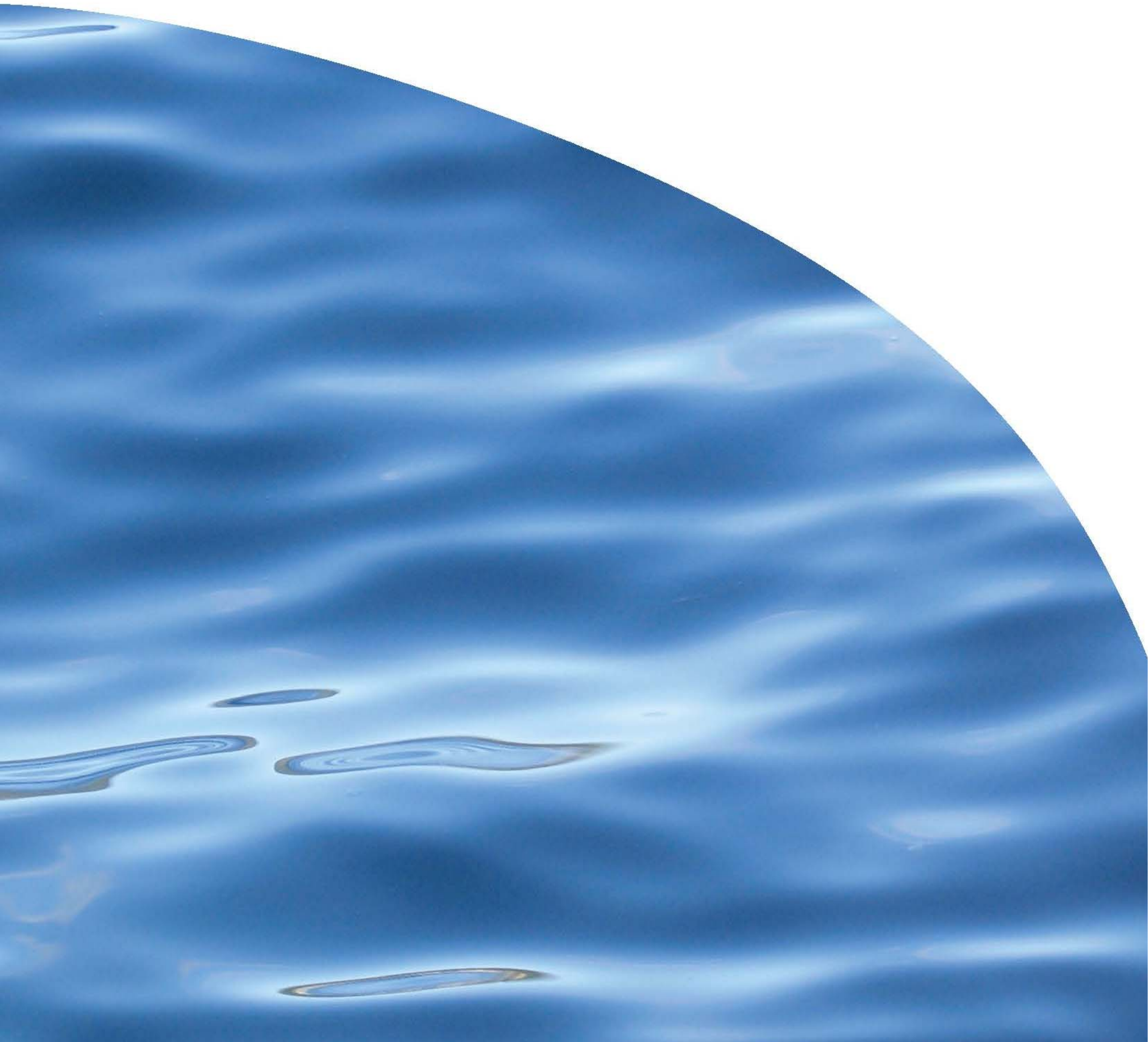
REPORT NO. 2075

ENVIRONMENTAL IMPACTS OF THE MFL-48 SALMON FARM: ANNUAL MONITORING REPORT 2011



ENVIRONMENTAL IMPACTS OF THE MFL-48 SALMON FARM: ANNUAL MONITORING REPORT 2011

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Prepared for New Zealand King Salmon Company Limited.

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1. INTRODUCTION

New Zealand King Salmon Company Limited (NZKS) is the largest finfish farming company in New Zealand and has a long history in the Marlborough Sounds. NZKS has eight consented farms in the region (Figure 1): Te Pangu Bay (TEP), Ruakaka Bay (RUA), Otanerau Bay (OTA), Waihinau Bay (WAI), Forsyth Bay (FOR), Clay Point (CLA), Marine Farm Licence 48 (MFL-48) and Marine Farm Licence 32 (MFL-32).

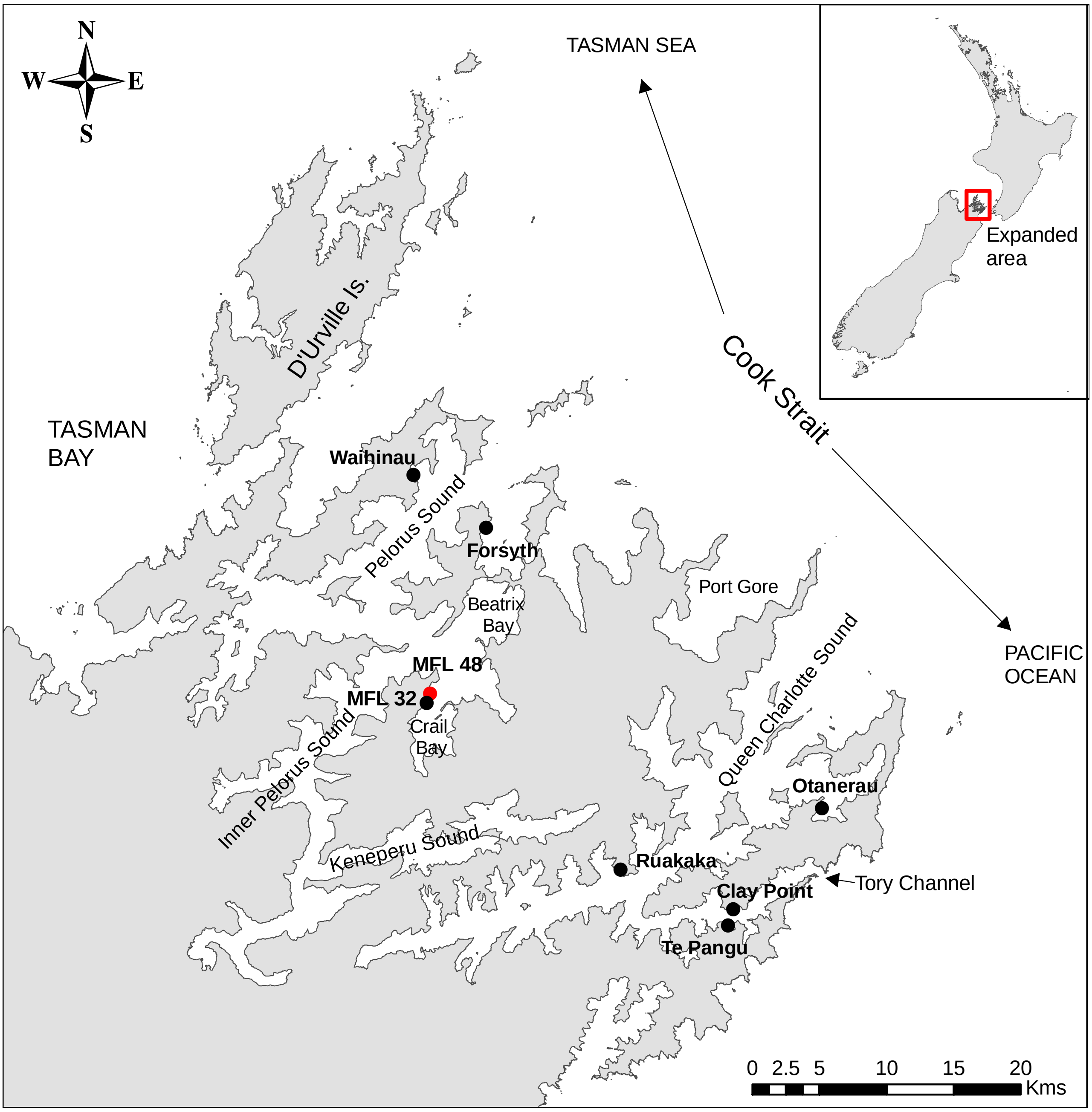

Figure 1. Map of Marlborough Sounds area showing the location of the MFL-48 salmon farm (red dot) along with NZKS's seven other farm sites (black dots).

NZKS is required to undertake environmental monitoring and reporting in accordance with its marine farm consents. The monitoring is conducted under an annual environmental monitoring plan (AEMP) that is prepared by Cawthron on behalf of NZKS. The specific methods of the plan were revised in 2010 to accommodate improvements in knowledge and techniques as described in Keeley (2011). Detailed methods and rationale relating to this year's monitoring can be found in Keeley 2012.

Consent conditions for all of the farms broadly require monitoring of the effects of deposition on the seabed, with particular regard to the benthic community composition and abundance, and dissolved oxygen (DO) levels. The environmental monitoring results determine whether the farms are compliant with the seabed impact zones concept; a model, which provides an upper limit to the spatial extent and magnitude of seabed impacts (see Keeley 2012). In addition, water column monitoring (measuring nutrients and chlorophyll-*a*) is undertaken each year at one low-flow and one high-flow farm, and TEP and CLA have adjacent rocky reef communities that are monitored. This report presents the 2011 annual monitoring results for the MFL-48 salmon farm.

1.1. Site details and history of feed usage

The MFL-48 farm site has been established as a salmon farm since 2009, and with average water current speeds of ~ 2.5-3.0 cm/s, it is considered a low- flow site. The site is relatively unique in that finfish cage culture is conducted alongside long line mussel culture, within the same lease. NZKS purchased the site in 2011 and has since destocked the site (December 2011); it currently lies fallow.

The conditions of the consent follow a two-staged approach where initial food input is limited to 1000 tonnes per 18-month period (666 tonnes/yr). Eighteen months after the commencement of consent, and dependent on the results of the environmental monitoring, production may increase to a maximum food input of 1770 tonnes per 18-month period (or 1180 tonnes/yr).

MFL-48 is managed under a fallowing strategy, meaning the council may give approval to rotate the cage positions within the site as needed to lessen the intensity of impact to the seabed. The need for shifting cages is determined by the environmental monitoring results. In order for a fallowing strategy to work, the degree of degradation prior to moving should be kept as low as possible so that the recovery time to a condition appropriate for reinstatement is as practically short as possible. As a result NZKS accepts a lower level of impact tolerance beneath the cages at the MFL-48 site, than farm sites that do not employ a fallowing strategy.

Feed inputs at this farm were ~ 15 tonnes in 2010, and over the 12-month period leading up to this year's monitoring (*i.e.* December 2010 to the end of November 2011) a total of ~ 287 tonnes of feed was used (Figure 2). Most, if not all, of this tonnage was used in the cages next to the Cage 1 sampling station; the other cages appeared to be recently installed/ unused (Figure 1). The 2010 environmental monitoring report (Clark *et al.* 2011) identified a moderately enriched seabed directly beneath the cages, however, as the farm is yet to be fully stocked it is still considered to be in Stage 1 of the consent.

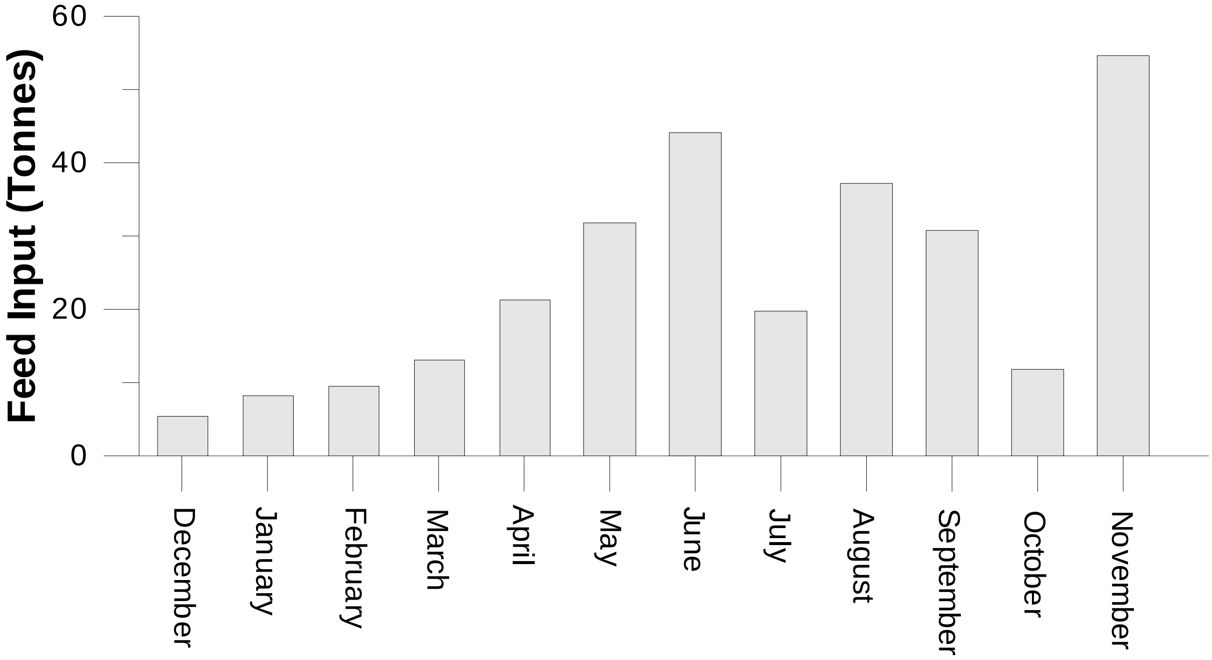

Figure 2. Monthly feed inputs at the MFL-48 farm from December 2010 to November 2011.

2. METHODS

The eight NZKS farms are situated at depths generally ~ 25-35 m and over similar seabed substrates, but they vary in terms of their flow regimes. The differences in flow rates (and flushing) have ramifications for how each farm is monitored due to the associated differences in how the various environmental variables respond. TEP and CLA are considered high-flow sites, WAI and OTA low- to moderate-flow and FOR, RUA, MFL-48 and MFL-32 are low-current sites. Detailed methods and rationale describing the sampling protocol for all of NZKS's farms can be found in the most recent Annual Environmental Monitoring Plan (AEMP, Cawthron Report 1872). Copies are held by Marlborough District Council (MDC) and NZKS. This plan is updated and modified routinely to accommodate the most relevant and effective sampling methods. A condensed summary of the revised techniques that were adopted this year is provided in the following sections.
Sampling at MFL-48 occurred on 8th December 2011.

2.1. Soft sediment habitat

2.1.1. Sampling locations

The MFL-48 salmon farm was monitored at two cage stations (at the edge of Zone 1), two stations along a transect aligned perpendicular to the shore (away from the cages) at distances that correspond to the Zone 2-3 and Zone 3-4 boundaries, specified under the zones concept (*i.e.* stations '50 m' and '150 m' respectively), and at two comparable reference or 'control' (*i.e.* 'Ctl-1' and 'Ctl-2') stations (Figure 3). For a full explanation of the zones concept, please refer to Keeley 2011. The Zone 2-3 and Zone 3-4 stations could not be positioned in line with the predominant direction of flow, due to the presence of mussel farms immediately to the north and south of the cages. MFL-48 is a low flow site and therefore will have minimal footprint deformity (*i.e*. skewing of the footprint) and the depth and substrates remain constant in the chosen direction.

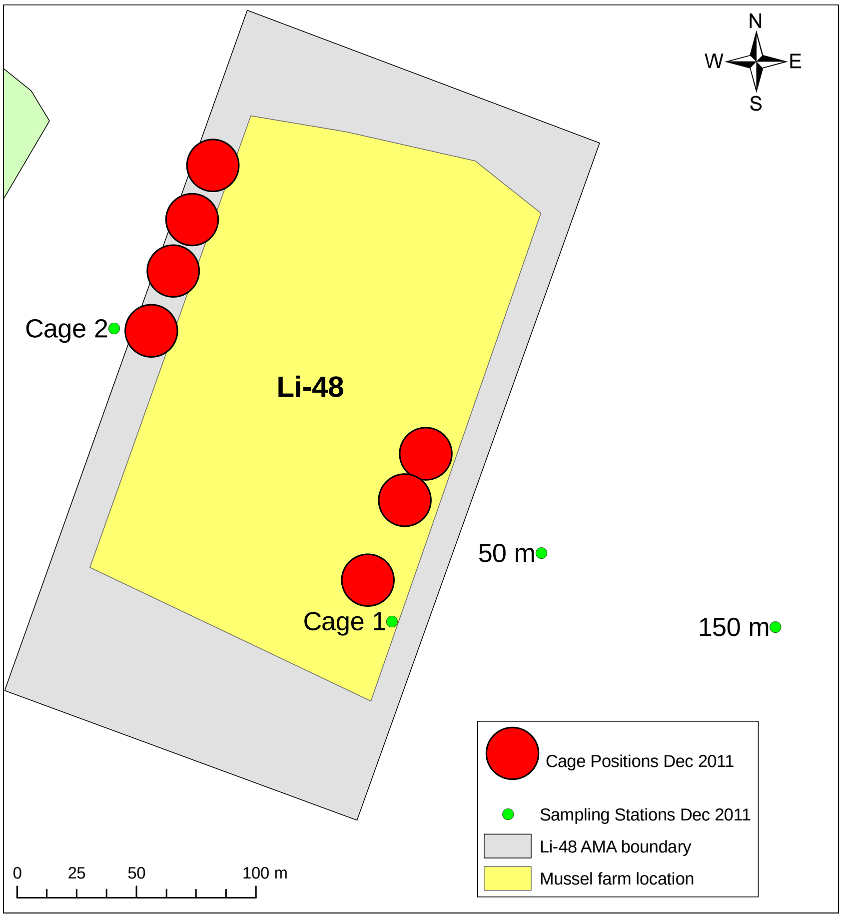

Figure 3. Soft sediment sampling locations for MFL-48 in 2011. 'Ctl 1' was located within Crail Bay, approximately 1 km northeast of MFL-48 and 'Ctl 2' was located in Popoure Reach (near Stafford Bay), approximately 5 km to the north west.

2.2. Environmental variables

Three replicate sediment (modified van Veen) grab samples were collected at each sampling station. Each grab sample was examined for sediment odour, texture, bacterial mat coverage and the top 3 cm of one sediment core (63 mm diameter) was analysed for organic content (as % AFDW), redox potential (Eh_{NHE}, mV), and total free sulphides (µM). In addition, 'cage' samples were analysed for copper and zinc concentrations. A separate core (130 mm diameter, ~ 100 mm deep) was collected from each grab for infauna identification and enumeration. The term infauna describes the animals buried within the sediment matrix and does not adequately represent the epifauna component (animals living on the sediment surface). Observations of sediment out-gassing visible at the surface were also made. Raw infauna data were further analysed to calculate the total abundance (N), total number of taxa (S), Shannon-Weiner diversity index (H'), Pielou's evenness index (J'), Margalef richness index (d), AMBI biotic coefficient (BC) and M-AMBI ecological quality ratio (EQR). Refer to Keeley 2012 for an explanation of each of the biotic indices.

2.3. Water column

Dissolved oxygen (DO) concentrations were measured at each of the benthic sampling stations by collecting water ~1 m from the seabed with a van Dorn sampling bottle and measuring with a calibrated, on-board DO meter.

Nutrients are measured at one low-flow and one high-flow salmon farm each year; in 2011 this was undertaken at RUA and CLA. Samples were collected from mid-water using a van Dorn sampler and analysed in the laboratory for nitrate-N (NO_3-N), nitrite-N (NO_2-N), ammoniacal-N (NH_4-N), dissolved reactive phosphorous (DRP) and chlorophyll-*a* (chl-*a*). Although these measurements were not undertaken at MFL-48, the results from the RUA low-flow site are considered to be generally representative.

3. RESULTS

3.1. Soft sediment habitats

The cage sampling stations showed elevated organic matter levels (ranging from 7.1 to 9.4% AFDW, average 8.3%) compared with the controls which had moderate levels (ranging from 6.2 to 7.3% AFDW, average 6.7%; Figure 4). Redox potentials were lower at all stations in comparison to the controls, and 'Cage 1' had negative redox potentials (average -58.5 Eh_{NHE}, mV). Total free sulphides were significantly elevated (~120 times) at the Cage 1 sampling station compared to the controls, and were elevated by 21 and 17 times at the Cage 2 and 50 m stations respectively, compared to the controls. Mild sulphide odours were detected in sediments collected from beneath the Cage 1 station, but no sulphide odours were detected in sediments from other stations (Appendix 1, Table 1.1.).

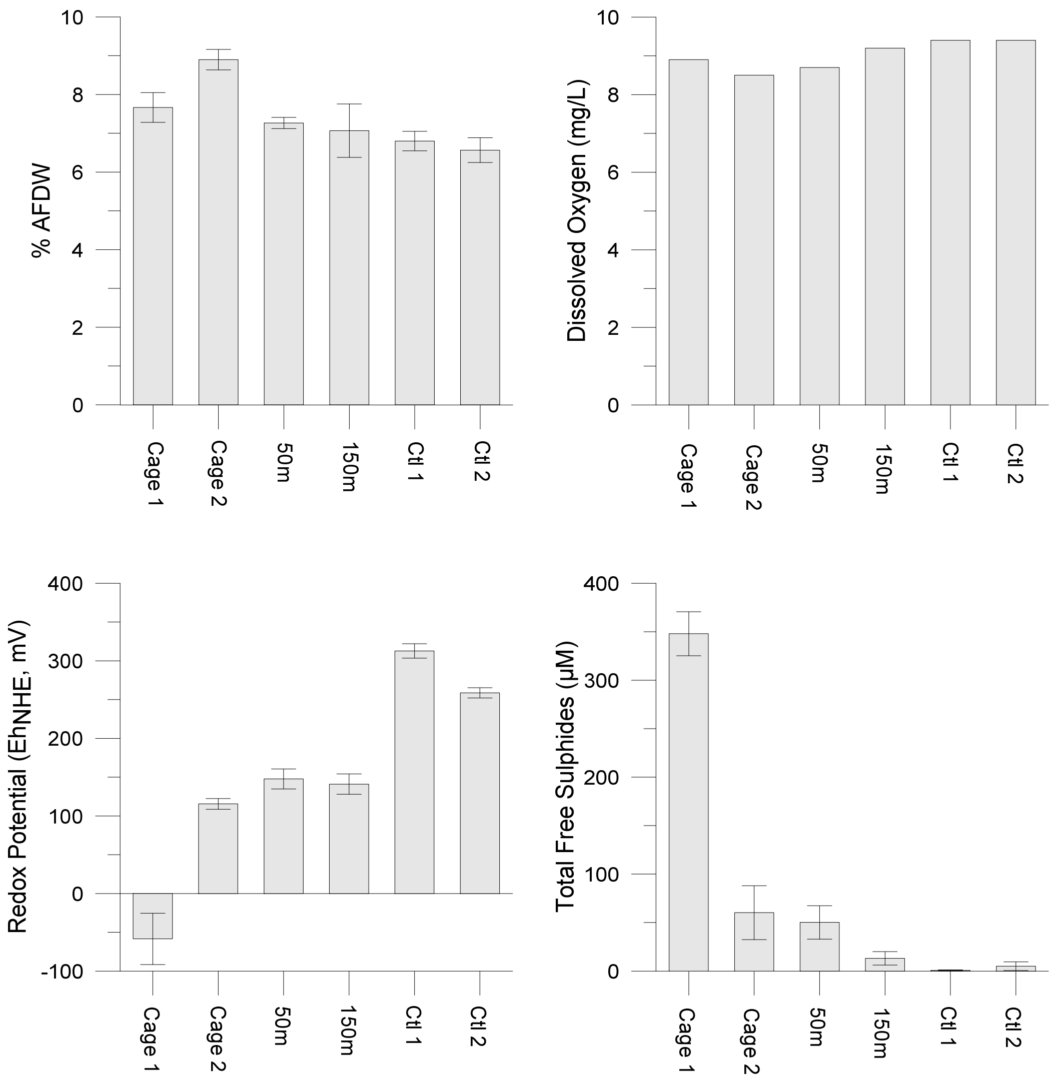

Figure 4. Organic matter (as %AFDW), redox potential (Eh_{NHE}, mV) and total free sulphide concentrations (µM) and near-bottom DO (mg/l). Error bars = standard error (SE), n=3

The infauna communities at the Cage 1 sampling station showed distinct signs of enrichment, with elevated abundances and lower numbers of taxa, diversity, richness, evenness and EQR in comparison with all other stations (Figure 5). Communities were dominated by enrichment-tolerant, opportunistic taxa (especially *Capitella capitata*). The Cage 2 station showed signs of mild enrichment, with slightly elevated abundances and high numbers of taxa. The infaunal community properties of the 50 m and 150 m stations were similar, and had lower numbers of taxa, diversity, evenness, richness and EQR in comparison with the controls.

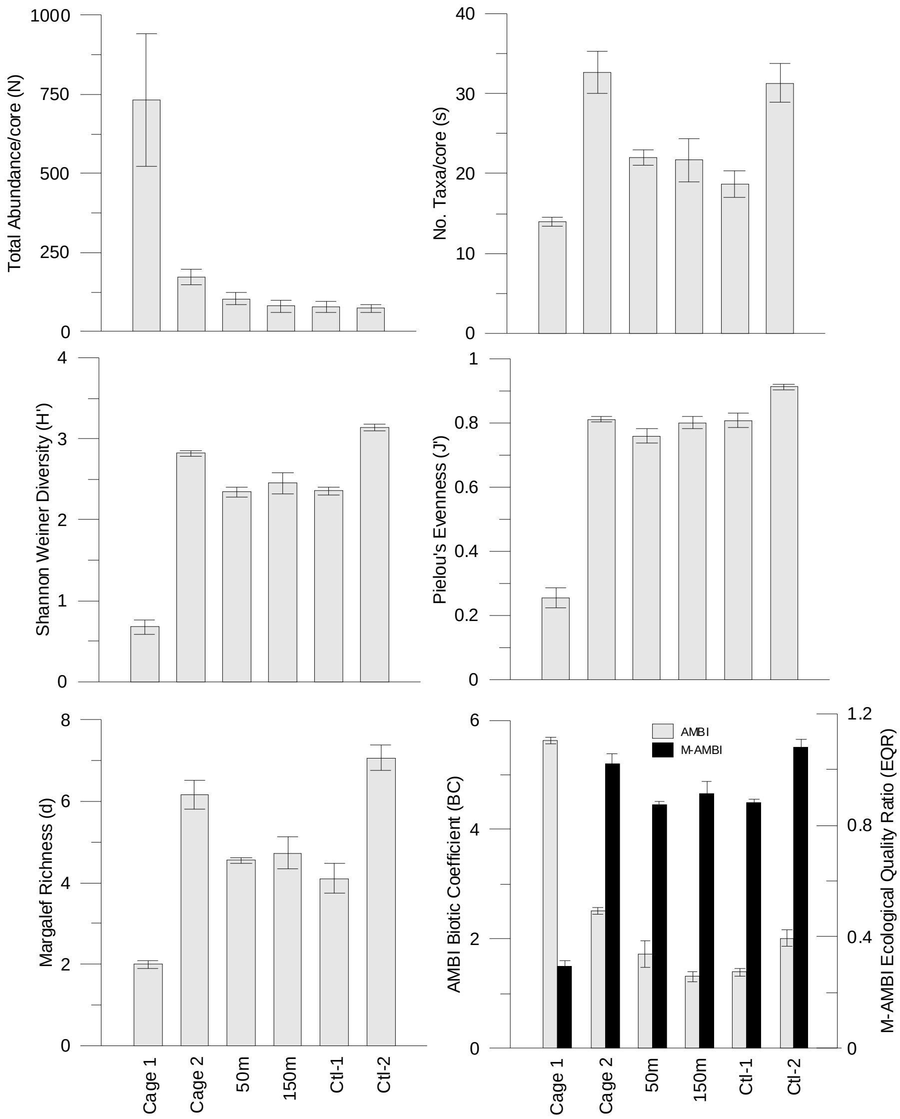

Figure 5. Infauna statistics. Error bars = standard error (SE), n=3.

3.2. Copper and zinc

Zinc and copper concentrations below the cages were well below the ANZECC (2000) ISQG-Low trigger values, and average values were 59 and 14 mg/kg respectively (n=3) (Appendix 2, Figure 2.2.).

3.3. Water column

Near-bottom (water column) dissolved oxygen (DO) levels were slightly depressed (*i.e.* by ~5 and 10%) at Cage 1 and Cage 2 respectively, relative to the controls (Figure 4). The DO level at the 50 m station was also slightly depressed (*i.e.* by ~7%).

Water column nutrient levels were not analysed at MFL-48 during the 2011 annual monitoring, but results from the RUA survey showed that chl-*a* was reduced and NH_4-N was elevated with proximity to the farm (Dunmore and Keeley 2012a). DRP, NO_3-N and NO_2-N levels were similar across all stations.

4. SUMMARY OF FINDINGS: ASSESSMENT OF ENRICHMENT STAGE AND COMPLIANCE

Enrichment stage (ES) was calculated by converting each environmental result (raw data) into an equivalent ES score using the appropriate linear model. Average ES scores were then calculated for the sediment chemistry variables (redox and sulphides), the 'infauna composition' variables (abundance, richness, diversity and biotic indices) and for total organic matter (TOM), representing 'organic loading' for each sample/ grab. The 'overall ES' for a given sample was calculated by determining the weighted average of those three groups of variables. Finally, the overall ES for the sampling station was equated to the average of the replicate samples with the degree of certainty reflected in the associated standard error. To determine compliance, the overall ES for each station was compared to predefined environmental quality standards under the zones concept. The methods and rationale for quantifying ES and assessing environmental compliance at the NZKS sites in 2011 is described in Keeley 2012.

4.1. Seabed habitats

The 2011 assessment of soft-sediment conditions, in terms of compliance with the zones concept and associated conditions, are summarised below and in Table 1.

- Overall, Cage 1 (where the cages had been stocked) was moderate-highly enriched with an ES of 3.8. Cage 2 was only mildly enriched (overall ES = 2.3), to a level that could be expected given that it is situated within a mussel farm (to our knowledge the cages situated above it were yet to be stocked). Both sites were within the specified maximum recommended ES (= 4.5) for the farm. Infauna communities at Cage 1 were indicative of major effects (ES 4.3), but at Cage 2 were indicative of mild enrichment (ES 1.9).
- The 50 m station (Zone 2-3 boundary) had an ES score of 2.3, which was less impacted than the permitted ES (maximum permitted ES = 3.5).
- The 150 m station (Zone 3-4 boundary) had an ES value of 2.1, which was comparable (within ± 0.5) to the control stations (average ES 1.9), and this station is therefore less impacted than the permitted ES.

Table 1. Seabed effects score card summarising compliance and requirement for management responses. Refer to Appendix for detailed enrichment stage (ES) calculations, and refer to Keeley 2012 for a more detailed breakdown of how overall ES was calculated from each environmental variable for each sampling station.

Station		ES (±SE)	Comments
Cage 1	Organic loading: Sediment chemistry: Infauna composition: **Overall:**	3.44 (0.13) 3.17 (0.39) 4.32 (0.10) **3.80 (0.15)**	Sediments with mild sulphide odours and elevated organic matter content. Negative redox values, and high sulphides. Infauna community with high abundances, low numbers of taxa, richness, diversity, evenness and EQR.
Cage 2	Organic loading: Sediment chemistry: Infauna composition: **Overall:**	3.85 (0.09) 1.87 (0.25) 1.89 (0.02) **2.27 (0.09)**	Sediments with no sulphide odours but elevated organic matter content. Reduced redox values, and elevated sulphides. Infauna community with elevated abundances and numbers of taxa, and slightly lower diversity, richness, evenness and EQR.
50 m (Zone 2-3 Boundary)	Organic loading: Sediment chemistry: Infauna composition: **Overall:**	3.31 (0.05) 1.94 (0.01) 2.05 (0.01) **2.30 (0.00)**	No sulphide odours, slightly elevated organic matter, reduced redox values and elevated sulphides. Infauna with reduced numbers of taxa, richness, diversity, evenness, EQR.
150 m (Zone 3-4 Boundary)	Organic loading: Sediment chemistry: Infauna composition: **Overall:**	2.81 (0.66) 1.93 (0.13) 1.91 (0.10) **2.10 (0.17)**	No sulphide odours, sediments with similar organic matter content to control, but with reduced redox values and slightly elevated sulphides. Infauna with similar densities to control, but with lower numbers of taxa, richness, diversity, evenness and EQR.
Control 1	Organic loading: Sediment chemistry: Infauna composition: **Overall:**	3.14 (0.09) 1.60 (0.13) 2.06 (0.09) **2.13 (0.09)**	Diverse infauna communities, moderate levels of organic matter and very low total free sulphide levels.
Control 2	Organic loading: Sediment chemistry: Infauna composition: **Overall:**	2.09 (0.59) 1.70 (0.27) 1.58 (0.06) **1.73 (0.12)**	Diverse infauna communities, moderate organic matter content and total free sulphide levels.

4.2. Water column

Near-bottom dissolved oxygen (DO) levels in the water were reduced at the cage stations, suggesting a farm-related effect. However, the 12 % reduction in DO encountered beneath the cages (relative to the control station) is unlikely to have been ecologically significant. If, as suspected, the oxygen demand is coming from organic waste material on the seabed, then it is likely that DO levels would be further reduced nearer to the surface of the seabed.

Monitoring of chl-*a* at the low-flow RUA farm showed that concentrations were lower closer to the farm, but were within levels observed naturally in the Marlborough Sounds (Dunmore and Keeley 2012a). Chl-*a* concentrations can be temporally and spatially variable, and the difference observed between near-farm levels and control levels was less than that observed over a tidal cycle in Pelorus Sound (Gibbs *et al.* 1992). The difference observed at RUA is not considered to be ecologically significant.

NH_4-N concentrations at RUA were slightly elevated with proximity to the farm, indicating localised low-level enrichment (Dunmore and Keeley 2012a). However, levels were not outside the range previously reported for the wider Marlborough Sounds environment (Gibbs *et al.* 1992). Elevated NH_4-N levels were also reported for this farm in 1998 and 2002 (Hopkins and Forrest 2002), and for other fish farming sites (La Rosa *et al.* 2002, Hopkins 2004, Dunmore and Keeley 2012b). It has been concluded that localised elevated NH_4-N concentrations of similar magnitude observed around the farms are unlikely to have significant adverse effects on the wider Marlborough Sounds ecosystem (Hopkins and Forrest 2002). This conclusion is consistent with the expected flushing rate and consequent dilution as the water is transported away from the farm (Gillespie *et al.* 2011).

5. CONCLUSION AND RECOMMENDATIONS

In December 2011, the MFL-48 salmon farm was assessed to be less impacted than the permitted ES limits and therefore no management response is required. This result is consistent with the farm not yet being fully stocked. As it stands, the consents specify the progression to Stage 2 feed levels can only occur after 18 months of operation at full capacity whilst remaining within the EQS. Hence, it is still considered to be within Stage 1.

Furthermore, if NZKS's intention (as the new owners of the site) is to operate it in a fixed location, then it may be appropriate to adopt the same Environmental Quality Standards (EQS) that are applied to the other salmon farms (as opposed to the reduced ES tolerances that were applied for rotational/ fallowing purposes). Ideally, consent conditions should also be standardised to remove confusion and ambiguity surrounding the requirements for feed loadings and management periods (*i.e.* 12 vs. 18 months).

6. REFERENCES

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7. APPENDICES

Appendix 1. Summary of 2011 results.

Table 1.1. Summary of infauna and the physical and chemical properties of sediments from the MFL-48 farm site during the 2011 monitoring survey. Bracketed values = standard error (SE).

	Station	Units	Cage 1	Cage 2	50 m	150 m	Control 1	Control 2
	Depth	m	33.4	28.1	33.6	33.4	32.4	32
Sediments	AFDW	%	7.7	8.9	7.3	7.1	6.8	6.6
	Redox	Eh_{NHE}, mV	-58.5	115.5	147.7	141	312.7	258.7
	Sulphides	µM	347.9	60.2	50.2	13.1	0.8	5.0
	Bacterial mat	-	absent	absent	absent	absent	absent	absent
	Out-gassing	-	none	none	none	none	none	none
	Odour	-	none	mild	none	none	none	none
Infauna	Abundance	No./core	731 (210)	172 (25)	104 (18)	81 (19)	78 (16)	74 (11)
	No. taxa	No./core	14 (0.58)	32.7 (2.6)	22 (1)	21.7 (2.73)	19 (1.67)	31.3 (2.4)
	Richness	Stat.	2 (0.10)	6.16 (0.34)	4.55 (0.06)	4.73 (0.4)	4.11 (0.37)	7.07 (0.31)
	Evenness	Stat.	0.26 (0.03)	0.81 (0.01)	0.76 (0.02)	0.8 (0.02)	0.81 (0.02)	0.91 (0.01)
	Shannon-Weiner	Index	0.67 (0.09)	2.82 (0.04)	2.34 (0.06)	2.45 (0.13)	2.35 (0.05)	3.14 (0.04)
	AMBI	Index	5.63 (0.07)	2.51 (0.07)	1.73 (0.24)	1.32 (0.09)	1.40 (0.08)	2.02 (0.15)
	M-AMBI	Index	0.29 (0.02)	1.02 (0.03)	0.87 (0.01)	0.91 (0.05)	0.88 (0.01)	1.08 (0.03)
	Near bottom DO	mg/l	8.9	8.5	8.7	9.2	9.4	9.4

Appendix 2. Historical comparisons.

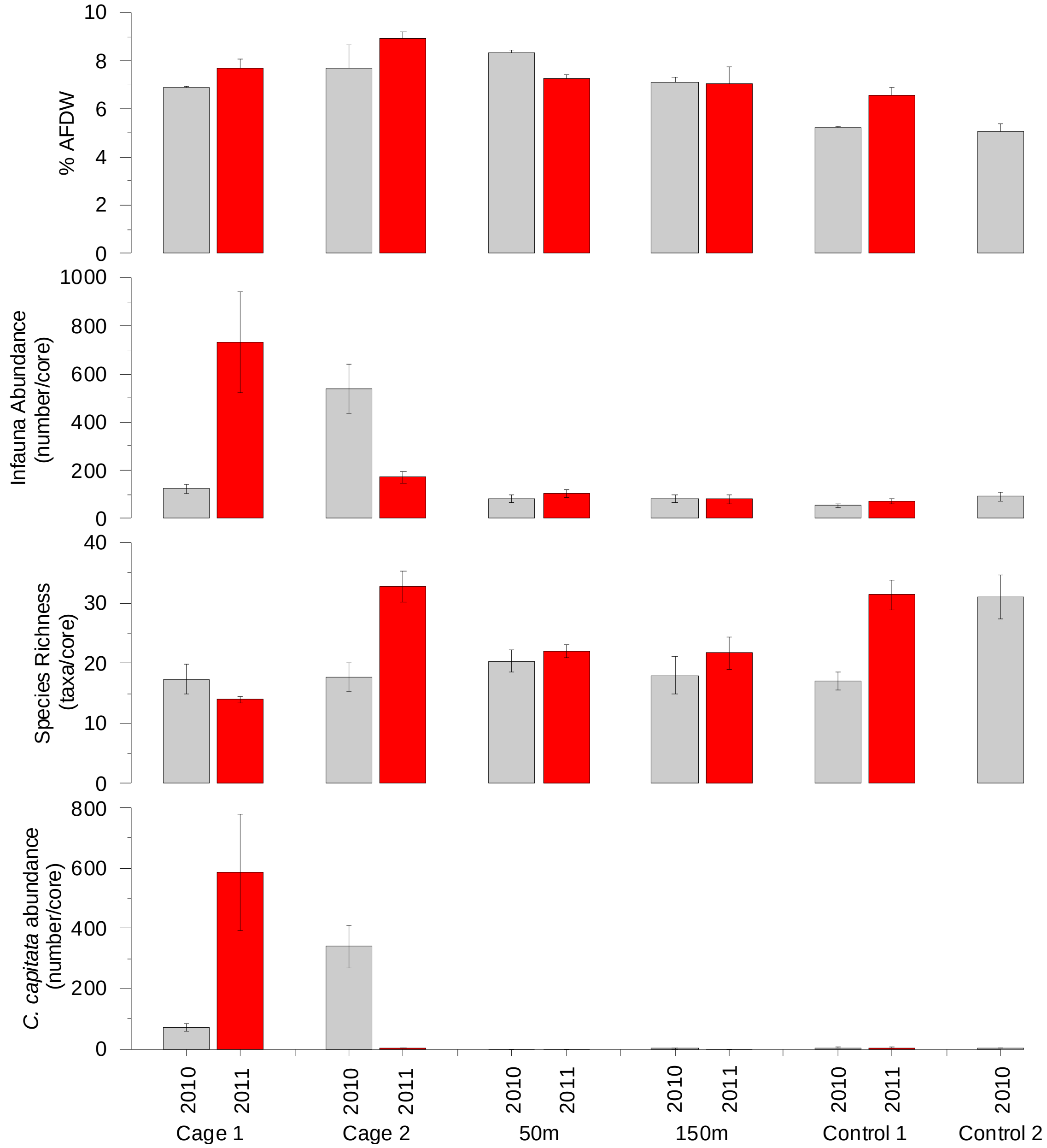

Figure 2.1. Comparison of mean AFDW, infauna abundance and richness (No. taxa), and C. capitata densities recorded at MFL-48 since 2010. High densities of capitellid polychaetes are typically 1,000 individuals m-2 (=13 per 0.013 m² core) or greater (ANZECC 2000 guidelines).

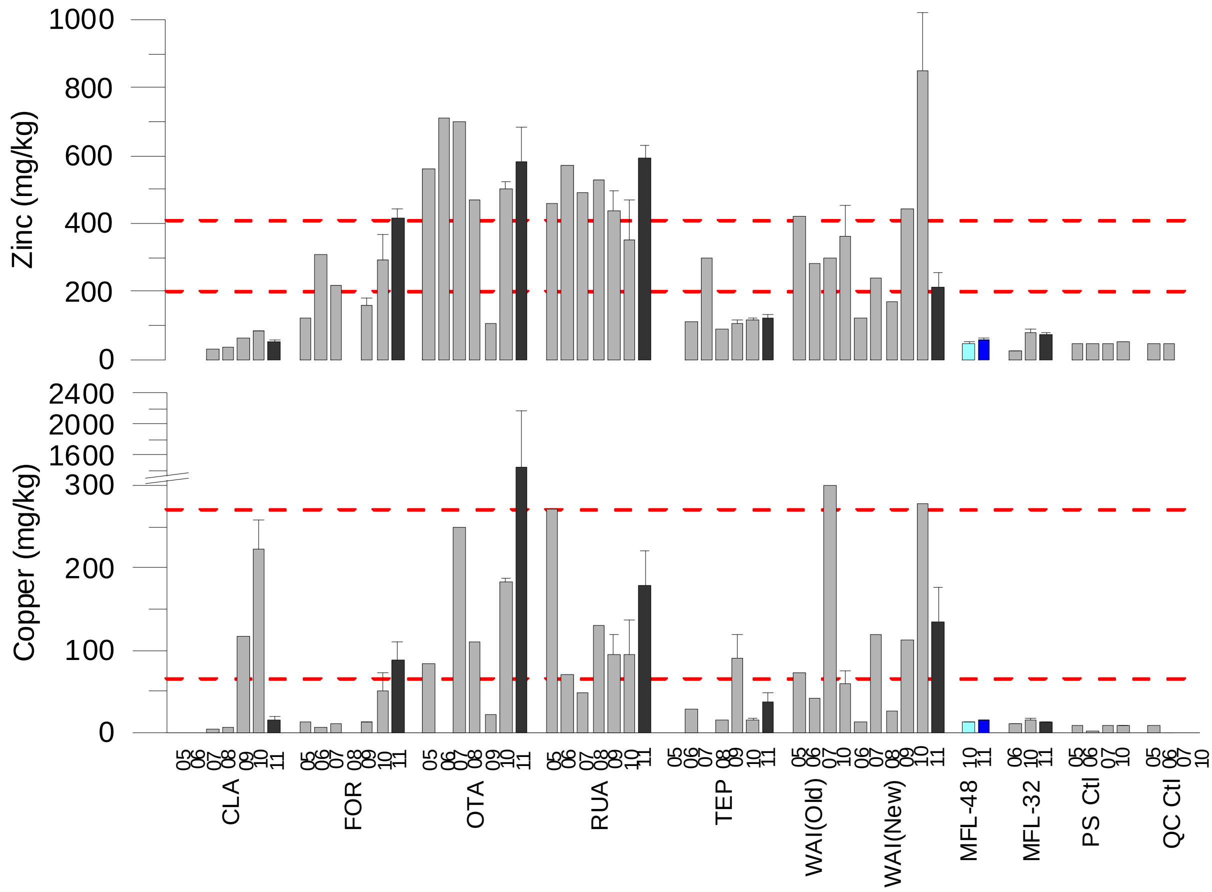

Figure 2.2. Comparison of the last seven years of annual monitoring data for sediment copper and zinc concentrations beneath all eight NZKS farms and two control stations (P.S. = Pelorus Sound, Q.C. = Queen Charlotte). Red dotted lines indicate respective ANZECC ISQG High and Low trigger levels. MFL-48 data are in blue. Note break in y-axis and change in scale in copper graph.

Appendix 3. Detailed ES calculations.

For details pertaining to how the figures in these tables were calculated, see Keeley 2012.

Flow environment:	**LF**
Farm	**MFL48**
Site	**Cage1**

Raw data (Input table)

Variable	Grab1	Grab2	Grab3	Grab4	Grab5		Ave	SD	n	SE
TOM	8.4	7.1	7.5				7.6667	0.67	3	0.39
Redox	-18	-99					-58.5	57.28	2	40.5
Sulphides	305.43	383.07	355.21				347.9	39.33	3	22.71
Abundance	1140	447	606				731	363.02	3	209.59
No. Taxa	14	13	15				14	1	3	0.58
P. evenness	0.1915	0.2796	0.2943				0.2551	0.06	3	0.03
Richness	1.847	1.966	2.185				1.9993	0.17	3	0.1
SWDI	0.5054	0.7172	0.80				0.6732	0.15	3	0.09
AMBI	5.7434	5.6284	5.51				5.6256	0.12	3	0.07
M-AMBI	0.2641	0.2865	0.3309				0.2938	0.03	3	0.02

ES equivalents (do not touch)

Variable	Repl 1	Repl 2	Repl 3	Repl 4	Repl 5		Ave	SD	n	SE
TOM	3.69	3.25	3.39				3.4433	0.22	3	0.13
Redox	4.29	5.02					4.655	0.52	2	0.37
Sulphides	2.31	2.52	2.45				2.4267	0.11	3	0.06
Abundance	4.41	3.61	3.87				3.9633	0.41	3	0.24
No. Taxa	3.15	3.34	2.97				3.1533	0.19	3	0.11
P. evenness										
Richness	4.07	3.94	3.7				3.9033	0.19	3	0.11
SWDI	5.35	4.98	4.85				5.06	0.26	3	0.15
AMBI	4.84	4.75	4.66				4.75	0.09	3	0.05
M-AMBI	5.24	5.12	4.88				5.08	0.18	3	0.1
	Grab1	**Grab2**	**Grab3**	**Grab4**	**Grab5**	Wt	Ave	SD	n	SE
Organic loading	**3.69**	**3.25**	**3.39**			0.2	**3.44**	0.22	3	0.13
Sediment chemistry	**3.3**	**3.77**	**2.45**			0.3	**3.17**	0.67	3	0.39
Infauna composition	**4.51**	**4.29**	**4.155**			0.5	**4.32**	0.18	3	0.1
Overall ES	4	3.9	3.5				**3.8**	0.26	3	0.15

Flow environment:	**LF**
	MFL48
Site	**Cage2**

Raw data (Input table)

Variable	Grab1	Grab2	Grab3	Grab4	Grab5		Ave	SD	n	SE
TOM	8.5	9.4	8.8				8.9	0.46	3	0.27
Redox	124	107					115.5	12.02	2	8.5
Sulphides	4.8029	84.624	91.26				60.229	48.12	3	27.78
Abundance	199	196	122				172.33	43.62	3	25.18
No. Taxa	37	33	28				32.667	4.51	3	2.6
P. evenness	0.795	0.8114	0.8253				0.8106	0.02	3	0.01
Richness	6.801	6.063	5.62				6.1613	0.6	3	0.35
SWDI	2.871	2.837	2.75				2.8193	0.06	3	0.03
AMBI	2.5873	2.5703	2.3771				2.5116	0.12	3	0.07
M-AMBI	1.0798	1.0248	0.9616				1.0221	0.06	3	0.03

ES equivalents (do not touch)

Variable	Repl 1	Repl 2	Repl 3	Repl 4	Repl 5		Ave	SD	n	SE
TOM	3.72	4.01	3.82				3.85	0.15	3	0.09
Redox	3.01	3.17					3.09	0.11	2	0.08
Sulphides	0.85	1.36	1.41				1.2067	0.31	3	0.18
Abundance	2.92	2.91	2.51				2.78	0.23	3	0.13
No. Taxa	2.43	2.04	1.87				2.1133	0.29	3	0.17
P. evenness										
Richness	1.46	1.46	1.53				1.4833	0.04	3	0.02
SWDI	1.28	1.34	1.49				1.37	0.11	3	0.06
AMBI	2.48	2.47	2.33				2.4267	0.08	3	0.05
M-AMBI	1	1	1.47				1.1567	0.27	3	0.16
	Grab1	**Grab2**	**Grab3**	**Grab4**	**Grab5**	Wt	Ave	SD	n	SE
Organic loading	**3.72**	**4.01**	**3.82**			0.2	**3.85**	0.15	3	0.09
Sediment chemistry	**1.93**	**2.265**	**1.41**			0.3	**1.87**	0.43	3	0.25
Infauna compositior	**1.9283**	**1.87**	**1.8667**			0.5	**1.89**	0.03	3	0.02
Overall ES	2.3	2.4	2.1				**2.27**	0.15	3	0.09

Flow environment	LF
	MFL48
	50m

Raw data (Input table)

Variable	Grab1	Grab2	Grab3	Grab4	Grab5		Ave	SD	n	SE
TOM	7.5	7.3	7				7.2667	0.25	3	0.14
Redox	173	139	131				147.67	22.3	3	12.87
Sulphides	84.624	34.2	31.713				50.179	29.86	3	17.24
Abundance	131	70	112				104.33	31.21	3	18.02
No. Taxa	23	20	23				22	1.73	3	1
P. evenness	0.7126	0.7861	0.7795				0.7594	0.04	3	0.02
Richness	4.513	4.472	4.662				4.549	0.1	3	0.06
SWDI	2.23	2.36	2.44				2.3443	0.11	3	0.06
AMBI	1.39	1.59	2.19				1.7265	0.42	3	0.24
M-AMBI	0.8945	0.8585	0.8691				0.874	0.02	3	0.01

ES equivalents (do not touch)

Variable	Repl 1	Repl 2	Repl 3	Repl 4	Repl 5		Ave	SD	n	SE
TOM	3.39	3.32	3.21				3.3067	0.09	3	0.05
Redox	2.57	2.88	2.95				2.8	0.2	3	0.12
Sulphides	1.36	0.96	0.94				1.0867	0.24	3	0.14
Abundance	2.57	2.03	2.43				2.3433	0.28	3	0.16
No. Taxa	2.02	2.28	2.02				2.1067	0.15	3	0.09
P. evenness										
Richness	1.91	1.93	1.84				1.8933	0.05	3	0.03
SWDI	2.38	2.17	2.02				2.19	0.18	3	0.1
AMBI	1.59	1.74	2.19				1.84	0.31	3	0.18
M-AMBI	1.83	2.03	1.97				1.9433	0.1	3	0.06
	Grab1	Grab2	Grab3	Grab4	Grab5	Wt	Ave	SD	n	SE
Organic loading	3.39	3.32	3.21			0.2	3.31	0.09	3	0.05
Sediment chemis	1.965	1.92	1.945			0.3	1.94	0.02	3	0.01
Infauna composit	2.05	2.03	2.0783			0.5	2.05	0.02	3	0.01
Overall ES	2.3	2.3	2.3				2.3	0	3	0

Flow environment	LF
	MFL48
	150m

Raw data (Input table)

Variable	Grab1	Grab2	Grab3	Grab4	Grab5		Ave	SD	n	SE
TOM	5.7	7.9	7.6				7.0667	1.19	3	0.69
Redox	130	126	167				141	22.61	3	13.05
Sulphides	25.285	1.3307	12.816				13.144	11.98	3	6.92
Abundance	57	66	119				80.667	33.5	3	19.34
No. Taxa	20	18	27				21.667	4.73	3	2.73
P. evenness	0.8342	0.7643	0.8049				0.8011	0.04	3	0.02
Richness	4.699	4.058	5.44				4.7323	0.69	3	0.4
SWDI	2	2	3				2.4537	0.23	3	0.13
AMBI	1	1	1				1.3152	0.15	3	0.09
M-AMBI	0.9013	0.8375	0.9949				0.9113	0.08	3	0.05

ES equivalents (do not touch)

Variable	Repl 1	Repl 2	Repl 3	Repl 4	Repl 5		Ave	SD	n	SE
TOM	1.5	3.52	3.42				2.8133	1.14	3	0.66
Redox	2.96	3	2.63				2.8633	0.2	3	0.12
Sulphides	0.88	1.34	0.78				1	0.3	3	0.17
Abundance	1.86	1.98	2.48				2.1067	0.33	3	0.19
No. Taxa	2.28	2.51	1.87				2.22	0.32	3	0.18
P. evenness										
Richness	1.82	2.15	1.57				1.8467	0.29	3	0.17
SWDI	1.92	2.42	1.66				2	0.39	3	0.23
AMBI	1.47	1.47	1.66				1.5333	0.11	3	0.06
M-AMBI	1.8	2.14	1.29				1.7433	0.43	3	0.25
	Grab1	Grab2	Grab3	Grab4	Grab5	Wt	Ave	SD	n	SE
Organic loading	1.5	3.52	3.42			0.2	2.81	1.14	3	0.66
Sediment chemis	1.92	2.17	1.705			0.3	1.93	0.23	3	0.13
Infauna composit	1.8583	2.1117	1.755			0.5	1.91	0.18	3	0.1
Overall ES	1.8	2.4	2.1				2.1	0.3	3	0.17

Flow environmen	LF
	MFL48
	Control 1

Raw data (Input table)

Variable	Grab1	Grab2	Grab3	Grab4	Grab5		Ave	SD	n	SE
TOM	6.3	6.2	7.2				6.5667	0.55	3	0.32
Redox	246	262	268				258.67	11.37	3	6.56
Sulphides	0.294	13.821	0.9838				5.0331	7.62	3	4.4
Abundance	96	66	59				73.667	19.66	3	11.35
No. Taxa	36	30	28				31.333	4.16	3	2.4
P. evenness	0.8951	0.9253	0.9165				0.9123	0.02	3	0.01
Richness	7.668	6.922	6.622				7.0707	0.54	3	0.31
SWDI	3.21	3.15	3.05				3.1363	0.08	3	0.05
AMBI	2.21	2.13	1.72				2.018	0.26	3	0.15
M-AMBI	1.1362	1.0561	1.0447				1.079	0.05	3	0.03

ES equivalents (do not touch)

Variable	Repl 1	Repl 2	Repl 3	Repl 4	Repl 5		Ave	SD	n	SE
TOM	1.5	1.5	3.28				2.0933	1.03	3	0.59
Redox	1.92	1.77	1.72				1.8033	0.1	3	0.06
Sulphides	2.47	0.78	1.51				1.5867	0.85	3	0.49
Abundance	2.3	1.98	1.89				2.0567	0.22	3	0.13
No. Taxa	2.31	1.9	1.87				2.0267	0.25	3	0.14
P. evenness										
Richness	1.64	1.48	1.45				1.5233	0.1	3	0.06
SWDI	0.71	0.81	0.97				0.83	0.13	3	0.08
AMBI	2.2	2.14	1.84				2.06	0.19	3	0.11
M-AMBI	1	1	1				1	0	3	0
	Grab1	**Grab2**	**Grab3**	**Grab4**	**Grab5**	**Wt**	**Ave**	**SD**	**n**	**SE**
Organic loading	1.5	1.5	3.28			0.2	2.09	1.03	3	0.59
Sediment chemis	2.195	1.275	1.615			0.3	1.7	0.47	3	0.27
Infauna composit	1.6933	1.5517	1.5033			0.5	1.58	0.1	3	0.06
Overall ES	1.8	1.5	1.9				1.73	0.21	3	0.12