From: Karen Mant
Sent: 31 May 2016 11:37:03 +1200
To: monitoring;Gina Ferguson-7541
Cc: Mark Gillard
Subject: Additional monitoring of RK & OT
Attachments: 2016-05-31 MG Letter to MDC re OT and RK samples.pdf, CawRpt_2785a_Additional sulphide sampling Otanerau March 2016.pdf, CawRpt_2786a_Ruakaka follow up survey Mar 2016.pdf

Kia Ora

Please find attached correspondence from Mark Gillard regarding the additional monitoring of Ruakaka and Otanerau sites, and the Cawthron reports for those sites.

Nga mihi, Karen

Karen Mant, *Environmental Coordinator*

New Zealand King Salmon

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New Zealand King Salmon

31 May 2016

Gina Ferguson
Marlborough District Council
PO Box 443
Blenheim 7240

Dear Gina

Following on from the 2015 monitoring of the Otanerau and Ruakaka salmon farms, please find attached reports for a re-sample of Ruakaka and Otanerau as recommended by Cawthron.

The Ruakaka results are marginally better than November 2015, and confirm the seabed is able to assimilate and that the reduction in feed, as proposed by NZ King Salmon, is a suitable management response for this site.

The Otanerau TFS measurements show an order of magnitude difference between November 2015 and March 2016. This can be significant in terms of calculating ES and is related to the technique as identified in the reports. When extrapolated back to the 2015 results, it is likely to result in an ES reduction of approximately 0.3.

Cawthron carried out a brief re-assessment of the 2105 results against the revised methodology, and potentially there could be up to an ES 0.2 improvement for Forsyth. On assessing these new results, re-assessments and reviewing records, it is clear the results for 2015 are not overall worse than previous years.

We are happy for council to contact Cawthron directly on this matter.

Yours sincerely

Mark Gillard
Environmental Compliance Manager

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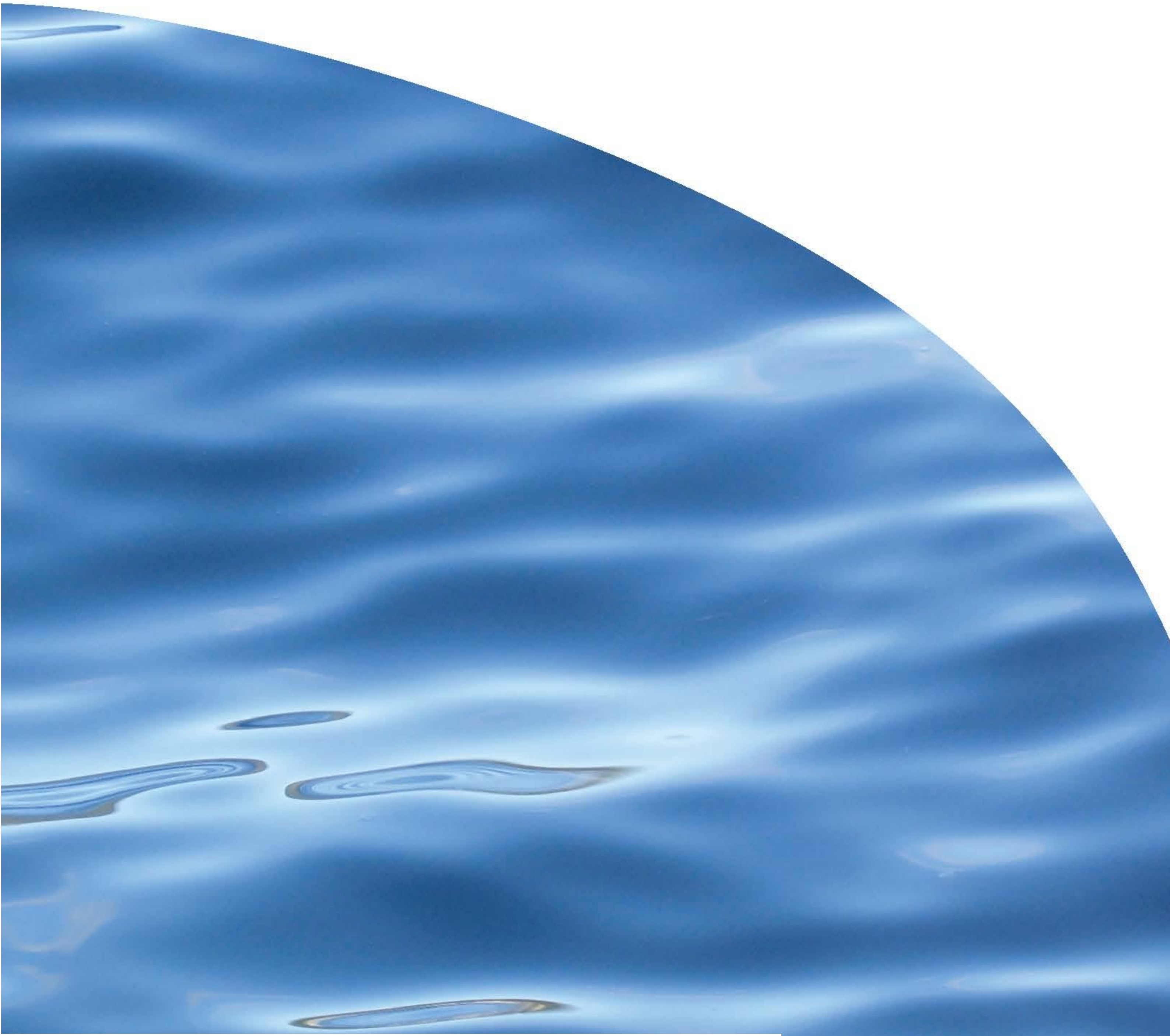
REPORT NO. 2785A

ADDITIONAL SULPHIDE SAMPLING AT THE OTANERAU SALMON FARM, MARCH 2016



ADDITIONAL SULPHIDE SAMPLING AT THE OTANERAU SALMON FARM, MARCH 2016

DAVID TAYLOR, DEANNA ELVINES

Prepared for The New Zealand King Salmon Co. Ltd.

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REVIEWED BY:
Grant Hopkins

APPROVED FOR RELEASE BY:
Chris Cornelisen

ISSUE DATE: 30 May 2016

RECOMMENDED CITATION: Taylor D, Elvines D 2016. Additional Sulphide Sampling at the Otanerau salmon farm, March 2016 Prepared for The New Zealand King Salmon Co. Ltd. Cawthron Report No. 2785a. 4 p.

1. INTRODUCTION

The New Zealand King Salmon Co. Ltd. (NZ King Salmon) currently has 11 consented salmon farms in the Marlborough Sounds. Annual benthic monitoring at these sites is required under the associated marine farm consents. During the November 2015 round of annual monitoring, anomalously high levels of sulphides, particularly at the pen stations, were reported at the Otanerau Bay (OTA) farm site (Elvines et al. 2016). Due to concerns over the accuracy of the sulphide readings, Cawthron instigated additional sediment sampling at OTA in March 2016.

2. RE-SAMPLING

Re-sampling was undertaken at the three pen stations at the OTA site on 31 March 2016. The full range of enrichment indicators were collected from three replicate grab samples (sulphides, redox, organic content, and macrofauna) at each pen station, but only the sulphide samples were analysed (the remaining indicator samples were archived). See Elvines et al. (2016) for more details on sample collection and analysis procedures.

3. RESULTS

Sulphide levels beneath the pens ranged from 841 to 2093 µM, an order of magnitude lower than those reported in 2015 (Figure 1), and more in keeping with those expected at a highly enriched salmon farm (Keeley and Taylor 2015). These findings suggest that the sulphide concentrations previous reported in the 2015 annual monitoring report (Elvines et al. 2016) are therefore likely to be inaccurate. If incorporated into the enrichment stage (ES) calculations presented in the 2015 annual monitoring report, the latest sulphide results would reduce the overall ES score at the OTA pen stations by an average of 0.3 (± 0.03 SE). Because the OTA November 2015 ES scores were compliant with the allowable EQS for the zone, the amendment of these results would have no compliance implications.

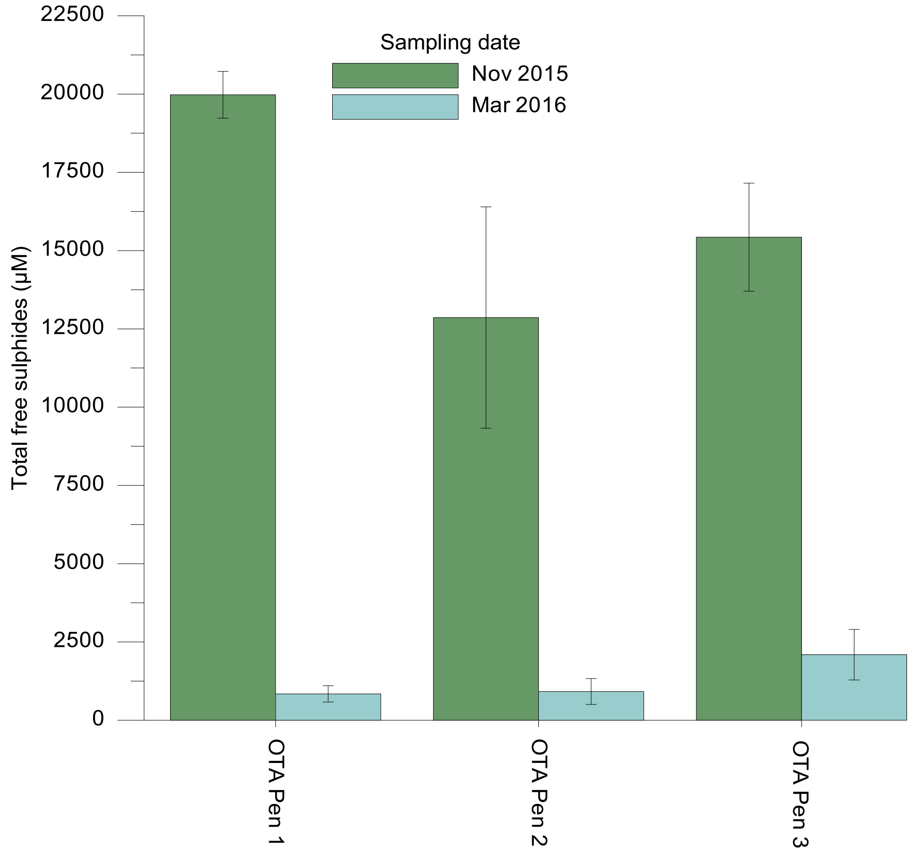

Figure 1. Total free sulphide levels concentrations (µM) in sediments collected at OTA pen stations in November 2015 and at the same locations in March 2016.

4. DISCUSSION

Determination of free sulphides using a probe requires the construction of a calibration curve in the laboratory. Due to the exponential shape of the curve, very small measurement errors in the initial construction of the curve can result in large anomalies at the high end of the scale (i.e. very high sulphide concentrations). The re-sampling and analysis undertaken during this survey has demonstrated the need to set a high standard for accuracy of the calibration curve used in estimating sulphide concentrations (e.g. r^2 of 0.98 or better). In addition, a second replicate probe is to be on hand for further verification of any anomalously high measures. These are now standard practices at Cawthron. The sulphide concentrations reported here for March 2016 should therefore be considered more reliable than those presented in the 2015 annual monitoring report (Elvines et al. 2016).

We continue to stress caution when considering single indicator variables to determine seabed effects, as has been stated in the annual monitoring reports (footnote in section 5.1 of Elvines et al. 2016). Among other reasons, this is due to the range of biological responses to elevated levels of sulphides (or any other single indicator variable). In general, sediments with sulphide concentrations of 6,000-10,000 µM are considered anoxic (Hargrave et al. 2008, and references therein), and there are few documented accounts of the variability in biological response to sulphide levels > 7,000 µM. Variability in biological response can be due to: small-scale patchiness (not truly 'paired' samples at spatial scales smaller than the actual sampled area), varying vertical gradients (for both macrofauna, and sulphides), and temporal lags in chemical and biological parameters; all identified in the sulphide report to MDC (Keeley and Taylor 2015). This emphasises the importance of using a suite of indicators, and not relying heavily on a single indicator such as sulphides to interpret benthic condition, which is the benefit of using the ES scoring system (MPI 2015).

5. REFERENCES

Elvines D, Taylor D, Newcombe E, Berthelsen A. 2016. Environmental Impacts of the Otanerau Bay Salmon Farm: Annual Monitoring 2015. Prepared for The New Zealand King Salmon Co. Ltd. Cawthron Report No. 2785. 21 p. plus appendices.

Hargrave BT, Holmer M, Newcombe CP 2008. Towards a classification of organic enrichment in marine sediments based on biogeochemical indicators. Marine Pollution Bulletin 56: 810-824.

Keeley N, Macleod C, Forrest B, 2012. Combining best professional judgement and quantile regression splines to improve characterisation of macrofaunal responses to enrichment. Ecological Indicators (12) 154-166.

Keeley N, Taylor D 2015. A review of total free sulfide concentrations in relation to salmon farm monitoring in the Marlborough Sounds. Prepared for Marlborough District Council. Cawthron Report No. 2742. 13 p.

MPI 2015. Best Management Practice guidelines for salmon farms in the Marlborough Sounds: Benthic environmental quality standards and monitoring protocol. Prepared by the Benthic Standards Working Group.

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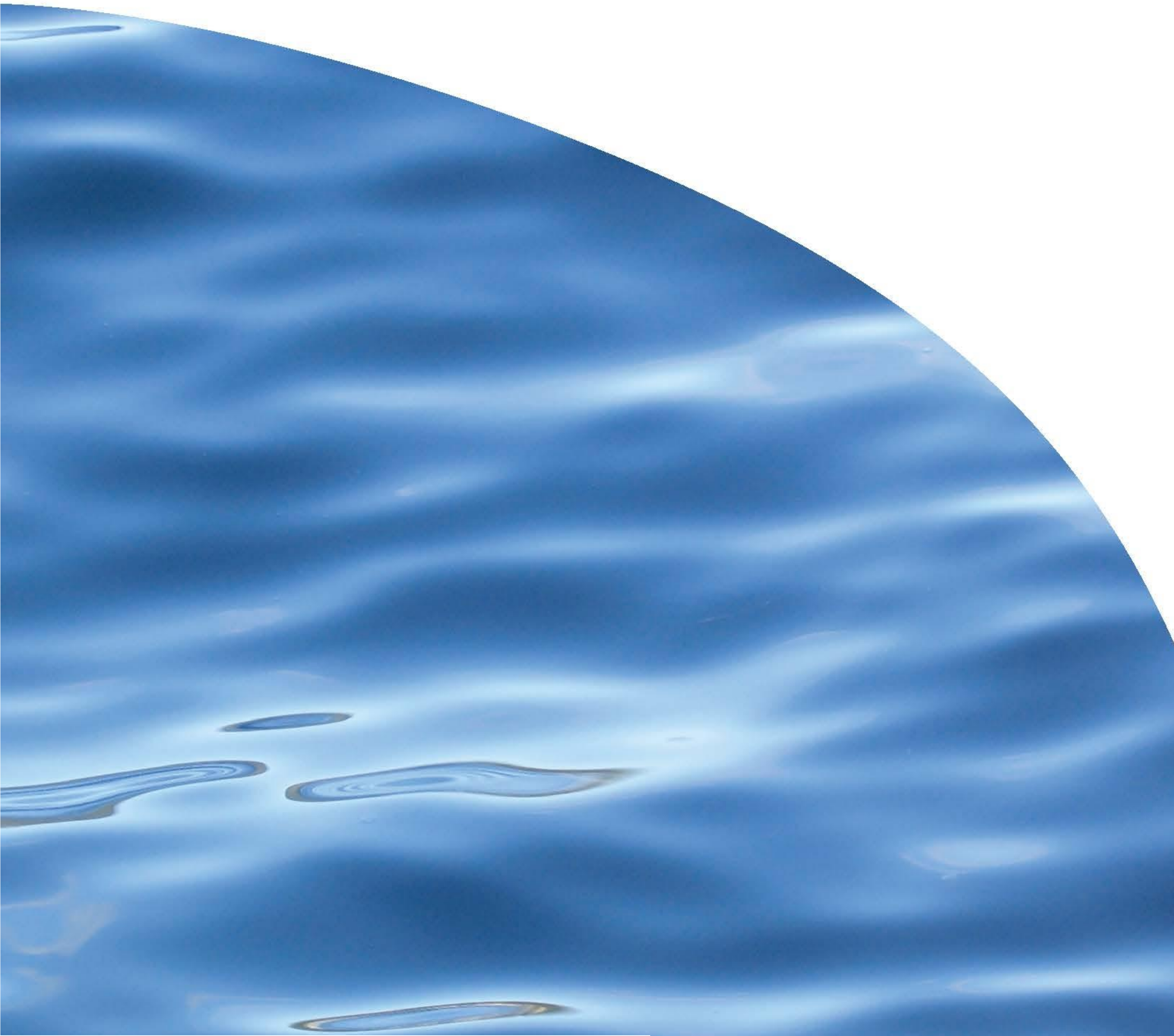
REPORT NO. 2786A

ENVIRONMENTAL IMPACTS OF THE RUAKAKA BAY SALMON FARM: ADDITIONAL MONITORING, MARCH 2016



ENVIRONMENTAL IMPACTS OF THE RUAKAKA BAY SALMON FARM: ADDITIONAL MONITORING, MARCH 2016

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1. INTRODUCTION

The New Zealand King Salmon Co. Ltd. (NZ King Salmon) currently has 11 consented salmon farms in the Marlborough Sounds. Annual benthic monitoring at these sites is required under the associated marine farm consents. During the November 2015 round of annual monitoring, deterioration in seabed conditions coupled with anomalously high sulphide levels was observed at the Ruakaka Bay (RUA) salmon farm (Elvines et al. 2016). Given the poor sediment chemistry in November, it was projected that continued organic input would result in further deterioration in seabed condition.

Therefore, additional monitoring of conditions at the pen stations was recommendation of the annual monitoring report with the aim of determining assimilative capacity beneath the pens after the summer period of ‘highest impact’ (i.e. highest feed levels and warmest temperatures). Results from resampled sulphides will also provide context around the reliability of the 2015 results.

1.1. Feed information update

From November (when the annual monitoring was undertaken), feed inputs increased by 17 tonnes, to a total of 238 tonnes for December. Feed levels progressively decreased from January onwards, to a total of 92 tonnes of feed in March 2016.

2. SAMPLING

Sampling was undertaken on 31 March 2016, using the same methodology as described in the RUA annual monitoring report for 2015 (Elvines et al. 2016). Samples were analysed for the following enrichment indicators: redox potential, sulphides concentration, organic content and macrofauna. Only the sampling stations located beside the pens were re-sampled. These were sampled in the same locations as in November 2015.

3. RESULTS

Overall enrichment stage (ES) assessment scores were marginally lower to that observed in November 2015, and remained compliant with the consented EQS for this zone (Table 1). Macrofaunal communities at the Pen 1 station had similar taxa richness between surveys (Appendix 1), but had higher comparative abundances in March (total of 16,008 individuals at Pen 1, compared to a total of 11,751; Table 2). A change in the community composition was also observed at this station; there were higher relative proportions of Dorveillidae and Nematoda (second-order opportunists), and lower relative proportions of *Capitella capitata* (first-order opportunists) (Table 2). Both the change in community composition and the increased abundances indicate seabed conditions have improved here. Organic matter has increased between the two sampling periods, while sediment chemistry scores remained comparable between sampling periods (Table 1), but with improved sulphide results (Appendices 1 and 2).

At Pen 2, the overall ES score remained compliant with the EQS for this zone, and were comparable between sampling periods (Table 1). Despite the similar overall ES between sampling, there were changes in the biological community measures that suggest deterioration in seabed condition since November 2015. Specifically, there were lower numbers of taxa present in the March 2016 survey (7 in total for March 2016, compared with 13 in November 2015) and significantly lower abundances (1,497 compared with 9,513). Conversely, sediment chemistry improved at Pen 2, due to lower sulphides recorded in the 2016 survey, and are more in keeping with those expected at a highly enriched salmon farm (Keeley and Taylor 2015). An explanation for the anomalous 2015 sulphide results is provided in the following discussion section. The unchanged ES score, despite the deterioration in macrofauna, is a result of the concurrent improvement in sulphides.

Table 1. Average enrichment stage (ES) scores (and 95% confidence intervals) for Ruakaka pen sampling stations sampled in November 2015 and March 2016.

Station		Nov 2015	Mar 2016
Pen 1	Organic loading	2.8 (0.4)	4.5 (0.8)
	Sediment chemistry	5.1 (0.3)	5.2 (0.4)
	Macrofauna	5.7 (0.1)	5.3 (0.1)
	Overall ES	**5.3 (0.1)**	**5.2 (0.2)**
Pen 2	Organic loading	4.0 (0.7)	4 (1.3)
	Sediment chemistry	6.1 (0.6)	5.1 (0.2)
	Macrofauna	5.2 (0.6)	5.6 (0.1)
	Overall ES	**5.3 (0.3)**	**5.3 (0.2)**

Table 2. Summary of macrofaunal composition (sum % per station) for both pen stations sampled in November 2015 and March 2016. Total taxa and abundance values are also shown, as the sum across three replicates for each station.

	Pen 1		Pen 2	
Taxa	**Nov 2015**	**Mar 2016**	**Nov 2015**	**Mar 2016**
Capitella capitata	99%	14%	94%	79%
Dorveillidae	0%	1%	0%	3%
Nematoda	0%	85%	5%	17%
Other	0%	0%	0%	1%
Total no. taxa	**8**	**10**	**13**	**7**
Total abundance	**11,751**	**16,008**	**9,513**	**1,497**

4. DISCUSSION AND CONCLUSIONS

4.1. Assimilative capacity

The results show that macrofaunal communities at both pen stations have maintained the capacity to assimilate organic matter. However, the biological communities still appear to be unstable (spatially patchy, with large changes observed over time). Improvements in macrofauna was observed at Pen 1 concurrent with deterioration at Pen 2 (albeit within the bounds of the allowable EQS for the zone), despite the reduction in feed inputs from January onwards.

The difference in exposure to organic input over time between these two stations may explain the spatial patchiness these communities are exhibiting (i.e. communities at the Pen 2 station are less resilient to continued, and fluctuating, inputs of organic matter). Pen 1 is located on an area of seabed with a lower historical organic input, because it was shifted to a new area of seabed in response to the relocation of pens channel-ward in 2014. The current location of the Pen 2 station has been subject to a longer period of organic input. Pen 1 can therefore be considered more recently impacted than Pen 2. The temporal instability is likely a result of levels of fluctuating organic input that is sometimes at (or possibly above; during the period of highest feed input) the maximum assimilative capacity for these communities.

Using less feed at this site (as NZ King Salmon anticipates for 2016) should go some way to ensuring the seabed at this site retains assimilative capacity. Future management of this farm should continue to consider the instability of the communities beneath the pens.

4.2. Sulphide results

Determination of free sulphides using a probe requires the construction of a calibration curve in the laboratory. Due to the exponential shape of the curve, small measurement errors can result in anomalies at the high end of the scale (i.e. very high sulphide concentrations). The re-sampling and analysis undertaken during this survey has demonstrated the need to set a high standard for accuracy of the calibration curve used in estimating sulphide concentrations (e.g. r^2 of 0.98 or better). These are now standard practices at Cawthron. Thus, the sulphide concentrations reported for March 2016 should be considered more reliable than those presented in the 2015 annual monitoring report (Elvines et al. 2016).

We continue to stress caution when considering single indicator variables to determine seabed effects, as has been stated in the annual monitoring reports (footnote in section 5.1 of Elvines et al. 2016). Among other reasons, this is due to the range of biological responses to elevated levels of sulphides (or any other single indicator variable).Variability in biological response can be due to: small-scale patchiness (not truly ‘paired’ samples at spatial scales smaller than the actual sampled area), varying vertical gradients (for both macrofauna, and sulphides), and temporal lags in chemical and biological parameters; all identified in the sulphide report to MDC (Keeley and Taylor 2015). This emphasises the importance of using a suite of indicators, and not relying heavily on a single indicator such as sulphides to interpret benthic condition, which is the benefit of using the ES index.

5. SUMMARY OF FINDINGS

- Following the annual monitoring survey, the communities beneath the pens have retained the capacity to assimilate organic waste. However, there is temporal instability and spatial patchiness of macrofaunal communities beneath the net pens.
- Reducing organic input, as anticipated for 2016, will benefit biological communities, and will help maintain assimilative capacity beneath the pens in the longer-term.
- Finally, sulphide results from the recent 2016 survey are more in line with that expected at the site compared to the anomalously high results from the 2015 survey. The sulphide method has been improved as a result of the comparison between sampling events.

6. REFERENCES

Elvines D, Taylor D, Newcombe E, Berthelsen A. 2016. Environmental Impacts of the Ruakaka Bay Salmon Farm: Annual Monitoring 2015. Prepared for The New Zealand King Salmon Co. Ltd. Cawthron Report No. 2786. 20 p. plus appendices.

Keeley N, Macleod C, Forrest B, 2012. Combining best professional judgement and quantile regression splines to improve characterisation of macrofaunal responses to enrichment. Ecological Indicators (12) 154-166.

Keeley N, Taylor D 2015. A review of total free sulfide concentrations in relation to salmon farm monitoring in the Marlborough Sounds. Prepared for Marlborough District Council. Cawthron Report No. 2742. 13 p.

7. APPENDICES

Appendix 1. Summary of the average (S.E.) sediment physical and chemical properties, infauna variables and calculated indices for the Ruakaka Bay (RUA) salmon farm pen stations sampled in March 2016.

	Pen 1		**Pen 2**	
	Nov 15	**Mar 16**	**Nov 15**	**Mar 16**
TOM	5.9 (0.5)	11.2 (1.5)	9.5 (1.2)	9.7 (2.4)
Redox	-57.7 (7.1)	-156.7 (7.1)	-165.7 (15.5)	-147.3 (7.4)
Sulphides	4381.7 (658.5)	2867.3 (794.2)	10551.8 (4239)	2423 (281.1)
Abundance	3917 (269.4)	5336 (1067.1)	3171 (1626.1)	499 (122.3)
Taxa	5.3 (0.9)	5.3 (0.3)	8.7 (2.3)	3.7 (0.3)
Evenness	0 (0)	0.3 (0)	0.1 (0)	0.5 (0.1)
Richness	0.5 (0.1)	0.5 (0)	1 (0.4)	0.4 (0.1)
SWDI	0.1 (0)	0.5 (0.1)	0.3 (0.1)	0.6 (0)
AMBI	6 (0)	4.7 (0.1)	5.9 (0)	5.7 (0)
MAMBI	0.1 (0)	0.2 (0)	0.1 (0)	0.1 (0)
BQI	1.4 (0.1)	1.9 (0.1)	1.7 (0.2)	1.2 (0)

Appendix 2. Detailed enrichment stage (ES) calculations for each station at the Ruakaka Bay (RUA) salmon farm pen stations, March 2016. For details about how these values were calculated, see MPI (2015). Underlined text are cases where best professional judgement (BPJ; Keeley et al. 2012) was used.

SITE INFORMATION
Date: Mar-15
Farm/site: Ruakaka
Flow environ LF

Variable group weightings: 0.1 (Organic loading), 0.2 (Sediment chemistry), 0.7 (Macrofauna)

RAW DATA (to be entered)

Station:	Repl.	TOM	Redox	Sulphides	S	N	J	d	h	AMBI	M-AMBI	BQI
RUA Pen 1	a	14.3	-146	4290	3210	5	0.36	0.5	0.58	4.85	0.22	1.78
RUA Pen 1	b	9.7	-154	1544	6560	6	0.28	0.57	0.49	4.71	0.23	1.99
RUA Pen 1	c	9.7	-170	2768	6238	5	0.23	0.46	0.37	4.65	0.20	1.85
RUA Pen 2	a	14.4	-162	2978	259	4	0.36	0.54	0.5	5.75	0.13	1.28
RUA Pen 2	b	6.6	-141	2067	578	4	0.46	0.47	0.64	5.74	0.15	1.30
RUA Pen 2	c	8.2	-139	2224	660	3	0.57	0.31	0.62	5.65	0.14	1.14

ES equivalents

Station:	Repl.	TOM	Redox	Sulphides	S	N	J	d	h	AMBI	M-AMBI	BQI	Organic loading	Sediment chemistry	Macrofauna	Overall ES
RUA Pen 1	a	5.28	5.44	5.64	5.29	5.5		5.85	5.22	4.17	5.49	5.13	5.28	5.54	5.24	5.3
RUA Pen 1	b	4.1	5.52	4.13	5.9	5		5.74	5.37	4.07	5.43	4.92	4.1	4.83	5.2	5.02
RUA Pen 1	c	4.1	5.66	4.95	5.86	5.5		5.91	5.58	4.02	5.57	5.05	4.1	5.31	5.36	5.22
RUA Pen 2	a	5.3	5.59	5.06	6	5.5		5.79	5.36	4.84	5.94	5.66	5.3	5.33	5.58	5.5
RUA Pen 2	b	3.07	5.4	4.53	5.5	5.5		5.89	5.12	4.83	5.83	5.64	3.07	4.97	5.47	5.13
RUA Pen 2	c	3.62	5.38	4.63	5.5	6		6.14	5.15	4.77	5.89	5.81	3.62	5.01	5.61	5.29