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Subject: Review of NZKS Env Monitoring 2013
Attachments: Review of NZKS Env Monitoring 2013 - Catriona Macleod (2-4-14).pdf

Good morning

Attached is the Peer Review of the 2013 Monitoring Reports completed by Catriona MacLeod.

Kind regards, Karen

New Zealand King Salmon

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REVIEW OF NEW ZEALAND KING SALMON ANNUAL ENVIRONMENTAL MONITORING REPORTS 2013 (2nd April 2014)

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Having reviewed all of the environmental monitoring reports for 2013 I would for the most part agree with Cawthron's overall assessment of site conditions. I have included below a summary of the key elements that I felt relevant to each site, in particular noting those points which appear most important for management (regulatory and farm-based). I have also provided some general comments on the findings and assessment process, and data interpretation that I hope you will find useful in discussions with the regulatory authorities. The deposition of copper and zinc are also discussed separately at the end of this summary.

REPORT NO. 2464 - ENVIRONMENTAL IMPACTS OF THE TE PANGU BAY SALMON FARM: ANNUAL MONITORING 2013

This site is considered high-flow (~ 15 cm/s). In current year feed input was 4,690 tonnes, a relatively small (190 tonne) increase in feed use since 2012. I understand that this lease is one of the high flow sites where there is currently discussion about boundary effects and the potential for a broader footprint (based on re-suspension issues) than the modelling might suggest, consequently I have included some discussion of the results on that basis.

Organic loading data indicate a major impact under cages but there is no evidence of significant elevation of organic material at sites outside of the farm itself. However, redox levels are reduced and sulphide levels have increased within the broader consent area (zones 2 and 3) relative to levels at selected controls. Sediments were quite coarse (sand based) suggesting that there is not a lot of natural organic enrichment at this location. Interestingly there was a clear spatial distribution gradient within the farm with impacts being greatest towards the NE, which would appear to be consistent with the prevailing current direction. It is worth noting that a greater proportion of shell material was noted in the video on the NE transect, shell material in the sediments can create areas of reduced water exchange, which may in turn result in greater variability (anoxic patchiness) in the sediment geochemistry.
It is interesting that the video for both transects notes marked changes in the sediment type along the transects, this is important as marked changes in sediment type can confound interpretation of changes in the ecological and biogeochemical measures, as the response to enrichment may as a result not be linear. It is interesting that in the "inner zone"/ zone 2 (i.e. under pens) a number of opportunistic benthic foragers were observed in the videos, this suggests that these species were taking advantage of the supplemented food supply but were not limited by anoxia/ hypoxia – this is encouraging as such communities will help to ensure the dispersal/ breakdown of farm derived material.

The nutrient loadings in the water column do not indicate any major concerns; the slight elevation in ammonia concentration observed proximate to the cages is not surprising so close to fish pens, or likely to be any cause for concern. There is no evidence of any direct impact on chlorophyll levels. However, for future reference it might be useful to note the tide situation at the point at which the water samples are collected, and perhaps seek to measure nutrient loads at a consistent stage in the tidal cycle in order to avoid any possibility of misinterpreting tidal differences as temporal/ production issues.

If I am interpreting the zonation correctly, the derived ES scores suggest that for 2013 zone 2 (pen1/2) – 5.0 and zone 3 – 3.6 are compliant based on the current consent conditions. However, the average ES score for sites in zone 4 was 2.7, which is greater than the level of 2.5 proposed for this location and more than 0.5 higher than the average of the associated reference sites, with the standard deviation of 0.2 identifying it as borderline.

Examination of the data underpinning the ES classification suggests that the cause of this potential infringement are the conditions at the NE 300m sample site, with both the sediment geochemistry and the macrofauna suggesting a level of impact greater than might be expected in this zone, although the number of taxa at this site were consistent with that found at the control locations both the abundance and sulphide levels were elevated. Unfortunately the data for each replicate from the NE 300m site are not included in the report so it is not possible to determine whether this was due to a single anomalous result or whether all replicates were consistently impacted. The standard error cited suggests that at least some of the samples were at or below the recommended levels. However, given the video comments note coarser sediments and shell hash at 300m on the NE transect it may be that the changing sediment type and presence of larger shell particles is also influencing these results. It is worth noting that the equivalent 300m position on the NW transect was within guideline levels.

The embayment sample site is also interesting, based on distance from the farming operations this site sits in spatial zone 3 and the ES criteria for that zone would indicate that the results are well within defined levels. However, it is important to note that these samples were collected from only 7m depth whilst the rest of the monitoring samples were from much deeper sites (23-41m). At this depth this site may be within the photic zone and consequently the underpinning conditions and ecological processes may be quite different from that of the other sampling sites. Whilst the results so far do not suggest any particular concern at this site, this difference should be taken into account when evaluating the results from this location in the future.

The borderline result at the outer zone appears to be localised and is not excessive. That is not to say that it should be dismissed. But determining whether the result is real and how it might have happened will enable meaningful actions to be taken to address the situation. Consequently a step-wise investigation of the data may help to identify the actual level of risk posed. Although the ES in the outer zone is close to the recommended level the standard error associated with the infaunal measures is relatively high, consequently, I'd suggest you need to examine the data to ascertain whether there is any potential that an outlier (i.e. a single measure) is artificially elevating the mean. Assuming the levels are realistic then the next step would be to dismiss the possibility that localised differences in sediment conditions are affecting the results (this can be done by examining what previous sampling/ video data tell us about the sediments at this location - although I note that this particular sampling position has moved since the last sampling). Is there any difference in the depth profile across the sampling area that might indicate the NE 300m site is in a deeper area or potential "sink" zone? Given that the sites closer to the pens (zone 3) were still compliant, and that there is no evidence of any clear temporal trend towards non-compliance, in fact over time the impacts at zones 3 and 4 would appear to be relatively stable or for the most part to be trending downwards, it seems unlikely that this result indicates a major increase or more generalised spread of farm impact over a broader area. However, based on the assessment of existing data (i.e. if there are no particular risk factors evident in that evaluation) you may want to consider some additional emphasis in this area for the next survey.

Copper and zinc levels appear consistent with reporting from previous years and not a cause for concern.

REPORT NO. 2465 - ENVIRONMENTAL IMPACTS OF THE OTANERAU BAY SALMON FARM: ANNUAL MONITORING 2013

This site is considered a low / moderate-flow site (~ 6 cm/s), with feed inputs ranging from 1,501 to 2,568 tonnes per annum, and over the previous production cycle (i.e. December 2012 to November 2013) a total of 1,045 tonnes of feed was used.

In 2013 all zones sampled were compliant based on the Cawthron interpretation of the proposed ES stage under current consent conditions. Conditions beneath the pens were highly organically enriched with the impacts being very localised. Sites outside the direct influence of the cages showed a marked improvement in ecological condition and by 150m conditions were indistinguishable from reference sites.
There was no evidence of any issues water column impacts; variability in chlorophyll levels in/ around pens most likely reflecting the physical interference of the pen structures and fish. Historical comparisons suggest that both the controls and transitional zone assessments have been broadly consistent over the last few years (perhaps with a very marginal deterioration at the 50 & 150m sites), but that there may have been a slight improvement in farm based performance.

Very high levels of copper and zinc under the cages.

REPORT NO. 2466 - ENVIRONMENTAL IMPACTS OF THE RUAKAKA BAY SALMON FARM: ANNUAL MONITORING 2013

This site has been in operation for many years (since 1985). Average current speeds at this site are low (~3.7 cm/s). However, feed inputs have been relatively high ranging from 1,705 to 3,255 tonnes per annum. In the 12-month period leading up to this year's monitoring (i.e. December 2012 to end November 2013) a total of 1,661 tonnes of feed was used (356 tonnes less than the previous year), with the majority used during the six months prior to assessment (June to November).

In 2013 all sites sampled were compliant with ES stages consistently lower than proposed limits. For the most part impacts were highly localised impacts although there was some evidence of increased sulphide S, reduced redox and slight faunal impacts at 60m.
Water column effects apparent at the pen sites, with ammonia , DRP and TP levels elevated and chlorophyll levels and DO slightly decreased, although the latter is most likely due to water disturbance/ mixing by the fish..
The Cawthron report suggests that conditions have worsened at 150m position over time, whilst this may be true in comparison with previous year it is possibly premature to suggest this over the longer term.

Cu and Zn high at both pens

REPORT NO. 2467 - ENVIRONMENTAL IMPACTS OF THE FORSYTH SALMON FARM: ANNUAL MONITORING 2013

Average current speed at this site is ~ 3 cm/s, consequently it is considered a low-flow site. This site is subject to rotational fallowing and was vacant for 8 years prior to 2009. Since 2001 feed input when stocked has ranged from 1,987 - 3,261t per annum. Site was stocked from Dec 2009 to Nov 2011 then fallowed prior to restocking again from Oct 2012- Oct 2103, with 1,914t feed used, but was vacant at the time of the survey.

All sites were compliant, with ES stages well within guideline levels.
Although both biogeochemical and faunal conditions were highly impacted under cages these impacts were very localised. There is still evidence of an effect at 150m with sediment redox reduced, sulphide elevated and some faunal changes, however for the most part the organic enrichment effects were highly localised, suggesting that the organic matter is staying within the site. There were no water column effects observed.
The temporal comparison for this site is probably not meaningful as the conditions operating at each sampling time are not consistent. However, although technically the results suggest the site is still compliant it is very clear (and recognised by environmental managers in both industry and council) that this is not a great site for farming. The results suggesting that the conditions are quickly returning to previous levels.

Zn levels elevated at pens

REPORT NO. 2468 - ENVIRONMENTAL IMPACTS OF THE CLAY POINT SALMON FARM: ANNUAL MONITORING 2013

Since 2007 feed input at this site has been slowly ramping up with feed inputs ranging from 3,152-4,304 t/yr, and is currently 4,315t. The site is considered high flow (~19.6 cm/sec up to ~109 cm/sec).
All pen positions sites were compliant with ES stages within guideline levels. There was a clear impact under the pens, which was evident in both the biogeochemistry and the faunal ecology. Although the biogeochemistry effects are largely restricted to beneath the pens there was evidence of effects on the biology at other sites, consistent with an easterly drift of impact which may be a response to the greater potential for dispersal of organic material at this site (see general conclusions for further discussion of this). As a consequence the ES level at the 90m E position (4.3 +/- s.e. 0.1), when placed within zone 2 in the historical comparison was above the recommended level of 4. However, the EQS for this site listed in the new consent U130466 proposes that the ES beneath the cages and out to 90m should be <5, and that the level between 90m to 300m should be <4; samples collected at 90m therefore fall between these two levels and this particular site may or may not be within guidelines depending on which side of the line you choose to place it. This highlights one problem with setting categorical limits to defined areas, and identifies the need to not just rely on a single number in making a decision but to also look at the details of the conditions at the site – trigger levels are most useful in identifying circumstances which need further examination. In this case whilst there was clearly evidence of organic enrichment extending out to the 90m site the sediment biogeochemistry (i.e. redox and sulphide levels) was not dissimilar to that of the equivalent station on the W transect. It is the infaunal community structure at the 90m E site which sets it apart from others and in particular the greatly increased abundances recorded at this location, one replicate having over 13,000 individuals.

The water column nutrients were only monitored on the western transect but showed some particularly unusual response, with elevated levels of nitrates at all sampling sites relative to the control. It is also interesting that ammonia, total nitrate and total phosphorus levels at the 300m site were higher than at any other sampling position. It is hard to understand how farming could contribute to increases in nutrients at the 300m position but not in the intervening waters. Single event sampling in the water column is very hard to attribute to any particular cause, as it is difficult to establish whether any given result may just be a transient localised pulse or whether it is a sustained input response. However, what is probably most important is the scale of the change and whether it persists. In this case the levels of nitrate observed were considerably higher than that experienced at any other site in the current survey, even those sites where current flows were low and significant localised impacts observed, so it seems perhaps inconsistent with the normal expectations of farming effects. I'm not sure I'd entirely agree with Cawthron observation that there is an increasing temporal trend of impact and deterioration in condition at this site; given the changes that have occurred in the locations of the sampling sites and the overall variability shown by the standard error levels, such an assessment might be a little premature.

I think the results for this site show quite clearly some of the difficulties that are being faced in setting appropriate environmental management levels for "high flow" sites, and particularly in defining both suitable "trigger" criteria and boundaries for monitoring and management. Unlike the more depositional sites where zones and levels of impact are well described and easier to model/ predict, I'd suggest the process for assessment still needs some refinement in these more dynamic areas. On that basis these results should be considered as useful in improving the process as they might be for identifying and managing current impacts.

REPORT NO. 2469 - ENVIRONMENTAL IMPACTS OF THE WAIHINAU SALMON FARM: ANNUAL MONITORING 2013

This site has been in operation since 1989 and has low to moderate current flow (~ 8.4 cm/s). It operates in rotation with the Forsyth site, and has had an annual feed input ranging from 1,014-3,790 tonnes per year. In the last cycle cages were in place from May-Nov 13 with a total feed input of 602 tonnes.

All sites reported ES stages consistently lower than the limits proposed by Cawthron.
There was no evidence of any impact on biogeochemistry at pens or 60m, but the under pens the faunal community was clearly impacted, with Pen 2 more impacted than Pen 1.
Samples collected at 180m were comparable to the Controls in all respects.
Nutrient levels are only shown for a single cage (Pen 1), and at that site there was evidence of some O2 draw down at pen level in water column and a slight elevation of both ammonia and TN. What is not clear is the timing for the water column sampling and whether this was consistent for all sites and locations. As previously noted a single water column sample is difficult to make sense of, it could reflect the normal conditions or it could relate to a single transitory event. The timing of sampling is also important as sampling at slack water may enhance localised oxygen depletion and nutrient accumulation effects around cages, and if sampling timing not consistent this might result in a false assessment of quite large changes.
No problems with Cawthron interpretation overall; but need to be mindful that changes at control may be background or just transitory effects from other sources, and are not necessarily due to farm impacts.

Cu & Zn levels elevated at P1: very high zinc in one replicate but overall lower than in previous year.

REPORT NO. 2470 - ENVIRONMENTAL IMPACTS OF THE MFL-32 (Crail Bay) SALMON FARM: ANNUAL MONITORING 2013

Average currents at this site were low (2.5 - 3 cm/s). Site was destocked in December 2011 and was fallow at the time of the survey.
No evidence of impact on faunal communities; redox levels at the cages were up a little, sulphide concentration was very low but still greater than control. There was no elevation of water column nutrients relative to the control location, in fact TN at the pen sites was actually lower that at the control – interestingly if this observation was reversed this it would elicit comment.

No issues with Cu and Zn.

REPORT NO. 2471 - ENVIRONMENTAL IMPACTS OF THE MFL-48 (Crail Bay) SALMON FARM: ANNUAL MONITORING 2013

This site was fallow at the time of the survey and there is no evidence of any impact or sediment changes as a result of previous pen placements.

No issues with Cu and Zn.

GENERAL COMMENTS:

Report Formatting/ Interpretation

I note that the reports do not employ any formal comparative statistics to assess differences between means when making temporal comparisons, as a consequence these comparisons where present are largely subjective. It is really important to take into account standard error (standard deviation) levels when making such comparisons, and not to just compare means directly. It is also important not be selective about the time periods employed when proposing/ interpreting trends. There is quite a lot of literature about interpreting long-term datasets. Ecosystems change at a range of spatial and temporal scales, and it is important to ensure that any trends or patterns inferred are relevant to the ecological scales that apply. It would be good if the graphical representation of the in situ sensor array outputs (i.e. dissolved oxygen, turbidity (optical backscatter), chlorophyll-a, temperature, and salinity data) could be orientated so that the depth is shown on the y-axis running from surface to seabed (as per MFL-48 plots). It may also be useful to view each variable together for all sites, rather than all variables for each site. The reports also need to be consistent in the levels to which the variables are reported (e.g. one/ two decimal places).

It is noted that there are inconsistencies in the monitoring requirements between farms/ locations, whilst I recognise that this is a legacy of the differing regulatory frameworks that have been implemented over time, it is important to understand and acknowledge how these differences make certain generalisations about performance particularly difficult.

As pointed out in the reports biological response variables assimilate the effects of changes in the biogeochemistry over time, rather than simply reflecting the conditions at a single sampling point, and therefore can provide a more integrated assessment of the overall sediment condition. A key rationale for the ES was the fact that it integrated both biogeochemical and ecological metrics to give a more holistic understanding of the environmental condition, consequently when proposing any trends in environmental performance it seems logical that all of the data for a site should be considered and not just individual measures.

Finally where there are clearly defined spatial gradients within the farm, for instance where impacts are clearly influenced by the prevailing current, then it is not necessarily meaningful to compare equivalent distance points, as there will always be a greater impact in one direction.

Defining Non-Compliance And Appropriate Management Responses

I am conscious that there is currently no assessment made as to the significance of any non-compliance event. I think it is important as part of the monitoring assessment to try to make some judgement as to the nature and scale/ importance of the breach when any non-compliance is recorded. It should be possible based on the location, severity and relationship to other measures nearby to make an assessment as to the significance of a breach, and thus inform the management (industry and regulator) response. Firstly it would be important to establish whether the breach can be considered real (i.e. how reliable is the data) and then to evaluate how significant the suggested impact might be. Perhaps there needs to be a scale of response such that multiple breaches, either within the one location or at a single sampling site over several times, might necessitate a greater requirement for further investigation or action. It is important that any response initiated as a result of a non-compliance event actually results in actions to improve environmental conditions. Consequently actions need to be based on a considered understanding of all the facts surrounding the non-compliance event (i.e. including both monitoring data, the broader environmental understanding and production information). This assessment also needs to be farm-based with the end result being a better understanding of the causal factors (farm based and otherwise) and a meaningful plan to avoid future non-compliance events – an adaptive management response.

Ecological Context – Key Points to Note

Where is the best place to locate a fish farm – in a low flow environment where the impacts are highly localised or in a higher flow region where the effects can be more broadly dispersed? There are two equally reasonable and compelling arguments as to which is the best receiving environment for the organic material associated with fish farming. The first argument suggests that the ecology at highly depositional sites may be better suited to the assimilation of organic material as the natural fauna are pre-disposed to organic inputs. Consequently, so long as the fauna is not overwhelmed then low flow assimilative sites that are well adapted to breakdown of organic material may be the best solution. As a consequence the ecological status can more easily and more rapidly return to background levels. However, on the down side management of such sites can be quite tricky, if the assimilative capacity of the site is exceeded the system can tip rapidly into a dysfunctional hypoxic/ anoxic state. The second contention is that a more dynamic site will “spread the load”, resulting in a low level impact across a greater area (dispersal range). Whilst this may mean a greater ecological area is affected this may not necessarily be a bad thing if the faunal community is able to cope (i.e. can utilise/ break down the extra organic material effectively). However, the organic material associated with fish farming does fundamentally change the biology and functional nature of these environments. It is not possible to say that one is necessarily better or worse than the other, however, they do need to be managed/ reviewed in different ways.

Unfortunately it is not possible to apply the same set of management responses/ criteria to both (except maybe in extremes). From a farming perspective there will be less risk with sites where the organic material is widely dispersed and impacts at a low level compared with higher level localised impacts (as this is where there is more likely to be a tipping point). Interestingly, the monitoring undertaken to date has shown that different pen positions at given locations can have quite different performance results, which clearly shows that there is potential to manage sediment condition through changes in farm management practices. It would be good to build on this data to identify some clear farm based strategies for impact reduction/ remediation, providing farms with the necessary tools to be able to respond effectively to the environmental monitoring results.

In making judgements on environmental impacts it is important to be careful not to assume that all environmental changes are farm related. Whilst some correlations may be quite clear, it is important not to over-interpret change and assume an impact where in reality there might be none. Need to take into account i) the inherent variability of the system – is any

suggested change in mean levels effectively just noise associated with the sampling/ site/ environmental variation and within the spread of the standard deviation, and ii) the actual levels observed – although there might be a “statistical” difference in the mean values there may be no biological significance to that difference and therefore the suggestion of change is just maths (need to put the numbers into context and consider the reality). Key questions following on from this would be:
- Is that change problematic for the ecosystem as a whole?
- Is the change reversible?
Also need to consider the effects of impact from both an environmental and a farming perspective – taking both into account will help to identify realistic management responses to ensure the most effective outcomes into the future.

A final point worth considering is whether the ecological response to feed inputs is parametric and linear, which may not necessarily be the case. Report 2465 suggests that farm inputs have reduced progressively since 2010 but that the associated cage ES stages have not responded in a similar manner. This assumes that the ecological response is directly (linearly) correlated with impact, but it may be that the response is more consistent with a connected series of successional states based on different biological and biogeochemical processing states and interactions. Consequently whether something is 5.1, 5.2 or 5.5 may be ecologically irrelevant, and perhaps it is better not to get too concerned about the numbers per se and focus on the underlying trends. It is perhaps the changes between ecological and functional stages that really need to be managed, rather than the variability within stages.

Copper and Zinc Assessment – Key Points to Note

The copper and zinc levels in the reports were highly variable, however, it does seem as though it is the more depositional (low-flow) sites and those which have been farmed for a long time which appear to have the highest levels (e.g. Ruakaka, Otanerau and Waihinau).

Both copper and zinc residues can accumulate in sediments as a result of copper based antifoulant use on salmon net-pens, with zinc being a lesser component of the paint formulation. Zinc is also included as a nutritional supplement in fish feed. Antifoulant usage is likely to be the primary source of elevated copper levels within farms, local environmental conditions and certain farming practices can have a significant effect on copper accumulation and impact levels throughout the system. Where levels are high it may be prudent to review farm-based activities, as adjusting the type of antifoulant used, the level of net handling required, the level of biofouling encountered and the net-cleaning approach employed can make a difference to the overall impacts.

The major risk with significant build-up of copper and zinc in the sediments is the potential for associated ecological impacts. Highest levels are typically associated with organically rich sediments, with a higher capacity to bind and accumulate such metals. For accumulated metals to have an effect on local ecology or sediment processes they must be “bioavailable”, which is in turn reliant on the form (speciation) of the metal. Metal speciation in sediments is complex and strongly related to the geochemical status of the sediments (i.e. redox status of surficial sediments, pH, degree of organic enrichment, presence of geochemical phases) and on the extent of processes such as bioturbation and resuspension. In anoxic sediments, metals are generally thought to be less bioavailable, being tightly bound as insoluble sulphides.

Recent results from a study in Tasmania have shown that bioavailability is quite low with copper from antifoulant based paints and that the risk of serious adverse impacts on sediment processes from current copper contamination levels is also relatively low; largely because most of the copper occurs as paint flakes and can't be easily taken up by benthic organisms. This study indicated that in Tasmania the major source of the zinc in the sediments is likely to have been from fish feed, rather than from the paint. Zinc is an essential element for many marine organisms and, as such, is readily bioaccumulated. Although zinc was not a key focus of the Tasmanian study some assessments were undertaken to evaluate whether zinc may be contributing to the overall toxicity, with the findings suggesting that there was no evidence of specific toxicity or particular ecological concerns at the levels observed. However, levels of any metals well in excess of ANZECC guidelines still pose a potential toxicity risk and should be avoided and/ or appropriately managed. The simplest solution would be to transition from antifouled to non-antifouled nets in these situations.

Metals such as copper are conservative in the environment and simply removing the source does not necessarily mean that the levels will reduce. In highly depositional environments the main mechanism for reduction of copper is dilution/ burial by non-contaminated sediments, whilst in more dynamic systems resuspension and intermittent scouring may transfer/ spread the copper more broadly within the environment and thus reduce localised loads. Note the Tasmanian report will be publicly available in April 2014.

Disclaimer

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