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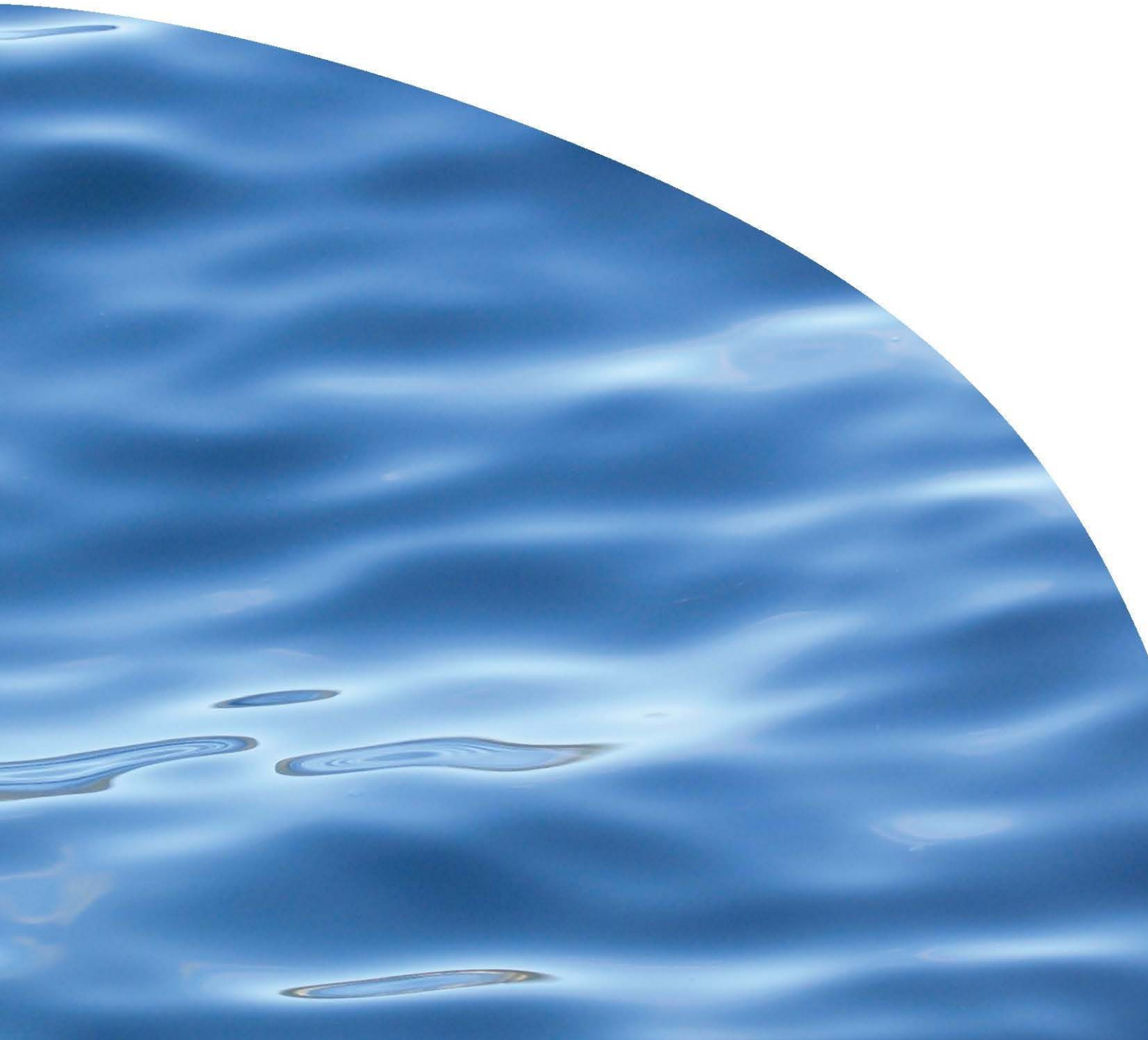

ENVIRONMENTAL IMPACTS OF THE MFL-48 SALMON FARM: ANNUAL MONITORING REPORT 2012

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Prepared for New Zealand King Salmon Company Limited.

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ISSUE DATE: 8 March 2013

RECOMMENDED CITATION: Dunmore R, Keeley N. 2012. Environmental Impacts of the MFL-48 Salmon Farm: Annual Monitoring Report 2012. Prepared for New Zealand King Salmon Company Limited. Cawthron Report No. 2280. 12 p. plus appendices.

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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).

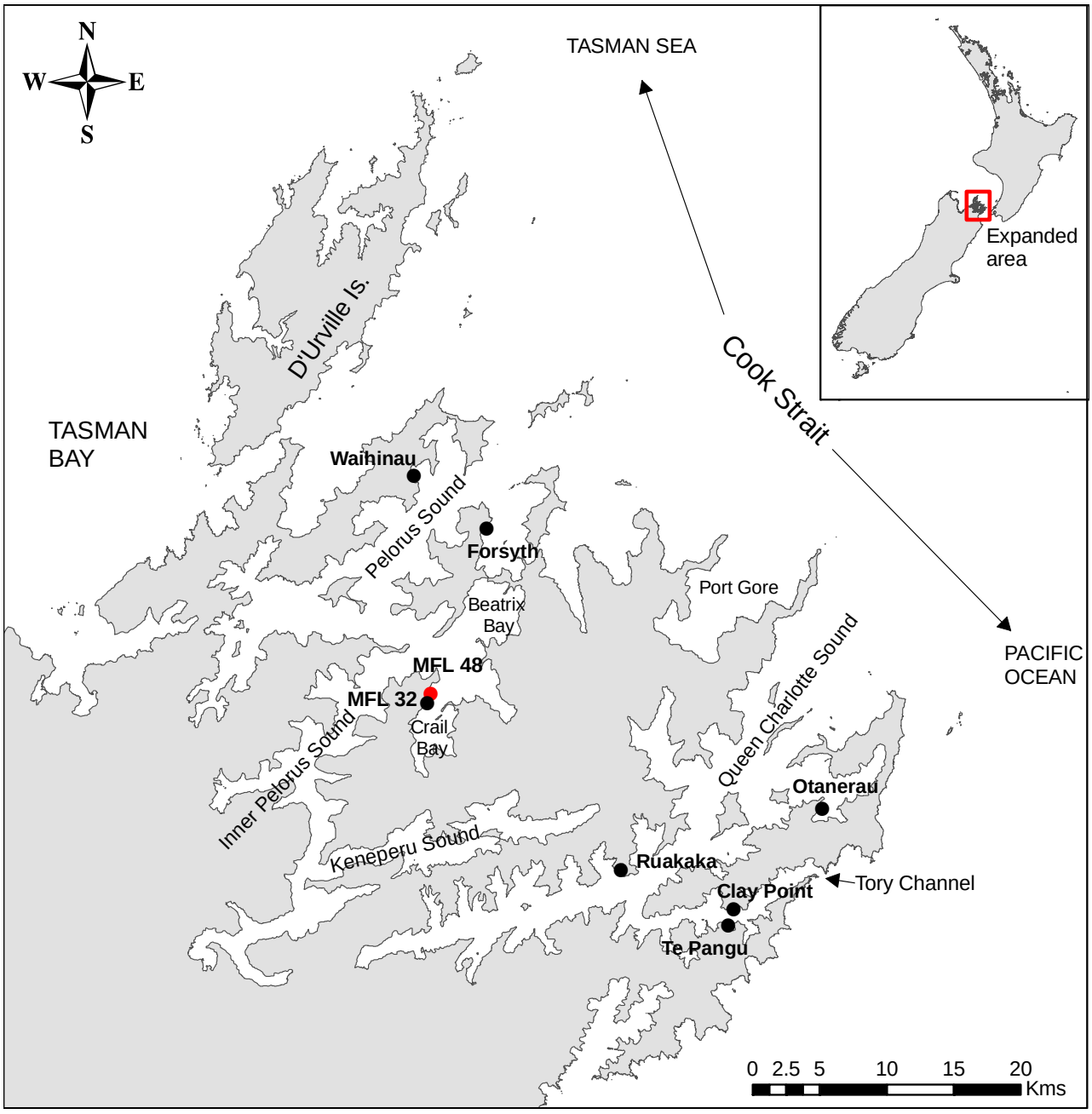

Figure 1. Map of Marlborough Sounds area showing the location of the Marine Farm Licence 48 (MFL-48) salmon farm (red dot) along with NZKS's seven other farm sites (black dots).

NZKS is required to undertake environmental monitoring and reporting in accordance with its marine farm consents. The monitoring programme is conducted under an environmental monitoring plan (EMP) 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). Details of the methods that were used to assess benthic enrichment stage in relation to the relevant consent conditions can be found in Keeley 2012.

Consent conditions for all of the farms (with the exception of Waihinau) broadly require monitoring of the effects of deposition on the seabed, with particular regard to the benthic community composition and abundance, dissolved oxygen (DO) and water quality. The environmental monitoring results are used to determine whether the farms are compliant with the Environmental Quality Standards (EQS) specified in the consent conditions for each farm. These are based on a 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 2012 annual monitoring results for the MFL-48 salmon farm.

1.1. Site details and history of feed usage

The MFL-48 farm site was established as a salmon farm in 2010. It is situated at a depth of ~ 32 m, and with average water current speeds of ~ 2.5-3.0 cm/s, it is considered a low- flow site. It is located approximately 430 m from MFL-32. The MFL-48 and MFL-32 sites are relatively unique in that finfish net pen culture has been conducted alongside long line mussel culture, within the same lease. Historical feed inputs at MFL-48 farm were ~ 15 tonnes in 2010, and ~ 287 tonnes from December 2010 to the end of November 2011[1]. NZKS purchased the site in 2011 and has since destocked the site (December 2011). It currently lies fallow.

[1] Feed input data provided by NZKS.

2. METHODS

Sampling at MFL-48 was undertaken on 9 November 2012. Detailed methods and rationale describing the sampling protocol for all of NZKS's farms can be found in the most recent Environmental Monitoring Plan (EMP, Keeley 2011). 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 techniques that were used in the present survey is provided below.

2.1. Soft sediment habitat

2.1.1. Sampling locations

The MFL-48 salmon farm was monitored at two pen stations (at the edge of Zone 1), two stations along a transect aligned perpendicular to the shore (away from the pens) 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 one comparable reference or 'control' (*i.e.* 'Ctl 1') station (Figure 2). 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 pens. 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.

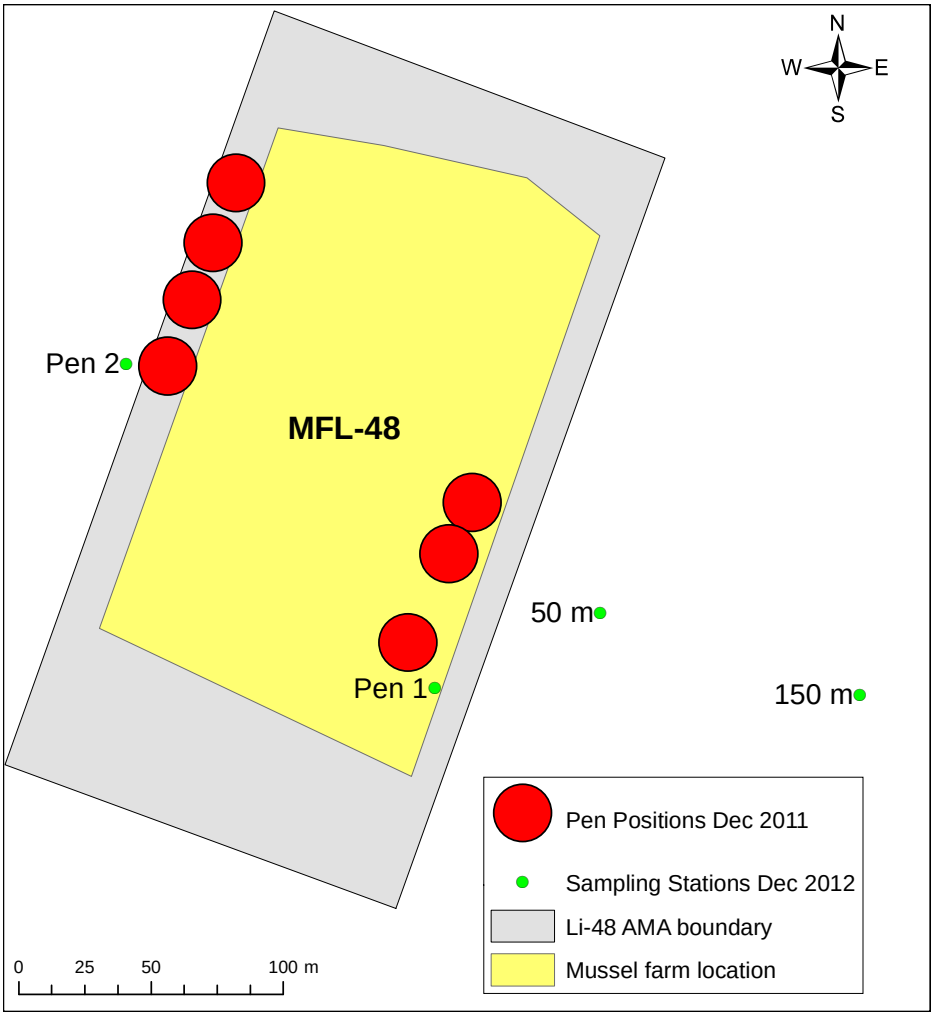

Figure 2. Soft sediment sampling locations for Marine Farm Licence 48 (MFL-48) in 2012. 'Ctl 1' was located within Crail Bay, approximately 1 km northeast of MFL-48. Station depths are shown in Appendix 1. Pen positions were last surveyed in 2011. Position accuracy +/- 5 m.

2.1.2. Environmental variables

Three replicate sediment (modified van Veen) grab samples were collected at each sampling station[2]. Each grab sample was examined for sediment odour, texture and 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). Unlike for the other NZKS farms, no copper and zinc analyses were conducted at MFL-48 because previous results have shown concentrations have been well below ANZECC (2000) ISQG-Low trigger levels, and the site has been destocked and no antifoul used since the previous survey. Observations of sediment out-gassing visible at the surface were also made. Three to four drop-camera images were taken at each station to obtain a visual record of benthic conditions and epifauna.

[2] Only two replicates were collected at the Pen 2 station due to the difficulty in obtaining samples at this station, which had a large amount of shell material within the sediments.

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. 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.

2.1.3. Assessment of enrichment stage (ES)

Seabed condition can be placed along an enrichment gradient which has been quantitatively defined by enrichment stage (ES). Each environmental result (raw data) was converted into an equivalent ES score using the appropriate linear model (Keeley 2012). 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 total organic matter (TOM). The 'overall ES' for a given sample was then calculated by determining the weighted average of those three groups of variables. Finally, the overall ES for the sampling station was calculated from the average of the replicate samples with the degree of certainty reflected in the associated standard error.

2.2. 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 2012 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

3.1.1. Physico-chemical characteristics

The average sediment organic content at the pen stations was 6.7% AFDW (range 5.2–7.9%). This level would be considered moderate for the region and was similar to that at the control station (average 6.5%, range 6.4–6.6%) Figure 3. Redox potentials were positive but lower at all stations in comparison to the control. Total free sulphides were variable at the pen stations, with three of the five replicates elevated compared to the down-current and control stations, which were at the lower limit of detection for the analysis.

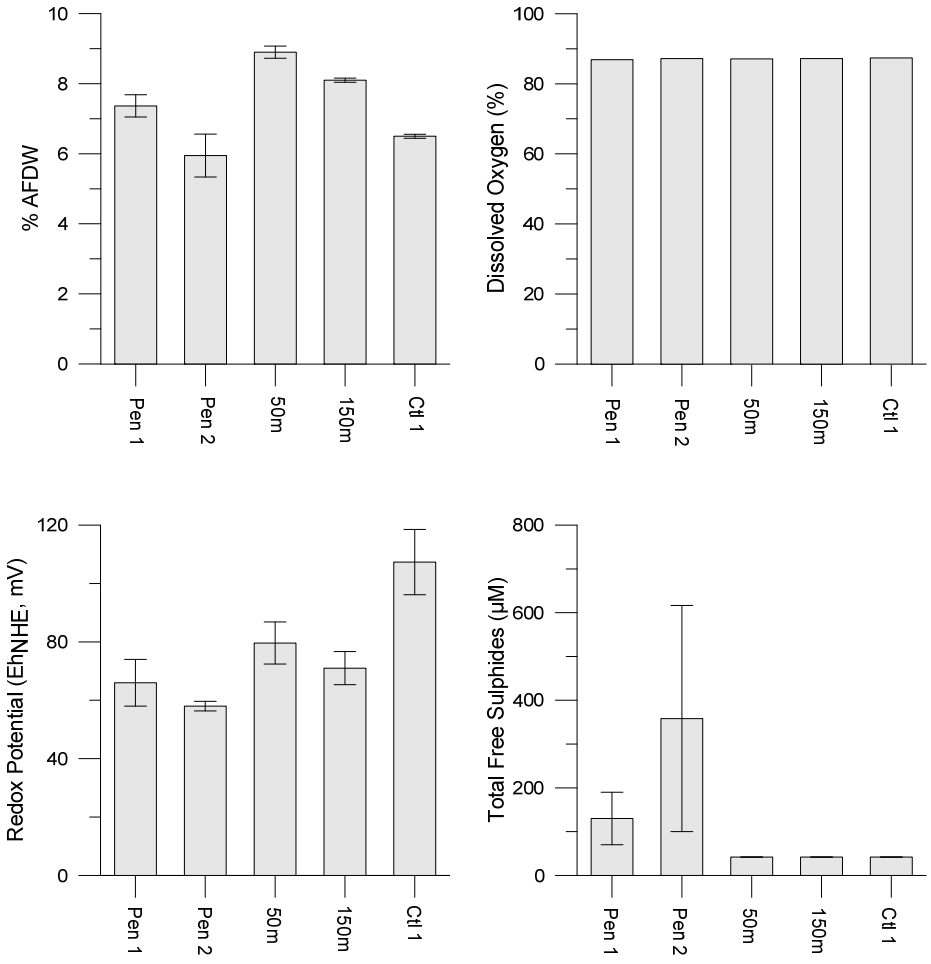

Figure 3. Organic matter (as %AFDW), redox potential (Eh_{NHE}, mV), total free sulphide concentrations (µM) and near-bottom dissolved oxygen (%). Error bars = standard error (SE), n=2 at Pen 2, n=3 for all other stations.

3.1.2. Biological communities

The infauna communities at the Pen 1 sampling station showed signs of mild enrichment, with elevated abundances and numbers of taxa in comparison with all other stations (Figure 4). In contrast to 2011 when the infauna community was dominated by enrichment-tolerant taxa, no *Capitella capitata* or nematodes were present (Appendix 2). The Pen 2 station had slightly elevated abundances, but numbers of taxa were similar to the down-current and control stations. Diversity, evenness and EQR values for both pen stations were variable, but generally lower than the down-current and control stations. The infaunal community properties of the 50 m and 150 m stations were similar to each other, and were comparable to the control.

Drop-camera images revealed very fine sediments under the pens, amongst extensive beds of mussel shells. A cushion star (*Patiriella* sp.) was present in an image from Pen 2. The 50 m station had fewer mussel shells, and no epibiota were captured in the images. The 150 m station images also had no epifauna, but revealed a fine brown diatom layer covering the sediments. The control images contained fan shells (*Chlamys zelandiae*) present, but no other epibiota.

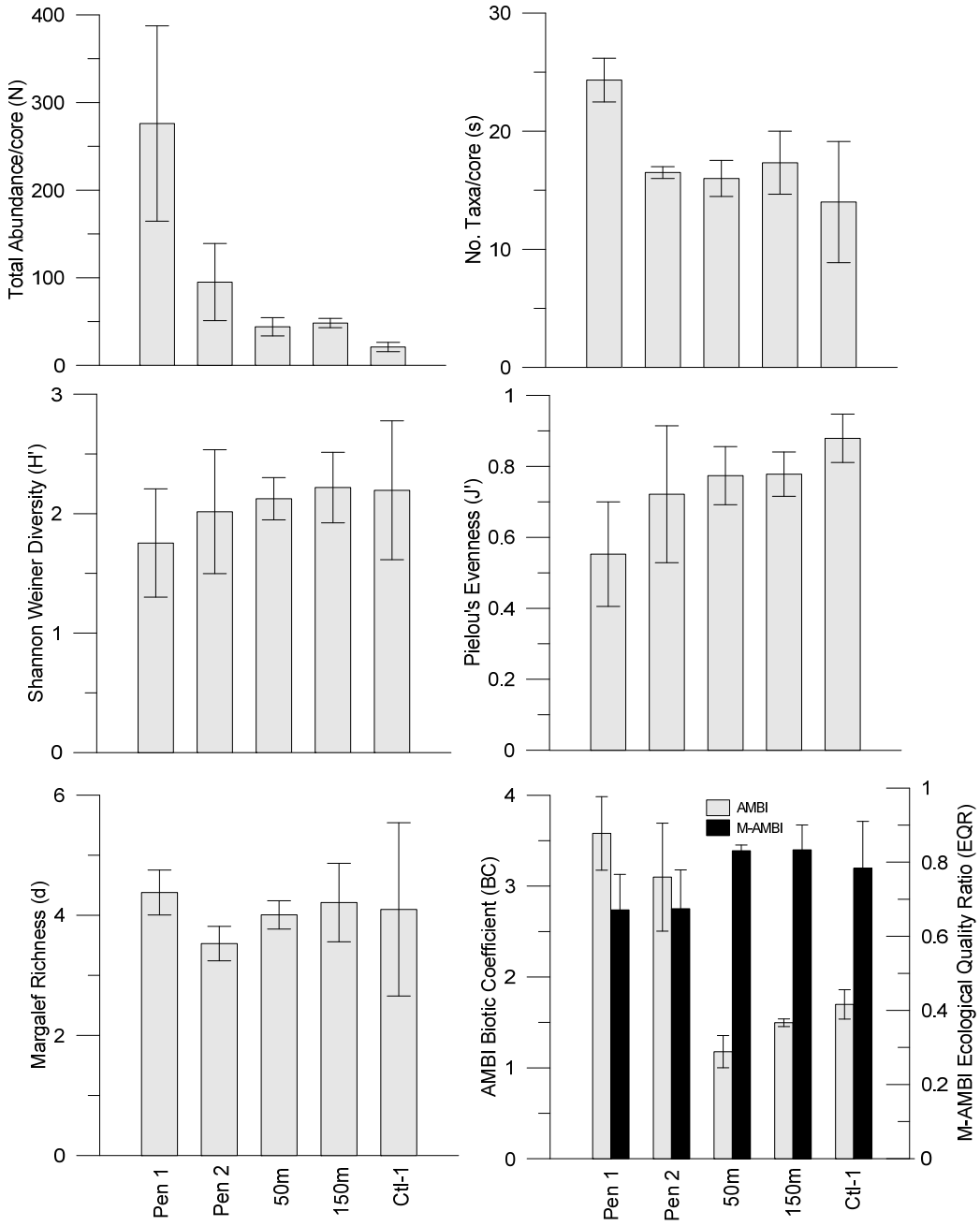

Figure 4. Infauna statistics. Error bars = standard error (SE), n=2 at Pen 2, n=3 for all other stations.

3.2. Water column

Near-bottom (water column) dissolved oxygen (DO) levels were similar across all stations (Figure 3). Water column nutrient levels were not analysed at MFL-48 during the 2012 annual monitoring, but results from the RUA survey (Dunmore *et al.* 2013) showed that chl-*a* and DRP were higher at the 50 m station. NH_4-N, NO_3-N and NO_2-N levels were similar across all stations.

4. SUMMARY OF FINDINGS

4.1. Seabed habitats

Seabed EQS are specified in the consent conditions. These are qualitatively defined. The EQS can be related to a stage along the enrichment gradient which has been interpreted quantitatively in terms of ES (refer Section 2.1.3). An initial interpretation of the qualitative EQS was provided in Keeley (2012). The methods and rationale for quantifying ES, and interpretation in relation to the qualitative EQS, are subject to ongoing refinement.

The current consent conditions and equivalent ES scores for MFL-48 are provided in Table 1.

Table 1. Environmental Quality Standards (EQS) for MFL-48 described for each zone (taken from consent U090660) and the equivalent enrichment stage (ES).

Spatial zone	Spatial extent (Condition 19)*	Requirement (Condition 22)	Interpretation
2	Beneath the cages and out to 50 m from the cages	Zone 2 shall not be more than the transition between stages IV and V	Less than ES 5.0**
3	From 50 to 200 m from the outside edge of the cages	Zone 3 shall not be more than the transition between stages III and IV	Less than ES 4.0**
4	Beyond 200 m from the outside edge of the pens	Zone 4 shall not be more than the transition between stages I and II	2.5 or less And No more than 0.5 greater than the highest ES score for a relevant reference site***

* In addition: Conditions 20 and 21 specify that the Zones can be distorted to allow for the effects of currents, and Condition 22 notes that the zones may be further refined subject to environmental monitoring and reports (Conditions 23–26).
** Based on further evaluation in Keeley 2012a and accepted in the conditions from the Board of Inquiry for new high-flow salmon farm sites.
*** Refer to Keeley (2012) for further details relating to ES scores.

The 2012 assessment of soft-sediment conditions are summarised below and in Table 2.

- Overall, Pen 1 (where the pens had been stocked prior to fallowing in December 2011) was mildly enriched with an ES of 2.7. Pen 2 was also mildly enriched (overall ES = 2.7). Both sites were within the specified maximum equivalent maximum ES for that zone.

- The 50 m station (Zone 2–3 boundary) was assigned an ES score of 2.4, which was less impacted than the equivalent maximum ES for that zone.
- The 150 m station (Zone 3–4 boundary) was assigned an ES value of 2.3, which was the same as at the control station (ES 2.3), and this station was therefore less impacted than the equivalent maximum ES for that zone.

Table 2. Seabed effects score. Refer to Appendix 3 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
Pen 1	Organic loading:	3.34 (0.11)	Moderate organic matter content which was slightly elevated compared to controls. Redox potential positive, but lower than control value. Sulphides variable, but elevated on average. Infauna community with higher abundances and numbers of taxa than control.
	Sediment chemistry:	2.54 (0.19)	
	Infauna composition:	2.71 (0.36)	
	Overall:	**2.74 (0.26)**	
Pen 2	Organic loading:	2.82 (0.28)	Sediments with moderate levels of organic matter, but less than control levels. Redox potentials positive, but lower than control. Sulphides variable, but elevated on average. Infauna community with elevated abundances, but similar numbers of taxa to the control.
	Sediment chemistry:	2.85 (0.53)	
	Infauna composition:	2.70 (0.45)	
	Overall:	**2.74 (0.39)**	
50 m (Zone 2–3 Boundary)	Organic loading:	3.85 (0.05)	Slightly elevated organic matter and reduced redox potentials. Sulphides at analytical detection limit. Infauna community characteristics comparable to control.
	Sediment chemistry:	2.23 (0.03)	
	Infauna composition:	2.21 (0.08)	
	Overall:	**2.38 (0.06)**	
150 m (Zone 3–4 Boundary)	Organic loading:	3.59 (0.02)	Slightly elevated organic matter and reduced redox potentials. Sulphides at analytical detection limit. Infauna community characteristics comparable to control.
	Sediment chemistry:	2.27 (0.02)	
	Infauna composition:	2.14 (0.24)	
	Overall:	**2.31 (0.17)**	
Control 1	Organic loading:	3.03 (0.02)	Moderate levels of organic matter and sulphide levels at analytical detection limit. Two replicates with diverse infauna communities, but one replicate with low abundance and number of taxa.
	Sediment chemistry:	2.10 (0.05)	
	Infauna composition:	2.24 (0.55)	
	Overall:	**2.29 (0.38)**	

4.2. Water column

Dissolved oxygen (DO) levels in the water collected from 1 m above the seabed were not reduced with proximity to the farm. Monitoring of chl-*a* at the low-flow Ruakaka farm showed that concentrations were lower at the pen stations than at the 50 m and control, but were within levels observed naturally in the Marlborough Sounds. Chlorophyll-*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. There was no evidence of localised enrichment at the farm, with similar, low levels of nutrients across the stations.

5. CONCLUSION AND RECOMMENDATIONS

In November 2012, the seabed conditions at the MFL-48 salmon farm were assessed to be less impacted than the equivalent ES limits for the relevant EQS specified in the consent conditions, and no management response is required. There was no evidence of farm-related effects on near-bottom DO levels.

The results are consistent with the farm undergoing recovery since being destocked one year prior to monitoring. The benthic environment still shows minor signs of enrichment, but some of this could be attributed to the presence of the mussel farm.

6. REFERENCES

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Gibbs MM, Pickmere SE, Woods PH, Payne GW, James MR, Hickman RW, Illingworth J. 1992. Nutrient and chlorophyll-*a* variability at six stations associated with mussel farming in Pelorus Sound, 1984-85. New Zealand Journal of Marine and Freshwater Research 26: 197-211.

Keeley N. 2011 NZKS Annual Monitoring Plan (revised Oct 2010). Prepared for New Zealand King Salmon Company Limited. Cawthron Report No. 1872. 28 p. plus appendices.

Keeley N. 2012 Assessment of Enrichment Stage and Compliance for Salmon Farms. Prepared for New Zealand King Salmon Company Limited. Report No. 2080 15 p.

Keeley N. 2012a Statement of evidence in relation to benthic effects of Nigel Brian Keeley for the New Zealand King Salmon Company Limited: June 2012.

7. APPENDICES

Appendix 1. Summary of 2012 results.

Table A1.1. Summary of infauna and the physical and chemical properties of sediments from the Marine Farm Licence 48 (MFL-48) farm site during the 2012 monitoring survey. Bracketed values = standard error (SE). n.a = not assessed.

	Station	Units	Pen 1	Pen 2	50 m	150 m	Control 1
	Depth	m	32.3	31.9	32.2	32.4	30.3
Sediments	AFDW	%	7.37	5.95	8.9	8.1	6.5
Sediments	Redox	Eh_{NHE}, mV	66	58	79.6	71	107.3
Sediments	Sulphides	µM	130.14	358.25	42	42	42
Sediments	Bacterial mat	-	absent	absent	absent	absent	absent
Sediments	Out-gassing	-	none	none	none	none	none
Sediments	Odour	-	n.a.	n.a.	n.a.	n.a.	n.a.
Infauna	Abundance	No./core	276(111)	95(44)	44(10)	48(5)	21(5)
Infauna	No. taxa	No./core	24.3(1.86)	16.5(0.5)	16(1.53)	17.3(2.67)	14(5.13)
Infauna	Richness	Stat.	4.38(0.37)	3.53(0.29)	4.01(0.24)	4.21(0.65)	4.1(1.44)
Infauna	Evenness	Stat.	0.55(0.15)	0.72(0.19)	0.77(0.08)	0.78(0.06)	0.88(0.07)
Infauna	Shannon-Weiner	Index	1.75(0.45)	2.02(0.52)	2.13(0.18)	2.22(0.3)	2.2(0.58)
Infauna	AMBI	Index	3.58(0.41)	3.1(0.59)	1.18(0.18)	1.5(0.04)	1.7(0.16)
Infauna	M-AMBI	Index	0.67(0.1)	0.67(0.1)	0.83(0.02)	0.83(0.07)	0.78(0.13)
	Near bottom DO	%	86.9	87.2	87.1	87.2	87.4

Appendix 2. Historical comparisons.

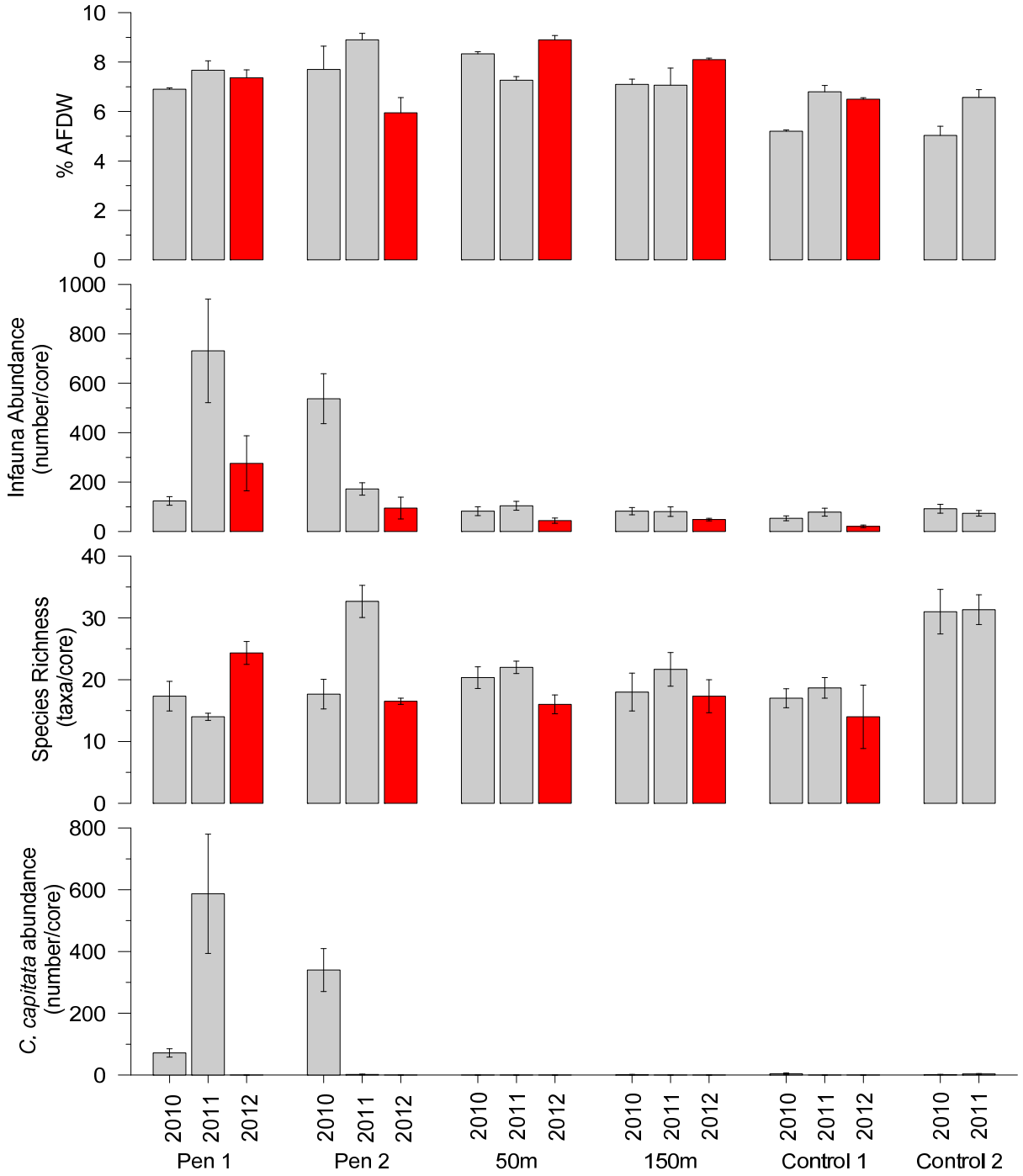

Figure A2.1. Comparison of mean ash-free dry weight (AFDW), infauna abundance and richness (No. taxa), and *C. capitata* densities recorded at Marine Farm Licence 48 (MFL-48) since 2010. High densities of capitellid polychaetes are typically 1,000 individuals per m^2 (=13 per 0.013 m^2 core) or greater (ANZECC 2000 guidelines).

Appendix 3. Drop camera images.

Pen 1

Pen 2

50 m

150 m

Control

Figure A3.1. Representative drop-camera images from Marine Farm Licence 48 (MFL-48) stations.

Appendix 4. Detailed enrichment stage (ES) calculations.

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

SITE INFORMATION															
Flow environment:	LF														
Farm/site:	MFL48														
Station:		Pen 1	Pen 1	Pen 1	Pen 2	Pen 2	50m	50m	50m	150m	150m	150m	Ctl 1	Ctl 1	Ctl 1
	TOM	7.9	7.4	6.8	6.7	5.2	8.9	9.2	8.6	8	8.2	8.1	6.6	6.5	6.4
	Redox	50	73	75	60	56	72	94	73	82	68	63	85	119	118
	Sulphides	244.6816	42	103.7473	42	674.4906	42	42	42	42	42	42	42	42	42
	Abundance	466	282	80	51	139	29	64	39	59	43	43	29	23	11
	No. Taxa	28	22	23	16	17	13	18	17	20	20	12	21	17	4
	P. evenness	0.417674	0.393331	0.847015	0.914214	0.52867	0.883794	0.613859	0.823769	0.802163	0.872007	0.659883	0.920337	0.971018	0.745557
	Richness	4.394398	3.722146	5.020508	3.815022	3.242494	3.56369	4.087636	4.367335	4.659675	5.051579	2.924598	5.939484	5.102864	1.251097
	SWDI	1.391776	1.215804	2.65581	2.53474	1.497836	2.266886	1.774282	2.333914	2.403066	2.6123	1.639748	2.801987	2.751102	1.033562
	AMBI	3.9459	4.0235	2.7708	2.37	3.8272	1.38	0.825	1.3286	1.4483	1.5789	1.4625	2.0192	1.575	1.5
	M-AMBI	0.6233	5.35E-01	0.85545	0.80261	0.54627	0.80916	0.82328	0.86016	0.88933	0.91092	0.69945	0.91552	0.90428	0.53142
	BQI	4.88077	4.280712	6.55888	5.513373	3.895071	4.672533	4.340743	5.322405	5.731216	6.079408	5.777407	8.161803	7.256212	5.100138
	ES equivalents														
	TOM	3.52	3.35	3.14	3.1	2.54	3.85	3.94	3.75	3.56	3.62	3.59	3.07	3.03	2.99
	Redox	3.68	3.47	3.45	3.59	3.63	3.48	3.28	3.47	3.39	3.52	3.56	3.36	3.06	3.07
	Sulphides	2.11	1.04	1.49	1.04	3.11	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
	Abundance	3.65	3.22	2.15	1.76	2.62	1.28	1.96	1.53	1.89	1.62	1.62	1.28	1.08	0.45
	No. Taxa	1.87	2.09	2.02	2.8	2.65	3.34	2.51	2.65	2.28	2.28	3.55	2.18	2.65	5.67
	P. evenness														
	Richness	1.96	2.36	1.69	2.3	2.72	2.47	2.13	1.98	1.84	1.68	2.98	1.48	1.67	4.8
	SWDI	3.82	4.13	1.65	1.86	3.64	2.32	3.17	2.21	2.09	1.73	3.4	1.4	1.49	4.44
	AMBI	3.5	3.55	2.62	2.32	3.41	1.58	1.17	1.54	1.63	1.73	1.64	2.06	1.73	1.67
	M-AMBI	3.3	3.77	2.05	2.33	3.71	2.3	2.22	2.02	1.86	1.75	2.89	1.72	1.78	3.79
	BQI	2.63	3.01	1.85	2.29	3.28	2.76	2.97	2.39	2.18	2.03	2.16	1.48	1.64	2.51
Wt		**Pen 1**	**Pen 1**	**Pen 1**	**Pen 2**	**Pen 2**	**50m**	**50m**	**50m**	**150m**	**150m**	**150m**	**Ctl 1**	**Ctl 1**	**Ctl 1**
0.1	**Organic loading**	**3.52**	**3.35**	**3.14**	**3.1**	**2.54**	**3.85**	**3.94**	**3.75**	**3.56**	**3.62**	**3.59**	**3.07**	**3.03**	**2.99**
0.2	**Sediment chemistry**	**2.9**	**2.26**	**2.47**	**2.32**	**3.37**	**2.26**	**2.16**	**2.26**	**2.22**	**2.28**	**2.3**	**2.2**	**2.05**	**2.06**
0.7	**Infauna composition**	**2.96**	**3.16**	**2**	**2.24**	**3.15**	**2.29**	**2.3**	**2.05**	**1.97**	**1.83**	**2.61**	**1.66**	**1.72**	**3.33**
	Overall ES	**3**	**3**	**2.21**	**2.34**	**3.13**	**2.44**	**2.44**	**2.26**	**2.18**	**2.1**	**2.65**	**1.91**	**1.92**	**3.04**