within Beatrix Bay, or inducing spatial variations across Beatrix Bay." Similarly, while it is known that intensive marine farms of filter-feeders can have a negative impact on the species composition in terms of palatability, the phytoplankton species composition monitoring data is relatively short (8 years), and more importantly began well after the impacts of mussel farming were becoming a concern in the Marlborough Sounds (circa 1990's) due to increasingly longer time periods to reach harvestable size; that is, species composition of phytoplankton had likely already shifted significantly by 2012.

Some of the conclusions of Newcombe and Broekhuizen (2020) repeat previous findings (e.g. that phytoplankton levels are driven by riverine inputs, and potentially inputs from the Cook Strait), while the trend in declined of chlorophyll a (a proxy for phytoplankton concentration) in the Marlborough Sounds since the 1980s is offset against decline nationwide "This decline is not a localised phenomenon: satellite data reveal that chlorophyll concentrations have declined around much of New

Zealand's coastline over the past 20–30 years. The reasons for this decline remain unclear." (Newcombe and Broekhuizen, 2020).

The decline of chlorophyll concentrations around much of New Zealand's coastline over the past 20–30 years has previously been linked to New Zealand's intensification of dairy farming and the associated poor management of the associated land-use impacts (Pinkerton and Gall, 2015), and is in no way associated with the decline in the Marlborough Sounds, where land-use practises have been improving over the same time period, as evident from the increasing depth of siechi disk visibly (i.e. the waters of the Sounds have gotten clearer over the past 3 decades). This suggests that declines in some areas of the Sounds are associated with intensive mussel farming, noting again that the data is deficient and there is little confidence around nearshore areas of the satellite imagery used to determine chlorophyll a. It is noted that this is unlikely to be due to wave breaking inside the Marlborough Sounds (as suggested as a potential reason for this) due to sheltered nature and the very steep nearshore bathymetry (i.e. even wind-generated waves will break just a few metres from shore). The amount of chlorophyll a in a system is driven by nutrients, and does not directly relate to carrying capacity.

Therefore, caution is required when applying the conclusions of the Newcombe and Broekhuizen (2020) to the impacts of intensive mussel farming, which has exceeded ecological carrying capacity in low flushing areas of the Marlborough Sounds when the tools used to assess this are applied.

The Use of Models and Standards

Appendix 5 illustrates the introduction of the Aquaculture Stewardship Guidelines (ASC, 2012) to assess sustainability/carrying capacity of a bi-valve aquaculture activity and also the Gibbs (2007) methods for assessing the sustainability performance of bivalve aquaculture activities. Both the ASC and the Gibbs CC methods of determining carrying capacity within a water body clearly indicate that both production and ecological carrying capacity have been exceeded in this part of the Marlborough Sounds. This is supported by the NIWA biophysical model (discussed below).

However, despite the abundance of information that provides strong evidence that farming density in these areas is negatively impacting on the wider environment, very little appears to have happened at a consenting level to address this. A lack of monitoring data to determine and quantify these impacts is often cited as a basis for disregarding these effects of existing farms. The position taken seems to be that existing farming can continue unless and until it is scientifically established that the farming is indeed beyond ecological carrying capacity, which needs to be underpinned by measured data.

Monitoring data has still not been initiated after almost 3 decades of concern with respect to impacts on the wider environment of the Marlborough Sounds. This notwithstanding that the Marlborough Sounds has been considered one of the most biodiverse marine areas in the world and an area of important biodiversity globally that is facing extreme threats (Davidson *et al*., 2011).

It is my opinion that the ASC (2012) carrying capacity assessment empirical model and the NIWA (2014) biophysical numerical model are underpinned by strong scientific processes and data measured in the Marlborough sounds. Therefore, and in the absence of environmental monitoring to determine ecological carrying capacity, models such as these provide the tools to both determine the existing impacts that mari-culture is likely to be having on the Marlborough Sounds and valuable guidance with respect to the management of the activity.

Numerical models, especially when calibrated (like the NIWA model has been), are very powerful tools, which when used within the context of existing scientific knowledge, provide reliable predictive and management tools. Similarly, internationally recognised empirical models such as the ASC (2012) are developed from large datasets (i.e. actual measurements in the field) and are applied widely in marine and coastal science for predictive and management purposes.

As noted above, we applied the ASC (2012) empirical model to properly assess the sustainability/carrying capacity of Beatrix Bay (i.e., all the marine farms in the bay were included) using filtration rate and mussel number parameters as provided by the Cawthorne Institute (Attachment 5). This supported the prior findings that the ecological carrying capacity in the bay has been exceeded. KCSRA has subsequently presented similar calculations to the Marlborough District Council for the Clova/Crail/Beatrix bay complex, which indicated that each bay and the entire bay complex may be exceeding ecological carrying capacity (Attachment 6). These calculations were in turn reviewed by NIWA, which provided a range of results based on how the various parameters were determined (Attachment 7). Even so, many of the results indicated that mussel farms in the bays and the bay complex are exceeding carrying capacity, and therefore unacceptably impacting on the wider environment and food-web.

I have reviewed the computer model that KCSRA have developed from the ASC Standard empirical model and believe that it provides a far more targeted and accurate depiction of the ASC pelagic effects of mussel farming than the spreadsheet-based broad area calculations that have otherwise been done to date (e.g. Attachment 6). The assumptions used in the ASC model are reasonable, and the outputs also closely align with the NIWA bio physical model with respect to the distribution and intensity of impacts (Figure 3 below). In addition, the model provides a very useful tool for the spatial allocation of bi-valve farming in the Sounds.

Of note in the ASC (2012) assessments of carrying capacity for the Clova/Crail/Beatrix bay complex is that Clova Bay was found to have exceeded ecological carrying capacity no matter how parameters were applied (Attachment 7). When this is taken with the results of the NIWA (2014) biophysical model Clova Bay appears to be the area worst affected by Mari-culture. For example, Figure 5-14 on Page 88 in NIWA (2015) (Attachment 8) presents the differences in model outputs when comparing 2012 mussel stocking levels (existing mussels/existing fish/with denitrification; EM/EF/WD) with no mussel farms (no mussels/existing fish/with denitrification: NM/EF/WD) This is reproduced as Figure 3 below. The differences are very large in some cases - especially when we consider food-web impacts (e.g. phytoplankton and zooplankton – Figure 2).

As noted by NIWA (2015), the effects tend to be greatest in the Beatrix/Crail/Clova and Kenepuru (Figure 3). Indeed, there are many references to food-web impacts in the NIWA (2015) report due to large areas of mussel farms in the Marlborough Sounds such as “grazing pressure”, “mussel induced depletion”, “growth rate changes”, etc.

It is noteworthy that the center box on the bottom row of Figure 3 shows zooplankton levels ten times greater in Clova Bay without the existing mussel farms, while phytoplankton (second from the bottom, central column) and detritus (third from the top, central column) levels in this area are 2-3 fold greater (NIWA, 2015). This undoubtably indicates a significant adverse impact on the Clova Bay marine ecosystem and food-web (refer to Figures 1 and 2 which indicate reductions in biodiversity and biomass, and on-flowing impacts to higher trophic levels).

As an aside I note that a NIWA Biophysical model was also run comparing mussel farming as at 2012 stocking levels with mussel farming as at 2014/2015 stocking levels. It is not clear why a ‘baseline’ of 2012 was so chosen - since the baseline conditions for biophysical impacts of aquaculture are without any aquaculture. While it is acknowledged that there have been various impacts on the Marlborough Sounds marine area through the 20th Century and into the 21st, this in no way changes the impacts of aquaculture activity. As such, the model scenario of 2012 farms c.f. no farms provides the correct baseline analysis from which to draw the impacts of aquaculture activity in the Sounds.

Manifestation of Food-Web Effects on Indigenous Biodiversity

How the impacts predicted by the NIWA Biophysical model are likely to manifest throughout the food-web is described in Attachment 3. Paragraphs 2.10 to 2.12 presents possible evidence[2] of impacts on indigenous bivalve populations in areas of intense mussel farming, with the concluding remarks that while there are uncertainties "Even so, the same conclusions and advice advocated by Grange (1997) are warranted, i.e. *it is likely that native species are being compromised to the detriment of both the aquaculture industry and native species. A precautionary approach should be taken and the granting of additional consents may not be wise until further research into the impacts of mussel farms on the wider Beatrix Bay ecosystem have been undertaken*".

Paragraph 2.13 of Attachment 3 then summarises these food-web impacts in the Marlborough Sounds:

> "As the biomass of bivalves increases, as it is in Beatrix Bay through the continual addition of mussel farms, the matter and energy necessary to maintain these animals increases proportionally at a greater rate (Dame and Prins, 1998). This will have direct effects on the existing ecosystem e.g. extraction of phytoplankton and zooplankton (feeding and pseudo-faeces), extraction/loss/changes of nutrients (harvesting and changes to nutrient cycling and dominant nitrogen source), habitat loss and modification (under farms), etc. In Beatrix Bay these effects may be bay-wide (e.g. nutrient limitations), although magnified further into the bay due to the low current (i.e. poor circulation and flushing, re-circulating eddy in the north western corner) and under mussel farms (e.g. loss/change of nutrient cycles and habitats), or limited to species with particular feeding behavior competing for phytoplankton (e.g. zooplankton, tubeworms, bivalves, brachipods, some crustaceans), mid-water feeders competing for zooplankton (kahawai, mullet, wrasse) or bottom feeders (skate, rays, pig fish, stargazer, witch flounder, mullet) and infauna (e.g. heart urchins, brittle stars, bivalves, worms) competing for space. These effects may then impact further up the food web to higher order predators such as kingfish, john dory, witch flounder, birds and cetaceans."

[2] As noted above, there is no monitoring data with which to support evidence of ecosystem impacts despite calls to initiate monitoring for the past 3 decades.

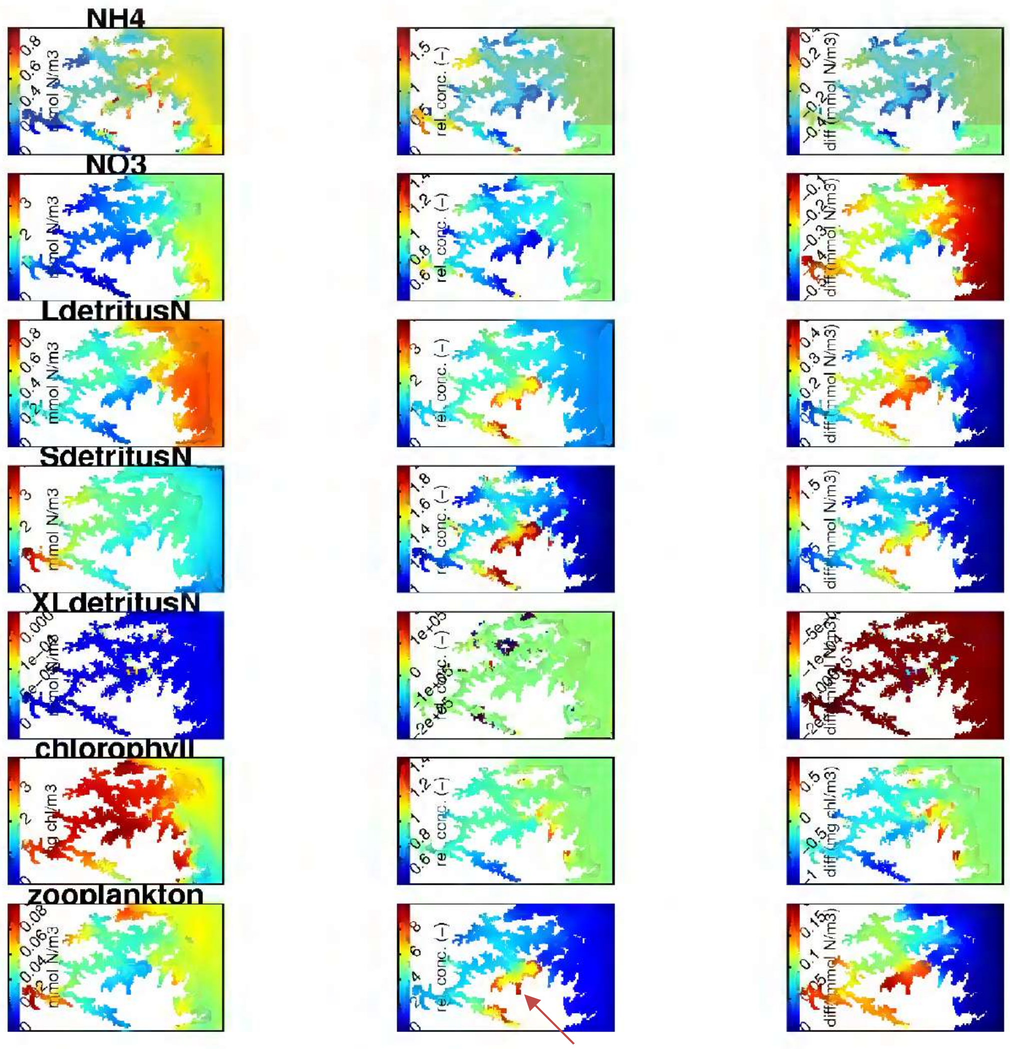

Figure 5-14: Comparison of summer time-averaged surface-layer concentrations in the EM-EF-WD and NM-EF-WD scenarios. Refer to the caption of Figure 5-13 for further explanation. These results are from simulations made with 400 m horizontal resolution.

Figure 3. An example model simulation output from the NIWA (2014) biophysical model indicating the large changes to a range of biophysical parameters in the Clova/Crail/Beatrix Bay complex (especially Clova Bay) due to mussel farms. The left column represents concentrations for the reference scenario, that is with 2012 stocking levels (existing mussels/existing fish/with denitrification). The central column of images presents the relative difference between a range of biophysical parameters with 2012 stocking rates and with no mussel farms (no mussels/existing fish/with denitrification). The differences are very large in some cases; for example, the center box on the bottom row shows zooplankton levels ten times greater in Clova Bay without the existing mussel farms (red arrow).

Other Anthropogenic Effects

I note that there are several reports that consider mussel farming in the Marlborough Sounds describing how many historical activities have degraded the Sounds and altered the natural state. The implication seems to be that the Sounds have been degraded by activities for many decades and so further development in the form of intensive aquaculture will have little additional impact, i.e. the area is already highly impacted, so more impacts are acceptable. This is an inherently sacrificial and thus inappropriate analysis. Dr Stewart's 2015 statement of evidence[3] picked up on this issue in his paragraph 7.39 "*It has been said that Beatrix Bay is a "Farming" area as though that somehow validates any ecological changes that ensue from marine farming*". I too strongly disagree with this kind of approach, which is in direct conflict with the Purpose and Principles of the RMA (1991). The opposite approach is required, that of reduction of impacts and restoration, which is being practised elsewhere in New Zealand (e.g. www.harbourcare.co.nz; www.mhrs.org.nz; www.mangawhaiharbourrestoration.co.nz) and worldwide (Attachment 5).

In conclusion, it is my opinion that some reduction of current mussel stocks in areas of intensive mussel farming is required and that some restoration measures need to be accordingly adopted to sustainably manage the marine ecosystems in these areas. This is given the results of the various assessments of ecological carrying capacity and the known and likely impacts that have already occurred or are occurring in areas of high farming intensity - as described in the literature and as predicted by the biophysical model etc. Modern aquaculture modelling and ecological carrying capacity standards provide the best available means of undertaking this.

It is unfathomable as to why no monitoring of the environmental impacts of mussel farming has ever been undertaken - after 3 decades of concerns and calls for monitoring. I note that the Marine Farming Association recently commissioned a report to consider the "Provision of ecological and ecosystem services by mussel farming in the Marlborough Sounds" (NIWA, 2019). This even though there is no underlying data or knowledge base from which such an exercise could actually be undertaken; i.e., as stated in the conclusions of this report "*Key areas that require investigation are biochemical pathways (especially denitrification), biodiversity measures, food webs, discard biomass and reef formations and sound scientific studies on the interactions between mussel farms and fish, seabirds and mammals*" (NIWA, 2019).

This lack of empirical science is attributable to an historical failure by the consenting authority to demand that monitoring be undertaken and the consistent failure by the majority of environmental consultants preparing applications for mussel farm resource consents over the past 3 decades to volunteer the need for this monitoring. This has led to the inability to sustainably develop aquaculture using the empirical processes/methods as advocated by NIWA (page 3 above).

Conclusions and Recommendations:

1. In the Marlborough Sounds "sustainable development of marine farming" has not been the case due to the complete lack of environmental monitoring regimes to detect unacceptable environmental changes. This has led to the opposite approach, that is, because we do not have scientific evidence of negative environmental impacts, then there is no reason to not continue with existing farming intensity and indeed to expand the industry.

2. It is my opinion that even though there continues to be no monitoring in order to determine and quantify the impacts of mussel farming in the Marlborough Sounds, in the past decade tools have been developed that are underpinned by science and that can be used to both consider and quantify the impacts of mussel farms throughout the Sounds and to set farming intensities that are within the ecological carrying capacity of at risk areas. Namely, the Aquaculture Stewardship Council (ASC, 2012) sustainability/carrying capacity empirical model and the NIWA (2015) biophysical model. The computer model that KCSRA have developed from the ASC Standard empirical model provides a far more targeted and accurate depiction of the ASC pelagic effects of mussel farming than the spreadsheet-based broad area

[3] ENV-2014-ENV-CHC-34

calculations that have otherwise been done to date, and would also be a very useful tool for the spatial allocation of bi-valve farming in the Sounds.

3. In my opinion the models affirm that bivalve farming has an adverse cumulative effect on indigenous ecosystem functionality. The models confirm that the existing level of farming is having a potentially significant adverse effect on the intrinsic ecosystems of some areas.

4. The NIWA (2015) model is a very powerful tool and should continue to be developed with field data to refine calibration and ecological responses. The ASC (2012) also provides a very useful tool for assessing existing and future effects and also affords an objectively determined threshold of acceptable farming intensity for at risk areas. Future refinements and advances could derive from commencing monitoring programmes using appropriate impact assessment design such as the BACI (Before/After, Control/Impact) methodology if possible, investigations to quantify significant effects in terms of levels of crucial ecosystem components such as zooplankton, phytoplankton, detritus, NH4, N03, etc., and standardisation of parameters for the application of the ASC (2012) sustainability/carrying capacity model.

5. As concluded in NIWA (2019), there is a need to develop integrated planning (e.g. as is being developed and applied for the Hauraki Gulf). This is an evidence and knowledge based approach, leading onto an ecosystem-based approach, and an integrative management framework that includes economic, environmental and social considerations. However, this will be difficult to achieve in the medium term, particularly given the absence of ecological monitoring and quantification data of how the ecosystem works and has been impacted by aquaculture.

6. In the meantime, the available models should be used to determine acceptable thresholds of intensive farming, including to manage down over-subscribed areas. For the future, they should be further developed to more accurately predict how aquaculture stresses on the ecosystem might transgress into loss of biodiversity and indigenous species abundance and resilience (which will likely be exacerbated by the impacts of climate change). Ultimately an integrated management plan (which requires comprehensive environmental monitoring in order to determine changes, what is causing them and how to manage them) should be developed to sustainably manage aquaculture in the Marlborough Sounds.

Please let me know if further clarification is needed.

Yours sincerely

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QUALIFICATIONS AND EXPERIENCE

My full name is Shaw Trevor Mead and I am an environmental scientist based at Raglan. I am currently an Environmental Scientist and Managing Director at eCoast, which is a marine consulting and research organisation.

I hold BSc (School of Biological Sciences) and MSc (Hons) (School of Environmental and Marine Sciences) degrees from the University of Auckland, and a PhD degree from the University of Waikato (Earth Sciences).

I have over 25 years' experience in marine research and consulting, have authored/co-authored 60 peer-reviewed scientific papers and 2 chapters in a practitioner's textbook on beach management[4] and coastal protection[5], and have solely or jointly produced over 450 technical reports pertaining to coastal oceanography, coastal engineering (design and impact assessments), marine ecology and aquaculture. I have undertaken over two thousand 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 also a

[4] Mead S. T., 2017. *Chapter 6 - Beach Management*. In: Marine and Coastal Resource Management: Principles and Practise. Eds D. Green and J. Payne. Routledge, 328 pg.
[5] Mead S. T., and J. C. Borrero, 2017. *Chapter 16 -Surf Science and Multi-Purpose Reefs.* In: Marine and Coastal Resource Management: Principles and Practise. Eds D. Green and J. Payne. Routledge, 328 pg.

part-time lecturer (environmental change and coastal engineering) and research provider at Unitec. I am a member of the New Zealand Coastal Society (ENZ), the New Zealand Association of Impact Assessment, and am on the editorial board of the Journal of Coastal Conservation, Planning and Management. In addition, I am a technical advisor for the Surfbreak Protection Society (NZ) and Save the Waves Coalition, which mostly entails consideration of marine structures and developments and the impacts they will have or have had on surfing breaks; I am co-author of the New Zealand Management Guidelines for Surfing Resources[6], which were first released in beta version in October 2018 and finalised in September 2019 (https://surfbreakresearch.org/downloads/).

I have a background in 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. My MSc in Environmental Science, Marine Ecology and Aquaculture included 4th year Environmental Law and a dissertation on the Quota Management System (QMS) legislative review. My PhD was primarily in coastal oceanography, with the marine ecological components of my Doctorate directed towards subtidal habitat enhancement of marine structures. The physical oceanography component was focussed on understanding the effects of coastal bathymetry on surfing wave breaking characteristics using field measurements (bathymetry surveys, aerial photography and GPS positioning of in situ data collection) and hydrodynamic numerical modelling. My PhD thesis is comprised of 6 peer-reviewed Journal Papers that describe the meso-scale components that combine to create high-quality surfing breaks and empirical methods of determining wave breaking intensity of high-quality surfing waves. My professional career has included involvement 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, MPR design and surf break impact assessment, coastal erosion control, marine reserves, 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).

I have been involved with the assessment of the impacts of aquaculture (both physical and ecological) and identification of aquaculture management areas (AMA's) for over 20 years. These projects have included mussel and salmon farming in the Marlborough Sounds, oyster farming in Whangarei Harbour and Matarangi Estuary, AMA's for the Northland Region and mussel farming in the Firth of Thames, Bay of Plenty and Pegasus Bay.

[6] Atkin, E., Bryan, K., Hume, T., Mead, S. T., and Waiti, J., 2019. Management Guidelines for Surfing Resources. Raglan, Aotearoa New Zealand: Aotearoa New Zealand Association for Surfing Research. ISBN: 978-0-473-49540-4