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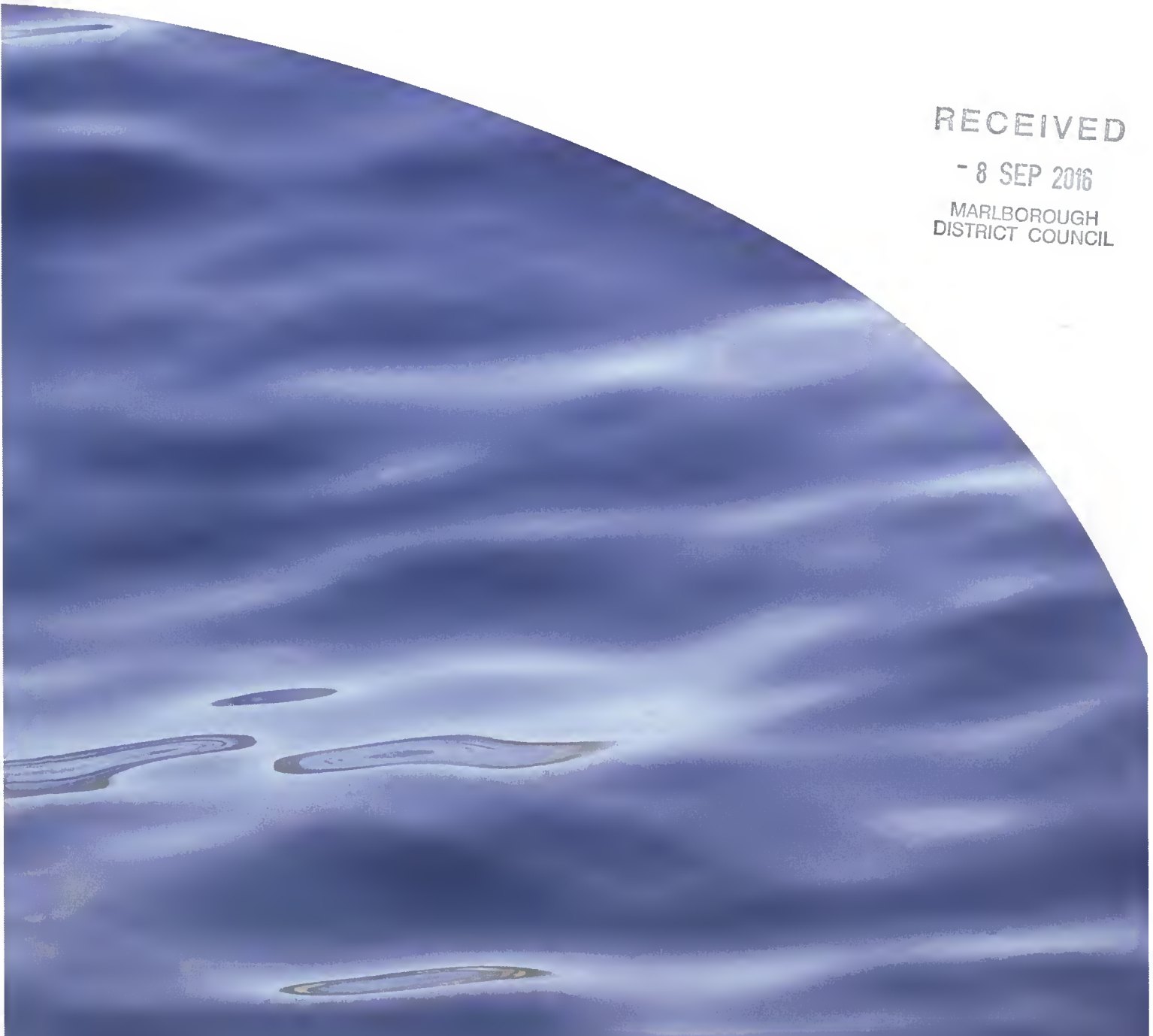
REPORT NO. 2909

**AREA EXTENSION AND IMPLEMENTATION OF
THE BMP-BENTHIC GUIDELINES AT THE CLAY
POINT SALMON FARM: BENTHIC EFFECTS
ASSESSMENT**

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AREA EXTENSION AND IMPLEMENTATION OF THE BMP-BENTHIC GUIDELINES AT THE CLAY POINT SALMON FARM: BENTHIC EFFECTS ASSESSMENT

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1. INTRODUCTION

The New Zealand King Salmon Company Ltd (NZKS) currently operates the Clay Point salmon farm along Tory Channel, Marlborough Sounds (Figure 1). In March 2016, NZKS contracted Cawthron Institute to provide an assessment of likely seabed effects associated with the implementation of the Best Management Practice – Benthic Guidelines (BMP-Benthic, MPI 2015) at the Clay Point salmon farm in Tory Channel. The assessment also considers the benthic effects of extending the area in which the net pens and moorings can be located by adding an additional 30 m to the outer (southern) edge of both the net pen area boundary and the farm boundary.

This report provides the following:

1. a description of the existing seabed within the Clay Point embayment
2. a description of the seabed beneath the proposed extension to the net pen area
3. a summary of the existing environmental quality standards for the site and the history of seabed enrichment at the site from 2011 to 2015
4. an assessment of effects on the seabed environment in relation to implementing the BMP - Benthic guidelines at the Clay Point farm
5. an assessment of effects on the seabed environment in relation to extending the net pen area at the Clay Point farm by 30 m to the south and installing moorings closer toward Tory Channel.

Our assessment draws on existing annual monitoring reports (2009 to 2016) and environmental data (seabed video imagery and water current data) collected from the embayment during field surveys conducted on 18 March and 22 April 2016.

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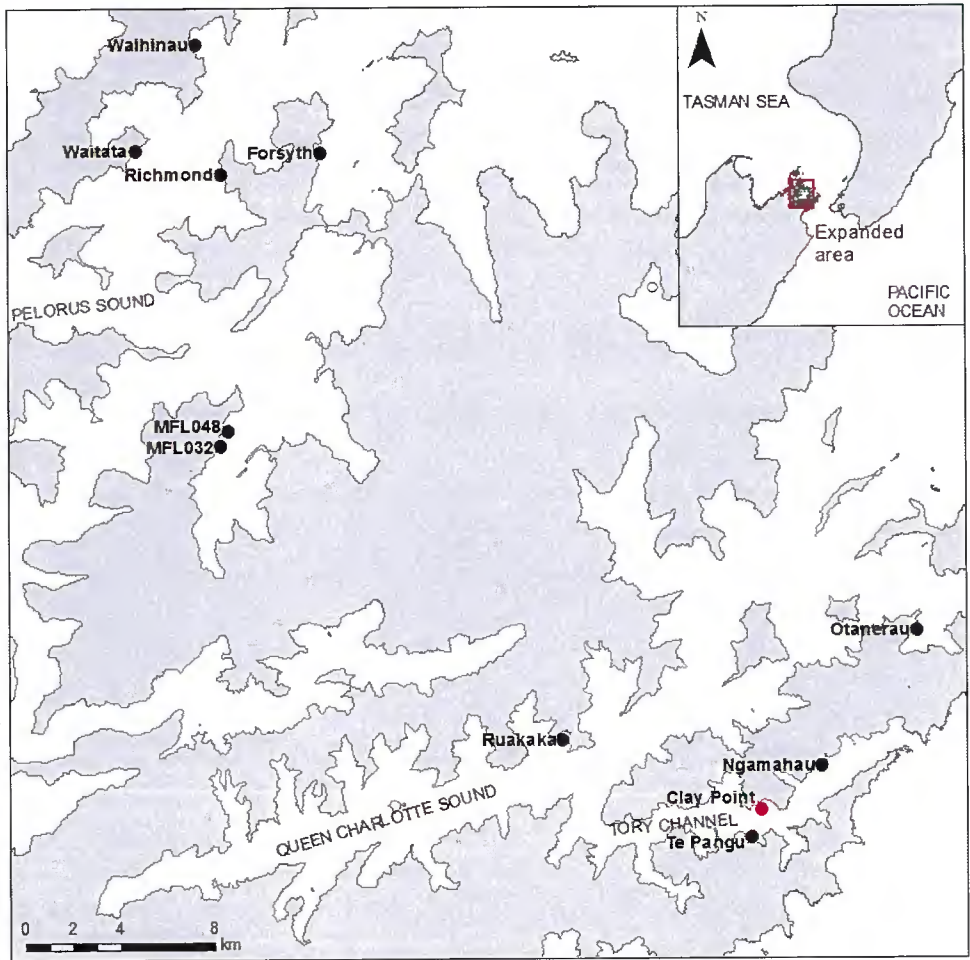


Figure 1. Map of the Marlborough Sounds area showing the location of the Clay Point salmon farm (red dot) along with NZ King Salmon's ten other existing farm sites (black dots).

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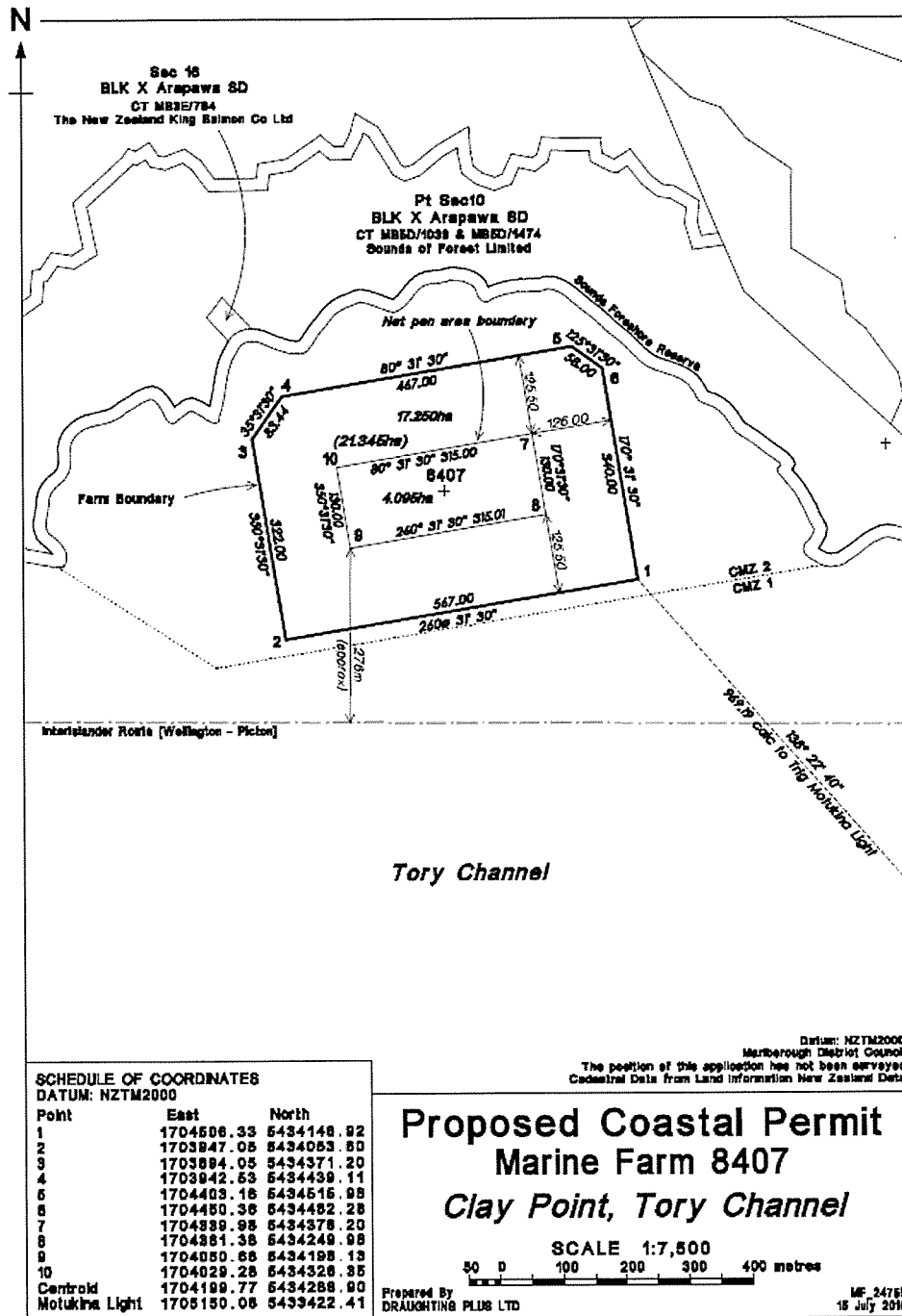


Figure 2. Proposed plan for the farm and net pen area boundaries at the Clay Point farm (Marine Farm 8407).

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2. EXISTING ENVIRONMENTAL CONDITIONS

2.1. Bathymetry and water currents

The bathymetry of the Clay Point embayment is reasonably complex (Figure 3). The current farm location is over a c. 40 m deep depression that is inshore of a bank of coarse sediment that rises to a depth of 25 m on the Tory Channel side of the farm. The proposed farm extension would move structures closer to this embankment. Beyond the bank of sediment, the seabed slopes towards Tory Channel proper, with depths reaching 40–50 m. A 35 m deep channel is present between the eastern extent of the bank and the eastern end the embayment.

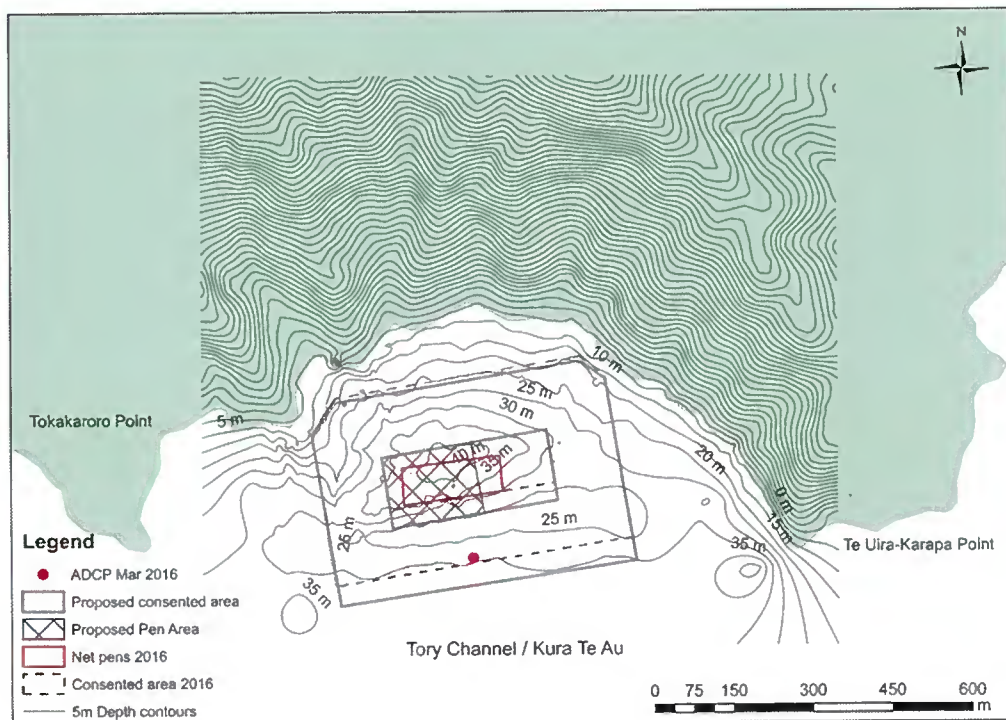


Figure 3. Bathymetry of the Clay Point embayment showing existing and proposed net pen areas.

Water currents in the vicinity of the farm were measured between 18 March–21 April 2016 with an ADCP. Near-bottom and mid-water current speeds averaged 22 and 30 cm s^{-1} , respectively (Figure 4). The mid-water currents for the proposed site show the prevailing current direction is easterly.

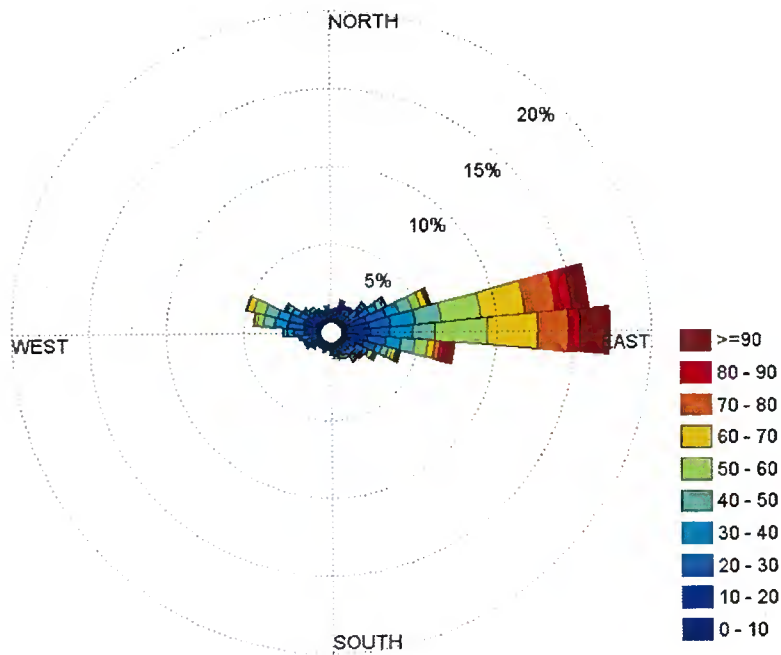


Figure 4. Current rose of the mid water depth bin (14 m above the seabed), showing data from the 18 March to 22 April 2016 ADCP deployment at the proposed Clay Point site. Data show the predominant current flow is in an easterly direction.

2.2. Soft sediment habitats

Underwater drop-camera images have been used extensively to describe soft sediment habitats within the Clay Point embayment (Figure 5). There is approximately 19.6 ha of soft sediment habitat in the 25–40 m depth range.

The limited extent of comparable soft sediment habitat in the vicinity of the Clay Point farm site was highlighted in a previous Cawthron assessment for the farm (Taylor et al. 2013b), and has implications for monitoring enrichment effects at this site (Figure 5). This is because the enrichment stage (ES) system (Keeley et al. 2012; Keeley et al. 2013a) was designed specifically for use in soft sediment habitats and cannot be directly applied to hard substrate habitats. The outermost distance away from the farm where comparable soft sediment seabed samples can be obtained is only about 300 m up- and down-current of the farm. Beyond this point, the seabed profile changes (either shallower toward shore, or significantly deeper towards the channel) and the sediments become dominated by reef, cobble and broken shell, which is not only difficult to sample, but contains a different array of organisms present (e.g., small sponges, cushion stars and tubeworms).

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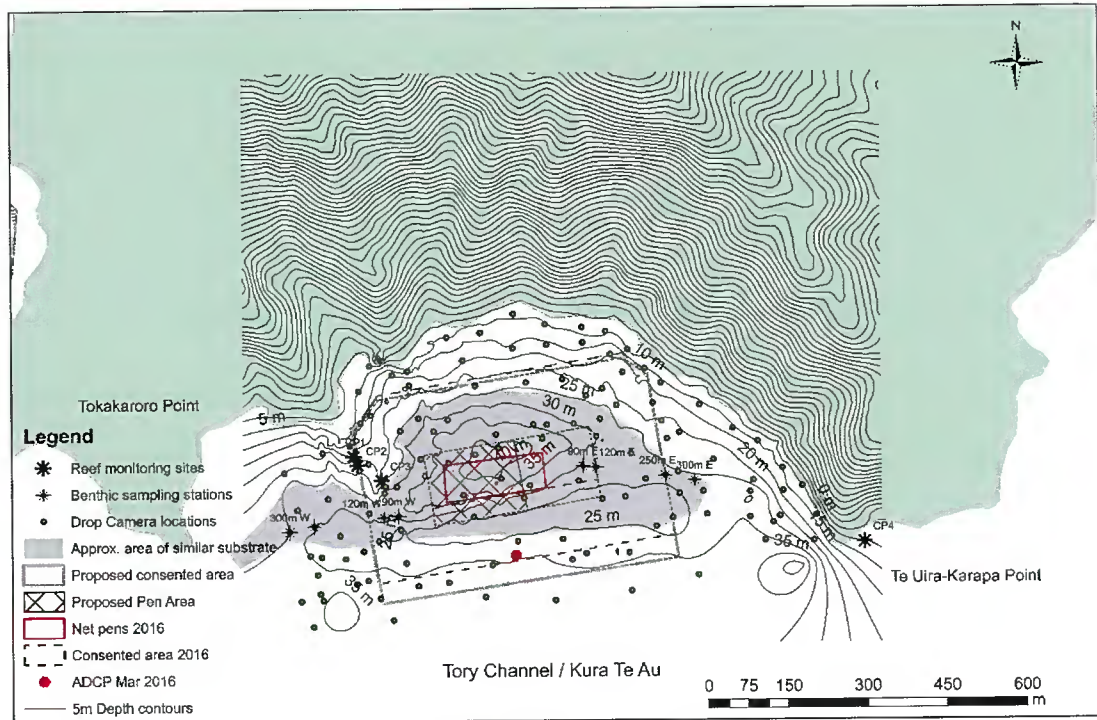


Figure 5. Drop camera locations, benthic sampling stations, reef monitoring sites, and the approximate area of comparable soft sediment substrate within the Clay Point embayment.

The proposed farm extension area featured sediments comprising coarse sand and small amounts of shell hash (see Figure 6, image B). Epifauna were sparse across this habitat but small numbers of the snake star (*Ophiopsammus maculata*), five-arm sea star (*Sclerasterias mollis*), eleven-arm sea star (*Coscinasterias muricata*), sea cucumber (*Australostichopus mollis*), and orange and white striped sea anemones (*Anthothoe albocincta*) were observed. Blue cod (*Parapercis colias*) and drifting pieces of sea lettuce (*Ulva* sp.) were also noted occasionally.

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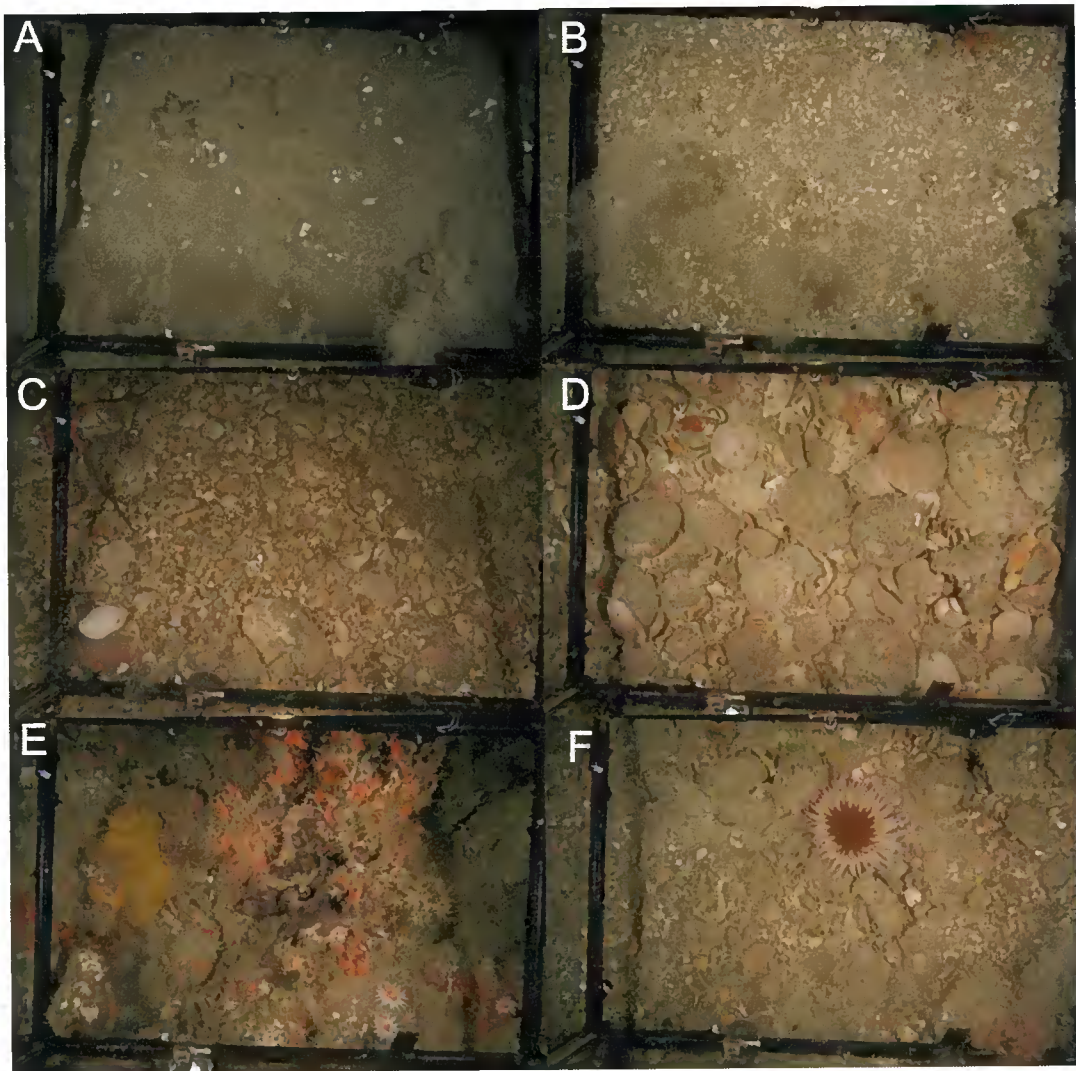


Figure 6. Representative images of habitat types observed during surveys within the entire Clay Point embayment in 2007 and 2016. A=mud, B=sand and shell hash, C=cobble, D=shell substrata, E=reef substrate, F=cobble and large shell hash.

Other less common seabed habitats identified in the wider Clay Point embayment included fine silt areas further inshore of the existing farm with small numbers of the cushion star (*Patiriella* sp., Figure 6, image A), and coarser cobble substrata with varying amounts of large shell and more diverse epifaunal assemblages (images C, D, and F). Reef habitat on the east and west headlands of the bay had relatively diverse epifaunal assemblages, typical of high-flow reef sites along Tory Channel (image E).

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2.2.1. Enrichment of soft-sediment habitats at the present site

Overview

The Clay Point farm began production in 2007, and the resource consent conditions for the site (U060926) require annual monitoring and adaptive management to meet seabed environmental quality standards (EQS). This monitoring has shown that seabed effects and feed inputs are correlated, and that the distribution of these effects are strongly influenced by the dominant water current direction (Elvines et al. 2016).

The present Clay Point site is situated in a high-flow area where high levels of resuspension and flushing result in a larger and more diffuse depositional footprint than traditional low-flow salmon farm sites. The way in which the seabed becomes enriched is also characteristically different from low-flow sites; organic accumulation is far less prevalent, sediment chemistry is less readily affected and total abundances of opportunistic taxa can be an order of magnitude higher. A relatively high number of taxa can also be maintained in the presence of very high numbers of opportunistic species; something which is uncommon at low-flow sites (Keeley et al. 2012; Keeley et al. 2013a).

The very strong currents present along Tory Channel proper act to resuspend and disperse farm deposits, reducing deposition and enrichment-related effects beneath the Clay Point farm. However, the dominant current direction is towards the east of the farm, and resuspended farm deposits tend to migrate towards the shallow subtidal slope in that direction. This migration of resuspended farm deposits has resulted in increased enrichment levels to the east of the farm relative to other areas of seabed around the farm (see below). Clay Point is also nearby to two other high flow salmon farm sites in Tory Channel; Te Pangu Bay (directly opposite on the other side of Tory Channel), and Ngamahau Bay (north and seaward along Tory Channel).

Review of monitoring results

A review of the seabed environmental monitoring results for the Clay Point farm at its current location, in relation to the environmental quality standards (EQS) in the existing resource consent conditions (see Appendix 1), was undertaken to provide some background to existing enrichment effects at the site. Feed levels at the site started at c. 3000 t per annum in 2009 and steadily increased over the following two years (Figure 8). In 2012 and 2013, feed levels at the farm increased to over 4000 t per annum, at which point there was an increase in enrichment levels along the monitoring transect to the east of the farm (Figure 5). Seabed monitoring results from 2012–2015 show that enrichment increased to an ES value greater than 4 at the 90 m east station and have reached an ES value over 3 at the 300 m east station since 2014, exceeding the existing EQS for these stations (Table 1). The ES at both sampling stations on the eastern transect reduced slightly after feed levels were reduced further in 2015. Enrichment has remained below the existing EQS ($ES \leq 5$) at the net pen sites since the farm was installed. These results suggest that

enrichment of the soft-sediment habitats within the bay is closely related to feed inputs, and has increased over time to the east of the farm due to the local bathymetry and hydrodynamic characteristics of the embayment.

Due to the dominant current flow pushing farm deposits to the east, the enrichment scores on the western transect, at the 90 and 300 m station, have remained below their designated EQS of ES 4 and ES 3 (respectively), since monitoring began.

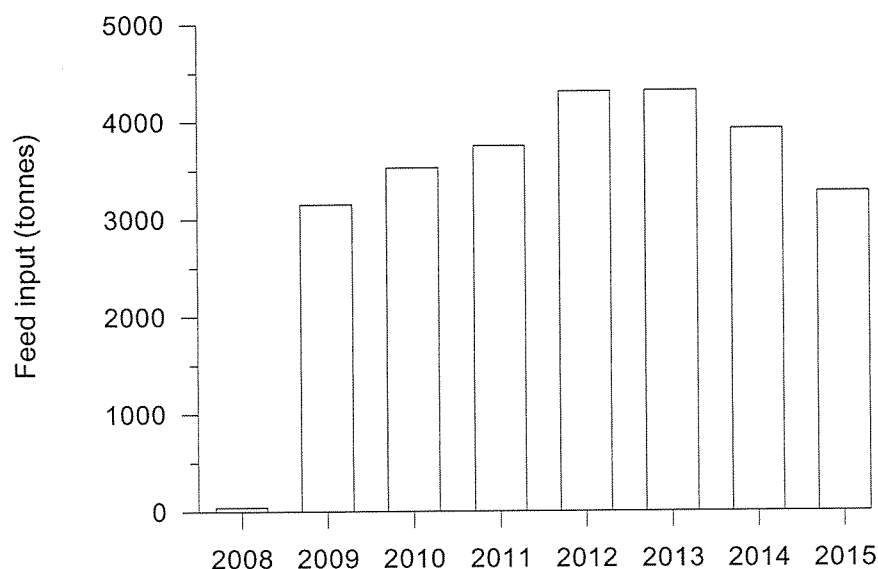


Figure 7. Annual feed inputs at the Clay Point salmon farm (December through November, 2008–2015).

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Table 1. Enrichment stage (ES) scores from annual monitoring conducted 2012–2015. Bracketed values are the SE (2012–14) and 95 % CI (2015). Values that exceed the existing environmental quality standards (EQS) are underlined.

	Enrichment stage				
	2012	2013	2014	Mar 2015	Nov 2015
Pen 1	4.4 (0.06)	4.7 (0.2)	4.7 (0.1)	-	4.7 (0.2)
Pen 2	4.1 (0.02)	4.4 (0.1)	4.4 (0.0)	-	3.6 (0.1)
Zone 2–3 boundary (90 m east)	3.6 (0.23) ⁺	<u>4.4 (0.0)</u> ⁺⁺	<u>4.7 (0.1)</u> ⁺⁺⁺	<u>4.3 (0.1)</u> ⁺⁺⁺	<u>4.4 (0.2)</u> ⁺⁺⁺
Zone 3–4 boundary (300 m east)	2.4 (0.05) ⁺	2.8 (0.3) ^{**}	<u>3.1 (0.2)</u> ^{**}	<u>3.2 (0.1)</u> ^{**}	<u>3.1 (0.3)</u> ^{**}
Zone 2–3 boundary (90 m west)	3.6 (0.12) ⁺	4.0 (0.1) ⁺⁺	3.3 (0.2) ⁺⁺⁺	-	3.2 (0.4) ⁺⁺⁺
Zone 3–4 boundary (300 m west)	2.4 (0.08) ⁺	2.6 (0.2) ^{**}	2.3 (0.1) ^{**}	-	2.3 (0.1) ^{**}
TC-Ctl-1	2.2 (0.13)	2.4 (0.1)	2.2 (0.2)	-	2.1 (0.1)
TC-Ctl-3	2.1 (0.11)	1.8 (0.1)	2.0 (0.1)	-	1.8 (0.2)
TC-Ctl-4	-	2.1 (0.1)	2.1 (0)	-	2.0 (0.1)
+Sampled at 70 m			*Sampled at 250 m		
++Sampled at 75 m			**Sampled at ~300 m		
+++Sampled at 90 m					

2.3. Rocky reef habitats

Rocky reef habitat is most common on the inshore cobble slopes and at the head of embayments along Tory Channel (Davidson et al. 2011). Rocky outcrops extend from the embayment into Tory Channel approximately 400 m to the west and 400 m to the east of the existing farm site. Annual monitoring at fixed locations has been carried out from 2008 to 2015 at three areas of reef habitat to the west (CP1-3, < 250 m from the net pens) and one area to the east (CP4) of the Clay Point farm (Figure 5 and Figure 8). These monitoring sites include areas of potentially sensitive reef assemblages, such as hydroid tree, sponge and bryozoan habitat, some of which are less than 150 m to the west of the current farm location (Figure 9). Annual reef monitoring has detected little change in community composition over the seven years of farm operation relative to reference locations (Dunmore 2016).

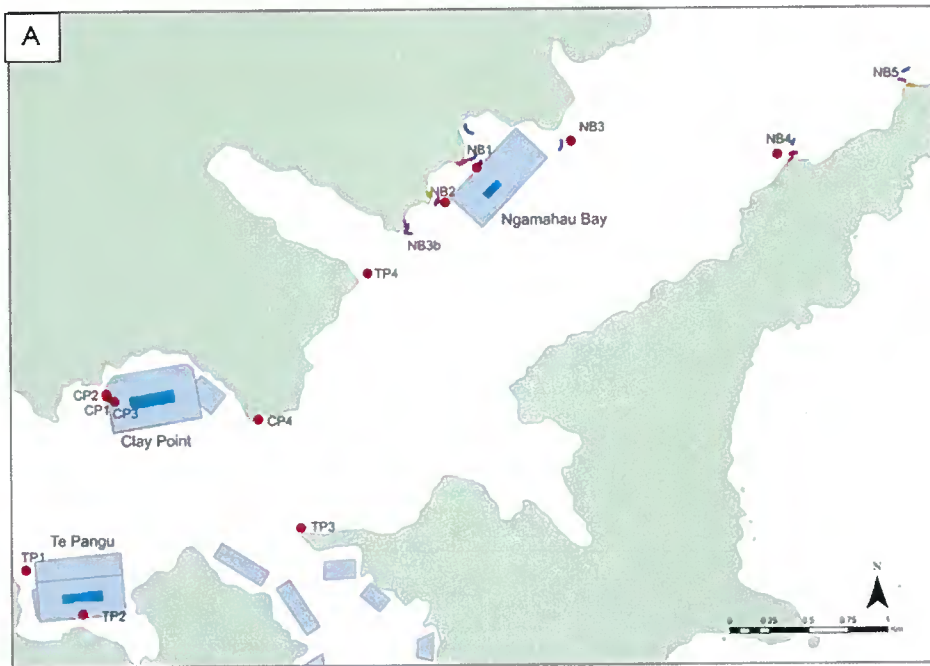


Figure 8. Location of fixed quadrat annual reef monitoring sites in Tory Channel.

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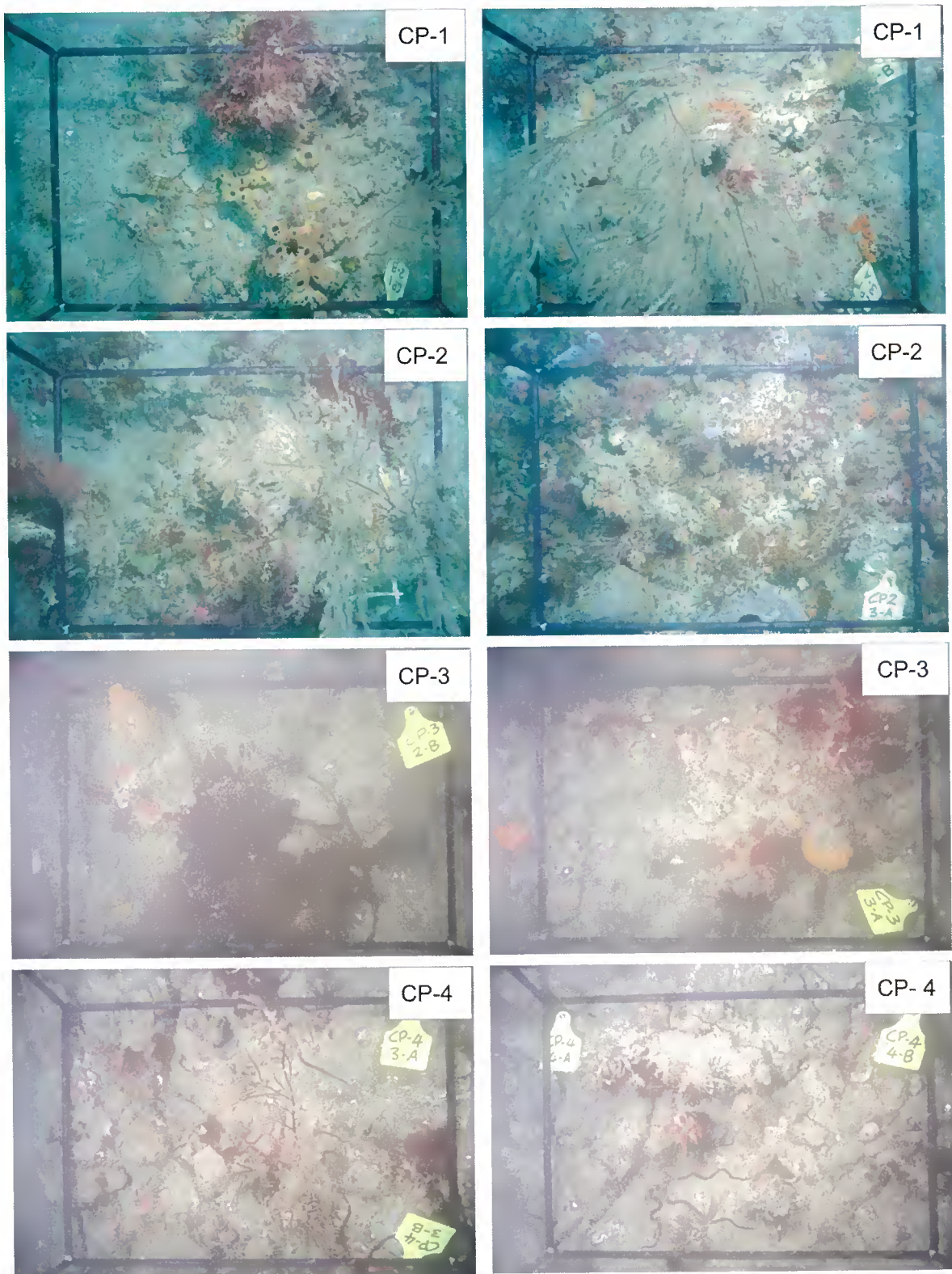


Figure 9. Representative photo-quadrate images of typical reef assemblages at CP1-4. (Images from Keeley et al. 2009).

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3. ASSESSMENT OF SEABED EFFECTS ASSOCIATED WITH EXTENDING THE FARM AREA

3.1. Soft sediment habitats

Depositional modelling (DEPMOD), based on the current speed data from the 18 March–21 April 2016 ADCP deployment, was used to predict the magnitude and spatial extent of seabed effects from salmon farm activities. A scenario of a 4000 t per annum feed discharge, the maximum currently consented, was modelled without resuspension¹ processes included in the model. An alternative farm layout with a 3 x 4 net pen arrangement, which would be possible if the net pen area boundary was extended 30 m to the south, was used in the model (Figure 10).

Under the scenario modelled, the pattern of the predicted farm footprint is an ellipse, with the dominant current flow predicted to move farm deposition furthest in an easterly direction. However, the area of greatest deposition was predicted to occur in a small area to the NW of the net pens where the bathymetry rises from almost 40 m to 20 m water depth. Based on previously published relationships (Keeley et al. 2012; Keeley et al. 2013a), the predicted deposition rate at pen edge of 13 kg m⁻² yr⁻¹ could result in ES scores approaching ES 5. However, a previous depositional footprint study at the site showed that scouring and resuspension reduces the magnitude of enrichment effects in the immediate vicinity of the farm by 1–1.5 ES (Keeley et al. 2013a). Consequently, effects to the soft sediment habitat beneath the net pens and to the NW of the pens, in terms of enrichment stage, are likely to range from ES 3.5–4.5. Depositional flux and enrichment is predicted to decrease with increasing distance from the net pens. While the model output shows low-level deposition to the east of the embayment, in reality, low levels of farm deposits are likely to align more closely with the bathymetry.

Due to the relatively high current flows at the site, the majority of farm biodeposits are likely to be resuspended and dispersed away from the net pen area. Consequently, a low level of seabed enrichment is predicted across much of the Clay Point embayment, some of which will likely move across the reef areas that extend from the west and eastern points of the embayment (see Section 3.2).

¹ Note that based on previous research of predicted DEPOMOD outputs and measured seabed enrichment (see Keeley et al. 2013b), the best predictor of seabed enrichment is typically provided by the no-resuspension outputs from the model.

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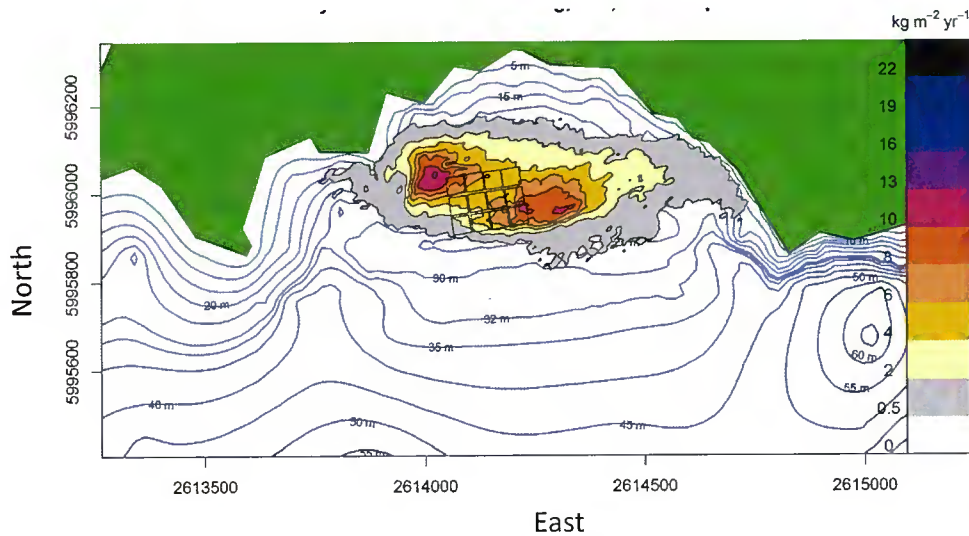


Figure 10. DEPOMOD output for 4000 t of feed per annum at Clay Point with an alternative farm layout, without resuspension processes included in the model.

3.2. Reef habitats and depositional areas

Fixed quadrat monitoring has been undertaken at reef sites to the west and east of the Clay Point farm since 2008 (Keeley et al. 2009; Dunmore et al. 2011; Clark et al. 2012; Dunmore & Keeley 2013, 2014; Dunmore et al. 2015). As mentioned in Section 2.3, to date no farm-related effects have been detected (Dunmore 2016). Although unlikely to settle and accumulate, low-levels of farm deposits are likely to continue to move across reef areas to the west and east of the farm. It is recommended, therefore, that reef monitoring stations continue to be monitored. While the water current flows are such that accumulation of biodeposits on these reef areas is not likely to occur, the movement of these deposits across these communities could increase the chances of effects to these communities from low levels of enrichment. Exactly how enrichment effects would manifest within these reef assemblages is yet to be determined, as negative effects from farm discharges in the region have not been detected to date (Dunmore 2016). However, effects might include changes in the cover and abundance of ephemeral, grazing invertebrates, and even long-lived perennial species such as sponges and hydroid trees.

The resuspension and re-deposition of farm deposits within the Clay Point embayment has seen increasing enrichment observed within the soft sediment areas 300 m east of the existing farm (Table 1). Because farm deposits will continue to be resuspended and dispersed within the embayment, areas of high deposition may occur in accumulation areas away from the net pens. The BMP-Benthic suggests that cumulative effects reference (CE-REF) stations can be established if areas of high deposition are suspected. The exact location of a CE-REF station would be detailed in

the annual Marine Environmental Monitoring and Adaptive Management Plan (MEM-AMP) for the farm.

3.3. Effects of moorings

Potential effects of moorings arise from the installation process and ongoing presence of the moorings. The sand-dominated habitat, with small numbers of snake stars and cushions star, identified in the anchoring areas is common in high-flow areas of Tory Channel. The main effect of the mooring installation will be a short pulse of disturbance in the form of localised physical movement of seabed material and small-scale siltation in the immediate vicinity of each screw anchor. The short-term and localised nature of this disturbance are unlikely to have continued adverse effects on the biota over the main habitat described from the visual survey, as the majority of species observed are mobile and have the ability to quickly recolonise the disturbed areas.

Continued effects of the screw anchors and mooring lines will be limited to localised shading and deposition of fouling material from the mooring lines. Again, this is unlikely to adversely affect the sand-dominated habitat described from the visual survey, but may result in localised increases in the abundance of mobile species like snake stars, sea stars and fish. Overall, the installation of moorings in the extended farm area is not likely to cause adverse effects to the seabed environment.

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4. SUMMARY AND RECOMMENDATIONS

The dominant habitat observed within the proposed net pen area extension and in the mooring area is relatively common in high-flow, sand-dominated areas of the Marlborough Sounds (Davidson et al. 2011).

Effects to the soft sediment habitat beneath the net pens and to the NW and east of the pens, in terms of enrichment stage, are likely to range from ES 3.5-4.5. Depositional flux and enrichment is predicted to decrease with increasing distance from the net pens. While the model output shows low level deposition to the north-west and east of the net pens, in reality, low levels of farm deposits are likely to align more closely with the bathymetry of the embayment.

Even with the modified net pen arrangement that is possible with the 30 m extension to the south, there is potential for enrichment to continue to increase in areas of soft sediment accumulation 300-350 m to the east of the net pens. To address this, a CE-Ref station is recommended 300 m to the east of the proposed net pen area.

The short-term and localised nature of the disturbance during and following screw anchor and mooring line installation is such that this habitat, and the mobile organisms that inhabit it, are unlikely to be adversely affected. The ongoing effects of shading and biodeposition from the extension to the net pen area are likely to have only minor overall effects.

An adaptive management approach is used to manage the salmon farm effects in the Marlborough Sounds. Annual monitoring results and recommendations are incorporated into an annual MEM-AMP for each farm to ensure that monitoring and management responses are carried-over between years, and that the most up-to-date and appropriate methods for monitoring farm effects are being used. The Best Management Practice guidelines for salmon farms in the Marlborough Sounds ('BMP'; Keeley et al. 2014), provide the most up-to-date guidelines for monitoring and adaptive management of benthic effects; including those in the far-field. NZKS have indicated that these guidelines will be adopted through the resource consent process for the proposed relocation of the Clay Point salmon farm.

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6. APPENDIX

Appendix 1. Existing environmental quality standards and BMP

The 'description and environmental bottom lines' detailed in the consent for the Clay Point farm (Table A1) were developed prior to the standards and monitoring protocols defined in the best management practice guidelines – benthic ('BMP'; Keeley et al. 2014). The consented environmental quality standards, EQS, provide a definitive and quantitative approach that uses enrichment stage (ES) scores that span a gradient from 1 (being natural) to 7 (being azoic / anoxic) (Figure A1). Details pertaining to the development of this gradient can be found in the BMP. A stylised depiction of the stages of the ES gradient is provided in Figure A1, which includes the typical responses of several commonly utilised environmental variables (redox, sulphides, total abundance, number of taxa and Shannon-Wiener diversity index). A description of each of the stages is reproduced in Table A2.

Through the development of the BMP, industry goals and EQS have been further refined to reflect current knowledge. The existing consent at Clay Point does not require the BMP to be adopted at this site. However, NZKS have indicated that the standards detailed in the BMP would be adopted as part of this proposal.

Table A1. Existing environmental quality standards (EQS) for the Clay Point salmon farm, with the enrichment stage (ES) limit for each zone (taken from consent U060926).

Compliance zone	Compliance monitoring location	EQS
Zones 1 and 2— beside and beneath the net pens	Measured beneath the edge of the net pens	ES ≤ 5.0 No more than one replicate core with no taxa (azoic) No obvious spontaneous out-gassing (H ₂ S/methane) Bacteria mat (<i>Beggiatoa</i>) coverage not greater than localized/patchy in distribution
Zone 3—near to the net pens	Measured at the Zone 2–3 boundary	ES ≤ 4.0 Infauna abundance is not significantly higher than at corresponding "pen" station Number of taxa > 75% of number at relevant/appropriate reference station(s)
Zone 4—outside the compliance zone area of Zones 1, 2 and 3	Measured at the Zone 3–4 boundary	ES ≤ 3.0

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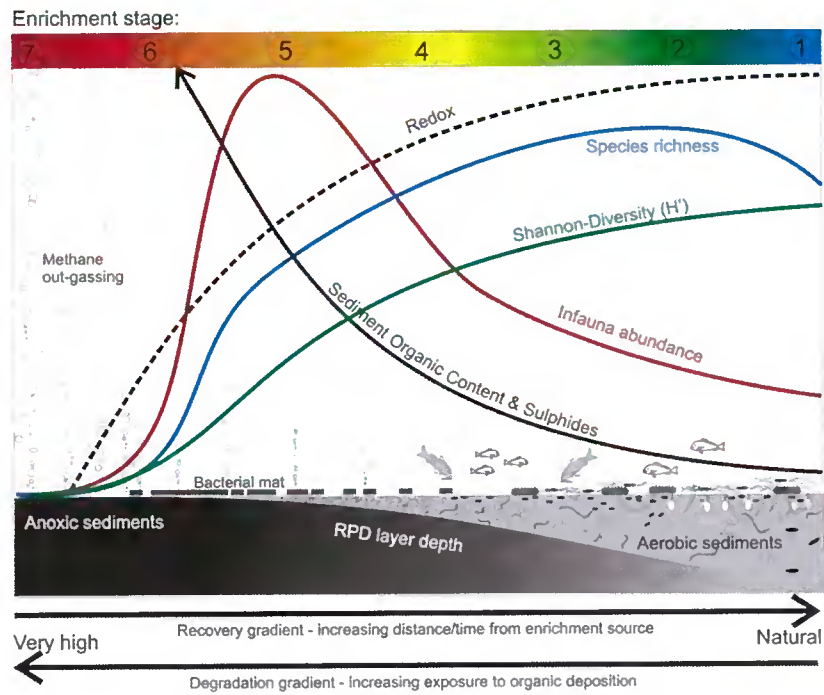


Figure A1. Stylised depiction of a typical enrichment gradient experienced at low-flow sites, showing generally understood responses in commonly measured environmental variables (species richness, infauna abundance, Shannon-Weiner diversity, sediment organic content and sulphides and redox). Apparent redox potential discontinuity depth (aRPD) and prevalence of bacterial (*Beggiatoa* sp.) mats and methane/H₂S out-gassing are also indicated. The gradient spans from highly enriched azoic conditions nearest the enrichment source on the left (ES 7) to natural or pristine conditions away from the source on the right (ES 1).

Table A2. General descriptions and primary environmental characteristics for the seven enrichment stages from Keeley et al. (2014). HF = High Flow sites (mean mid-water current speeds $\geq 10 \text{ cm s}^{-1}$), LF = Low Flow sites ($< 10 \text{ cm s}^{-1}$).

ES	General description		Environmental characteristics
1.0	Pristine end of spectrum. Clean unenriched sediments. Natural state, but uncommon in many modified environments	LF	Environmental variables comparable to an unpolluted / unenriched pristine reference station.
		HF	As for LF, but infauna richness and abundances naturally higher ($\sim 2 \times \text{LF}$) and %organic matter (OM) slightly lower.
2.0	Minor enrichment. Low-level enrichment. Can occur naturally or from other diffuse anthropogenic sources. 'Enhanced zone.'	LF	Richness usually greater than for reference conditions. Zone of 'enhancement' – minor increases in abundance possible. Mainly a compositional change. Sediment chemistry unaffected or with only very minor effects.
		HF	As for LF
3.0	Moderate enrichment. Clearly enriched and impacted. Significant community change evident.	LF	Notable abundance increase; richness and diversity usually lower than reference station. Opportunistic species (<i>i.e.</i> Capitellid worms) begin to dominate.
		HF	As for LF
4.0	High enrichment. Transitional stage between moderate effects and peak macrofauna abundance. Major community change.	LF	Diversity further reduced; abundances usually quite high, but clearly sub-peak. Opportunistic species dominate, but other taxa may still persist. Major sediment chemistry changes (approaching hypoxia).
		HF	As above, but abundance can be very high while richness and diversity are not necessarily reduced.
5.0	Very high enrichment. State of peak macrofauna abundance.	LF	Very high numbers of one or two opportunistic species (<i>i.e.</i> Capitellid worms, nematodes). Richness very low. Major sediment chemistry changes (hypoxia, moderate oxygen stress). Bacterial mat usually evident. Out-gassing occurs on disturbance of sediments.
		HF	Abundances of opportunistic species can be extreme ($10 \times \text{LF ES 5.0}$ densities). Diversity usually significantly reduced, but moderate richness can be maintained. Sediment organic content usually slightly elevated. Bacterial mat formation and out-gassing possible.
6.0	Excessive enrichment. Transitional stage between peak abundance and azoic (devoid of any organisms).	LF	Richness and diversity very low. Abundances of opportunistic species severely reduced from peak, but not azoic. Total abundance low but can be comparable to reference stations. %OM can be very high ($3-6 \times \text{reference}$).
		HF	Opportunistic species strongly dominate, with taxa richness and diversity substantially reduced. Total infauna abundance less than at stations further away from the farm. Elevated %OM and sulfide levels. Formation of bacterial mats and out-gassing likely.
7.0	Severe enrichment. Anoxic and azoic; sediments no longer capable of supporting macrofauna with organics accumulating.	LF	None, or only trace numbers of infauna remain; some samples with no taxa. Spontaneous out-gassing; bacterial mats usually present but can be suppressed. %OM can be very high ($3-6 \times \text{reference}$).
		HF	Not previously observed — but assumed similar to LF sites.

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