MARLBOROUGH
DISTRICT COUNCIL

RESOURCE CONSENT APPLICATION

U190438

The New Zealand King Salmon Co. Limited

North of Cape Lambert, North Marlborough

Submissions Close

5.00 pm Monday
16 December 2019

Application for Resource Consent or Fast Track Resource Consent

This application is made under Section 88 or 87AAC of the Resource Management Act 1991

MARLBOROUGH DISTRICT COUNCIL

For Office Use	ISO 9001 Document Number: RAF0002-CI1913
Lodgement Fee Paid $	
Receipt No.	
Consent No.	
Case Officer:	
Date Received:	

Please read and complete this form thoroughly and provide all details relevant to your proposal. Feel free to discuss any aspect of your proposal, the words used in this form or the application process with Council staff, who are here to help.

This application will be checked before formal acceptance. If further information is required, you will be notified accordingly. When this information is supplied, the application will be formally received and processed further.

You may apply for more than one consent that is needed to cover several aspects of the activity on this form.

1. Applicant Details *(If a trust, list full names of all trustees.)*

Name: *(full legal name)* The New Zealand King Salmon Co. Limited

Company/Trust Number: *(if applicable)* 287485

Electronic Address for Service: Mark.Gillard@kingsalmon.co.nz

Mailing Address: *(including post code)* PO Box 1180, Nelson 7040

Phone: (Daytime) (03) 548 5714 Phone: (Mobile) 029 245 2529

2. Agent Details *(If your agent is dealing with the application, all communication regarding the application will be sent to the agent.)*

Name: Gascoigne Wicks Lawyers (C/- Quentin Davies and Emma Deason)

Electronic Address for Service: qdavies@gwlaw.co.nz / edeason@gwlaw.co.nz

Mailing Address: *(including post code)* PO Box 2
Blenheim 7240

Phone: (Daytime) (03) 578 4229 Phone: (Mobile)

3. Type of Resource Consent Applied For

☑ **Coastal Permit** ☐ **Discharge Permit** ☐ **Land Use** ☐ **Subdivision** ☐ **Water Permit**

☐ **Fast Track Application**

- ☐ I **opt out** of the fast track consent process
- ☐ I **do not opt** out of the fast track consent process

4. Description of the Activity

The activity to which the application relates is as follows:

An application pursuant to s88 of the Resource Management Act 1991 to install a salmon farm(s) within a 1,792 hectare site (3.3km wide by 5.4km long) in the open ocean, 6km to 12km due north of Cape Lambert.

5. Supplementary Information Provided? ☐ Yes ☑ No

Council has supplementary forms for some activities, such as moorings, water permits, domestic wastewater, discharge permits, to assist applicants with providing the required information.

6. Site Details

The site to which the proposed activity is to occur is as follows:

Location (address): 6km to 12km due north of Cape Lambert, Cook Strait

Legal description (i.e. Lot 1 DP 1234): N/A - see Appendix A to the application

(Attach a sketch of the locality and activity points. Describe the location in a manner which will allow it to be readily identified, e.g. house number and street address, Grid Reference, the name of any relevant stream, river, or other water body to which application may relate, proximity to any well known landmark, DP number, Valuation Number, Property Number.)

Please attach a copy of the Certificate of Title that is less than 3 months old (except for coastal or water permits).

Owners/Occupiers of the Site The names and addresses of the owner and occupier of the land (other than the applicant): N/A - see Appendix A to the application

Affected Persons

Please attach the written approval of affected persons/adjoining property owners and occupiers.

Note: As a matter of good practice and courtesy you should consult your neighbours about your proposal. If you have not consulted your neighbours, please give brief reasons on a separate sheet why you have not.

7. Assessment of Effects on the Environment (AEE) *(Attach separate sheet detailing AEE.)*

I attach, in accordance with Schedule Four of the Resource Management Act 1991, an assessment of environmental effects in a level of detail that corresponds with the scale and significance of the effects that the proposed activity may have on the environment. Applications also have to include consideration of the provisions of the Resource Management Act 1991 and other relevant planning documents.

Note: Failure to submit an AEE will result in return of this application.

8. Part 2 of the Resource Management Act 1991

I attach an assessment of the proposed activity against the matters set out in Part 2 of the Resource Management Act 1991.

9. Section 104 of the Resource Management Act 1991

I attach an assessment of the proposed activity against any relevant provisions of a document referred to in Section 104(1)(b) of the Resource Management Act 1991, including the information required by Clause 2(2) of Schedule 4 of the Resource Management Act 1991.

10. Other Information

Are there other activities which are part of the proposal to which the activity relates, for example permitted activities, or building consents, etc?

Permitted activities:	Movement of vessels
Non Resource Management Act 1991 activities relating to this application:	N/A
Additional consents that need to be applied for, or have been applied for:	

Section 124 or 165ZH(1)(c)

If the application is affected by Section 124 or 165ZH(1)(c) of the Resource Management Act 1991 (which relate to existing resource consents), the value of the investment of the existing consent to the consent holder. (*This assessment should include more than stating a monetary value.*)

N/A

11. Fees

1. The applicable lodgement (base) fee is to be paid at the time of lodging this application. If payment is made into Council's bank account 02-0600-0202861-02, please put Applicant Name and either U-number, property number or consent type as a reference. If you require a GST receipt for a bank payment, please tick ☐
2. The final cost of processing the application will be based on actual time and costs in accordance with Council's charging policy. If actual costs exceed the lodgement fee an invoice will be issued (if actual costs are less, a refund will be made). Invoices are due for payment on the 20th of the month following invoice date. Council may stop processing an application until an overdue invoice is paid in full. Council charges interest on overdue invoices at 15% per annum from the date of issue to the date of payment. In the event of non-payment, legal and other costs of recovery will also be charged.
3. Please make invoice out to: ☑ Applicant ☐ Agent
   (if neither is ticked the invoice will be made out to Applicant)

12. Declaration

I *(please print name)* Quentin Davies

confirm that the information provided in this application and the attachments to it are accurate.

Signature of applicant or authorised agent: [signature]

Date: 5/7/19

Notes to Applicant

You may apply for two or more resource consents that are needed for the same activity on the same form.
You must pay the charge payable to the consent authority for the resource consent application under the Resource Management Act 1991 (if any).

Privacy Information

The information you have provided on this form is required so that your application can be processed and so that statistics can be collected by Council. The information will be stored on a public register and held by Council. Details may be made available to the public about consents that have been applied for and issued by Council. If you would like access to or make corrections to your details, please contact Council.

Environmental Protection Authority

If you lodge the application with the Environmental Protection Authority, you must also lodge a notice in form 16A at the same time.
If your application is to the Environmental Protection Authority, you may be required to pay actual and reasonable costs incurred in dealing with this matter (see section 149ZD of the Resource Management Act 1991).

Fast Track Applications *(relates to a land use consent for a controlled activity)*

An electronic address for service must be provided if you are applying for a Fast Track consent.
Under the Fast Track resource consent process, notice of the decision must be given within 10 working days after the date the application was first lodged with the council, unless the applicant opts out of that process at the time of lodgement.
A Fast Track application may cease to be a Fast Track application under Section 87AAC(2) of the Resource Management Act 1991.

Reset Form

MARLBOROUGH
DISTRICT COUNCIL
ISO 9001:2000
Document Number:
RAF0022-CI1579

Schedule Four
Resource Management Act 1991
Information Required in Application for Resource Consent

1 Information must be specified in sufficient detail

Any information required by this schedule, including an assessment under clause 2(1)(f) or (g), must be specified in sufficient detail to satisfy the purpose for which it is required.

2 Information required in all applications

(1) An application for a resource consent for an activity (the **activity**) must include the following:

(a) a description of the activity:

(b) a description of the site at which the activity is to occur:

(c) the full name and address of each owner or occupier of the site:

(d) a description of any other activities that are part of the proposal to which the application relates:

(e) a description of any other resource consents required for the proposal to which the application relates:

(f) an assessment of the activity against the matters set out in Part 2:

(g) an assessment of the activity against any relevant provisions of a document referred to in section 104(1)(b).

(2) The assessment under subclause (1)(g) must include an assessment of the activity against—

(a) any relevant objectives, policies, or rules in a document; and

(b) any relevant requirements, conditions, or permissions in any rules in a document; and

(c) any other relevant requirements in a document (for example, in a national environmental standard or other regulations).

(3) An application must also include an assessment of the activity's effects on the environment that—

(a) includes the information required by clause 6; and

(b) addresses the matters specified in clause 7; and

(c) includes such detail as corresponds with the scale and significance of the effects that the activity may have on the environment.

3 Additional information required in some applications

An application must also include any of the following that apply:

(a) if any permitted activity is part of the proposal to which the application relates, a description of the permitted activity that demonstrates that it complies with the requirements, conditions, and permissions for the permitted activity (so that a resource consent is not required for that activity under section 87A(1)):

(b) if the application is affected by section 124 or 165ZH(1)(c) (which relate to existing resource consents), an assessment of the value of the investment of the existing consent holder (for the purposes of section 104(2A)):

(c) if the activity is to occur in an area within the scope of a planning document prepared by a customary marine title group under section 85 of the Marine and Coastal Area (Takutai Moana) Act 2011, an assessment of the activity against any resource management matters set out in that planning document (for the purposes of section 104(2B)).

4 Additional information required in application for subdivision consent

An application for a subdivision consent must also include information that adequately defines the following:

(a) the position of all new boundaries:

(b) the areas of all new allotments, unless the subdivision involves a cross lease, company lease, or unit plan:

(c) the locations and areas of new reserves to be created, including any esplanade reserves and esplanade strips:

(d) the locations and areas of any existing esplanade reserves, esplanade strips, and access strips:

(e) the locations and areas of any part of the bed of a river or lake to be vested in a territorial authority under section 237A:

(f) the locations and areas of any land within the coastal marine area (which is to become part of the common marine and coastal area under section 237A):

(g) the locations and areas of land to be set aside as new roads.

5 Additional information required in application for reclamation

An application for a resource consent for reclamation must also include information to show the area to be reclaimed, including the following:

(a) the location of the area:

(b) if practicable, the position of all new boundaries:

(c) any part of the area to be set aside as an esplanade reserve or esplanade strip.

Assessment of environmental effects

6 Information required in assessment of environmental effects

(1) An assessment of the activity's effects on the environment must include the following information:

(a) if it is likely that the activity will result in any significant adverse effect on the environment, a description of any possible alternative locations or methods for undertaking the activity:

(b) an assessment of the actual or potential effect on the environment of the activity:

(c) if the activity includes the use of hazardous substances and installations, an assessment of any risks to the environment that are likely to arise from such use:

(d) if the activity includes the discharge of any contaminant, a description of—

(i) the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and

(ii) any possible alternative methods of discharge, including discharge into any other receiving environment:

(e) a description of the mitigation measures (including safeguards and contingency plans where relevant) to be undertaken to help prevent or reduce the actual or potential effect:

(f) identification of the persons affected by the activity, any consultation undertaken, and any response to the views of any person consulted:

(g) if the scale and significance of the activity's effects are such that monitoring is required, a description of how and by whom the effects will be monitored if the activity is approved:

(h) if the activity will, or is likely to, have adverse effects that are more than minor on the exercise of a protected customary right, a description of possible alternative locations or methods for the exercise of the activity (unless written approval for the activity is given by the protected customary rights group).

(2) A requirement to include information in the assessment of environmental effects is subject to the provisions of any policy statement or plan.

(3) To avoid doubt, subclause (1)(f) obliges an applicant to report as to the persons identified as being affected by the proposal, but does not—

(a) oblige the applicant to consult any person; or

(b) create any ground for expecting that the applicant will consult any person.

7 Matters that must be addressed by assessment of environmental effects

(1) An assessment of the activity's effects on the environment must address the following matters:

(a) any effect on those in the neighbourhood and, where relevant, the wider community, including any social, economic, or cultural effects:

(b) any physical effect on the locality, including any landscape and visual effects:

(c) any effect on ecosystems, including effects on plants or animals and any physical disturbance of habitats in the vicinity:

(d) any effect on natural and physical resources having aesthetic, recreational, scientific, historical, spiritual, or cultural value, or other special value, for present or future generations:

(e) any discharge of contaminants into the environment, including any unreasonable emission of noise, and options for the treatment and disposal of contaminants:

(f) any risk to the neighbourhood, the wider community, or the environment through natural hazards or the use of hazardous substances or hazardous installations.

(2) The requirement to address a matter in the assessment of environmental effects is subject to the provisions of any policy statement or plan.

MARLBOROUGH DISTRICT COUNCIL
ISO 9001:2000
Document Number:
RAF0023-CI1579

Section 88 Resource Management Act 1991 Making an Application

88 Making an application

(1) A person may apply to the relevant consent authority for a resource consent.

(2) An application must—

(a) be made in the prescribed form and manner; and

(b) include the information relating to the activity, including an assessment of the activity's effects on the environment, as required by Schedule 4.

(2A) An application for a coastal permit to undertake an aquaculture activity must include a copy for the Ministry of Fisheries.

(3) A consent authority may, within 10 working days after an application was first lodged, determine that the application is incomplete if the application does not—

(a) include the information prescribed by regulations; or

(b) include the information required by Schedule 4.

(3A) The consent authority must immediately return an incomplete application to the applicant, with written reasons for the determination.

(4) If, after an application has been returned as incomplete, that application is lodged again with the consent authority, that application is to be treated as a new application.

(5) Sections 357 to 358 apply to a determination that an application is incomplete.

Gascoigne Wicks LAWYERS

Partners:
Brian Fletcher LLB
Paul Gibson LLM, BCA
Quentin Davies LLM (Hons), BSc (Hons)
Scott Wight LLB, BSc

Associate:
Claire McKendry LLB, BSc
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Tom Dobbs LLB, BA

5 July 2019

Marlborough District Council
15 Seymour Street,
Blenheim

Attention: Peter Johnson,
Senior Resource Management Officer

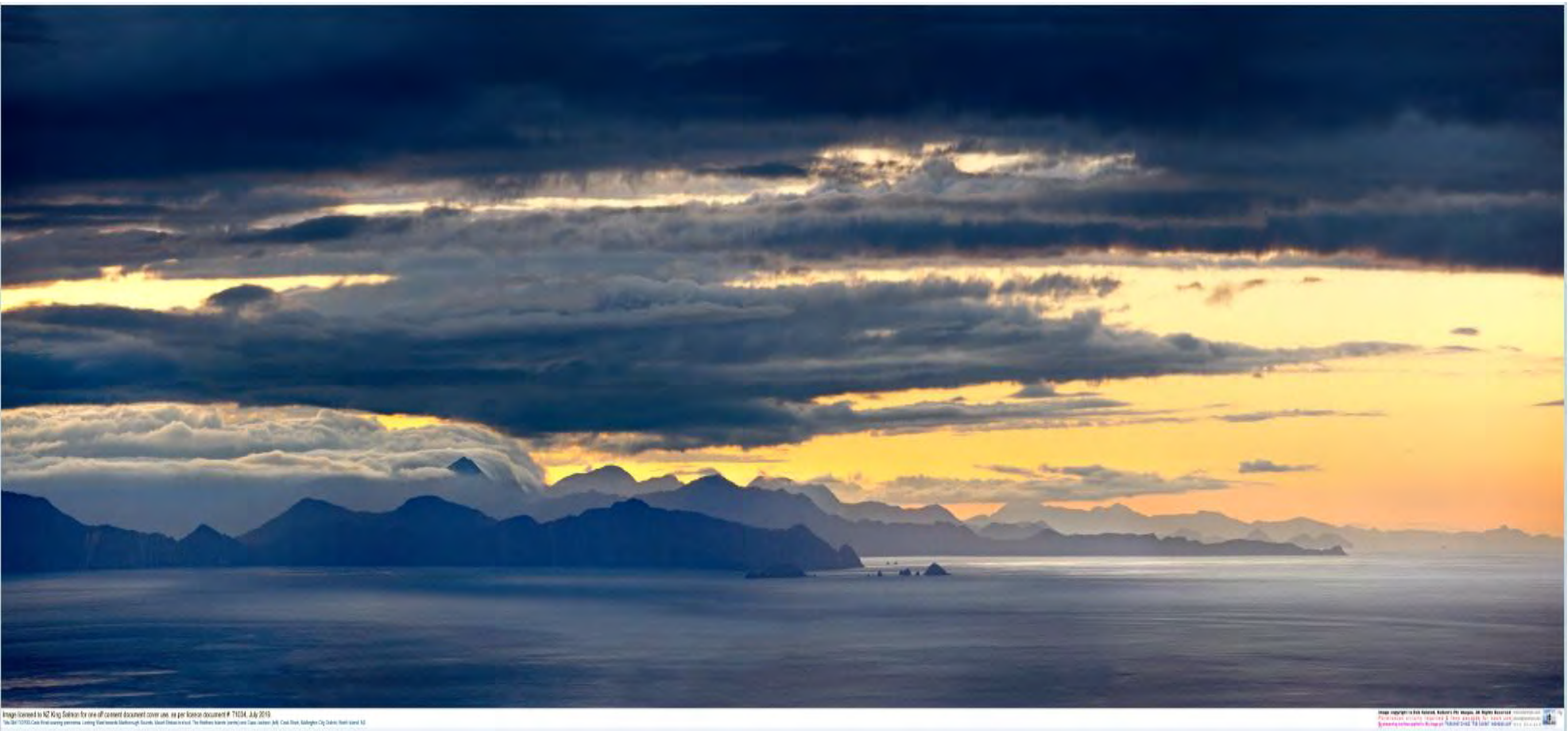
The New Zealand King Salmon Co Ltd - Resource Consent Application (Open Ocean)

1. Please find **enclosed** a resource consent application for NZ King Salmon for a 1,792 hectare site in the open ocean North Marlborough (Cook Strait). As confirmed with Council on 26 June 2019, this application has been lodged electronically via a USB drive.
2. This application consists of an Assessment of Effects and supporting documentation (totalling 19 appendices).
3. Please also find **enclosed** a cheque covering the application fee for a notified resource consent application, being $5,600.00.

Yours faithfully
GASCOIGNE WICKS

Quentin Davies | Emma Deason
Partner | Staff Solicitor
Email | qdavies@gwlaw.co.nz | edeason@gwlaw.co.nz

ELD-247141-158-2479-V1



New Zealand King Salmon

OPEN OCEAN SALMON FARMING: COOK STRAIT

Application for Resource Consent

The New Zealand King Salmon Co. Limited

July 2019

Gascoigne Wicks Lawyers

SDC-247141-158-1625-V9

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1 Executive Summary

NZ King Salmon has been urged by community representatives to farm salmon offshore. Ngati Koata has applauded the potential development of open ocean salmon farming as a "significant environmental and social benefit to our nation" (letter dated 27 June 2019). A collaborative working group advising the Minister of Aquaculture on the future direction of aquaculture in Marlborough,[1] stated:

"The SWG generally agrees that offshore farming is an attractive option in concept. Offshore farming technology is not available yet at a commercial scale or level of engineering robustness required for NZ conditions. Together with very high upfront investment capital and high operating costs makes this option prohibitive at this time. Members agree that further research into offshore farming technology is necessary as part of the continued improvement and evolution of NZ salmon farming practices. The SWG notes that research on this option is ongoing and will be looked at again if and when it is demonstrated to be beneficial and operationally and economically feasible. Some SWG members believe this option has not received sufficient attention."[2] [emphasis added]

NZ King Salmon is delivering on that commitment to pursue offshore salmon farming. In the intervening two and a half years since the above advice, technology has reached a point that NZ King Salmon is prepared to invest in offshore farming sites.

The benefits which the community members of the Marlborough Salmon Working Group saw in offshore farming are that: farming offshore is unconfined when compared with farming in parts of the Marlborough Sounds, it is away from many significant natural marine sites[3] and it is away from waterways with significant human uses such as transport, recreation and fishing.

Farming in Cook Strait requires sufficient scale for it to be economic. Equally, NZ King Salmon needs to maintain relativity between its farming areas. Scale must be balanced with appropriate environmental management. There are four elements of this:

a. The area has been identified minimising interference with fishing, navigation, marine mammals, sea birds and significant natural areas.
b. Appropriate standards will be set within which marine farming must operate. They will ensure that the effects of the activity are appropriate.
c. There will be monitoring of the effects of the activity against those standards; and

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[1] Marlborough Salmon Working Group: Advice to the Minister of Aquaculture: 23 November 2016: https://www.mpi.govt.nz/dmsdocument/15982-marlborough-salmon-working-group-advice-to-the-minister-of-aquaculture (accessed 20 June 2019).

[2] Above n 1, at p 15.

[3] With the exception of McManaway Rock, and Witts Rock.

d. There will be a flexibility inherent in the consent to take action where that proves necessary.

This regime enables a staged development to occur. The proposed consent conditions would enable feed increases above the initial 20,000 tonnes following a thorough review of all available data and a peer review from an independent panel of scientists. Adaptive management will enable the size of the farm to be increased in Stage 1 where that is appropriate. Additional area has been provided for that purpose. That additional area might also enable:

a. Polyculture to be trialled (with an additional resource consent); and
b. Where it is necessary to fallow areas, alternative parts of the site can be used; and
c. If unexpected environmental effects are identified, they can be remedied; and
d. Changes to types of structures, orientation of structures and other techniques can be employed to improve the environmental and social or economic performance of the site.

Except for where the farms are located, public access and other activities such as fishing will not be precluded. Other activities will be able to occur so long as they do not unreasonably interfere with the farm.

Effects will be reversible. Effects on the water column are unlikely to persist beyond a few tidal cycles once the fish are removed. Effects on the benthos may take time to return to something approximating natural conditions. On the other hand, effects on individuals within small communities, such as a threatened seabird species, might take longer to recover. However, such effects will be avoided through conditions.

In summary:

a. There is generally good baseline information about the receiving environment;
b. The applicant is able to effectively monitor adverse effects using appropriate indicators;
c. Thresholds can be set for adverse effects above which effects become inappropriate; and
d. The applicant can remedy those effects before they become irreversible.

This development is dwarfed by the sheer scale of Cook Strait. It represents an opportunity for Marlborough and for New Zealand.

2 The Applicant

NZ King Salmon is the largest producer of King salmon in the world, and has been successfully farming salmon for over 30 years. It farms approximately 8,300 tonnes of King salmon annually and has consent for eleven salmon farms located within the Marlborough Sounds. NZ King Salmon has a current staff of approximately 510, with around 115 working Marlborough. Average earning per employee is above the Marlborough average and is approximately $60,000.

NZ King Salmon generates significant regional and national economic benefits. Annual revenue is approximately $170 million. In addition, NZ King Salmon provides significant contributions to support services such as charter boats, freight, road, sea and air haulers, specialist divers, hardware suppliers, science providers and a host of other New Zealand based companies.

NZ King Salmon has an Operations Report which explains the background to the company, and how it operates it farms. This Operations Report is provided at **Appendix Q**. This report is dated 2016. It provides general information on how NZ King Salmon operate their farms. Since 2016, changes have occurred to this Operations Report. These are also provided at (the end of) **Appendix Q** and the Operations Report should be read with those changes in mind.

3 Background

NZ King Salmon has, for a number of years, been indicating that it regards open ocean aquaculture as the future of sustainable salmon farming in New Zealand. Until recently the company believed technology was not available to provide sufficient security for fish rearing in this high energy environment. Technology, and experience with that technology, has rapidly developed and has now advanced to a point where NZ King Salmon is ready to farm in suitable open ocean locations.

A move to open ocean is consistent with the recommendations of the Marlborough Salmon Working Group (SWG), which provided advice to the Minister of Aquaculture in relation to the Marlborough Salmon Relocation Proposal.[4]

The SWG (made up of nominated individuals from Ministry for Primary Industries (MPI), The Department of Conservation (DoC), Marlborough District Council, Te Tau Ihu, NZ King Salmon, Aquaculture New Zealand, the Marine Farming Association, and a number of environmental and community interest groups[5]) was charged with ensuring the enduring sustainability of salmon farming in Marlborough, with the intention that the recommendations would also help inform future planning.[6]

The SWG recommended that “The Marlborough salmon farming industry is encouraged to continue research into … offshore farming to ensure ongoing environmental and social improvement.”[7]

[4] Marlborough Salmon Working Group Advice to the Minister of Aquaculture, 23 November 2016. A copy is publicly available online.
[5] Guardians of the Sounds, Sounds Advisory Group, and Kenepuru & Central Sounds Residents Association.
[6] Above n 4, SWG Advice at [26] to [27].
[7] Above n 4, SWG Advice at [9, point 10].

The SWG's conceptual framework for developing a vision for salmon farming in Marlborough is depicted in the diagram at Figure 1, included at **Appendix S**.[8]

An equivalent framework was included in MPI's Final Right of Reply to the Marlborough Salmon Farm Relocation Advisory Panel. The Advisory Panel was also supportive of the move to open ocean farming.[9]

Opponents of the Board of Inquiry applications and the Relocation Proposal similarly indicated a preference for moving to open ocean farming.[10]

NZ King Salmon regards open ocean farming as the way of the future, because of its capacity to:

a. Give the salmon farming industry the ability to implement International Best Practice in terms of biosecurity;
b. Reduce environmental effects by locating farms in deeper, cooler waters with higher currents;
c. Improve fish welfare as a result of those improved environmental conditions;
d. Move farms further away from areas of residential development or high recreational use; and
e. Enable the company to grow with the corresponding economic, employment, and social benefits.

In addition, NZ King Salmon needs the ability to adapt to the effects of climate change. Sea temperatures have been well above the long term average over the past two summers.

4 Overview of the Application

4.1 Outline of this Approach Taken to this Application

To further provide context for this application, a brief summary of the outline of this application is provided below.

There are benefits to open ocean farming, such as those discussed in the water column report prepared with this application[11]:

"Offshore sites such as that considered in this assessment provide multiple advantages in terms of environmental effects on the water column over near-shore sites. They provide good conditions for turbulent mixing and stronger currents

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[8] Above n 4, From SWG Advice at p 17.
[9] Report and Recommendations of the Marlborough Salmon Farm Relocation Advisory Panel at p23 and p122.
[10] *Final Report and Decision of the Board of Inquiry – New Zealand King Salmon requests for Plan Changes and applications for Resource Consents* (22 February 2013) at [154] – [155].
Relocation proposal: refer for example, presentation by Bev Doole for the Marlborough Environment Centre, dated 2 May 2017; and presentation by Laurence Etheredge for the French Pass Residents Inc. part 1 at p 2. Copies are available here: https://www.mpi.govt.nz/news-and-resources/consultations/marlborough-salmon-relocation/hearings/.
[11] E. Newcombe, B. Knight, M. Smeaton, H. Bennett, L. Mackenzie, M. Scheel, C. Campos, "Water Column Assessment for a Proposed Salmon Farm Offshore of the Marlborough Sounds", Report No. 3313, June 2019.

thereby increasing the rate of dilution and dispersal of farm-derived wastes (Welch et al. 2019). Because they are located in deeper open waters, they are likely to have cooler water temperatures than more protected near-shore waters, and lower water temperatures can be favourable for fish health and survival."[12]

NZ King Salmon's proposal is to construct a marine farm within the parallelogram shown within the site plan at **Appendix A**. There may be two blocks of pens within that area. Development of the site will be staged. The first stage will be to discharge up to 20,000 tonnes of feed per annum in total on the site over two separate blocks of pens. That will equate to up to 20 pens.

NZ King Salmon will be required to report regularly in areas where it is plausible that it will have an environmental effect. Various Management Plans are proposed to be created for this site. They are addressed below in this assessment, and in the proposed conditions at **Appendix B**.

Given that open ocean farms are new in New Zealand, this resource consent is sought to enable adaptive management (as indicated above in the Executive Summary). Where monitoring results or specific instances concerning seabirds or marine mammals result in a notifiable incident or an alert, depending on the nature of the issue, a low level or full scale independent review of the operation might be called for. A peer review panel can be used when needed by the Council.

Stage 1

NZ King Salmon has identified a way in which it would begin to implement the resource consent, if granted. At Stage 1, up to 20,000 tonnes of feed will be discharged in up to 20 pens (using pens of up to 200 metres in circumference). In the medium term, NZ King Salmon considers the following layout as being a realistic scenario on the information it has to hand:

a. On the site there will be two sets of pens. Each set of pens will comprise up to eight plastic circles with a circumference of up to 200 metres each. Each set of pens will be supported by one barge. Consequently, at Stage 1 there will be approximately 16 plastic circle pens and two barges.
b. There will be a maximum discharge of approximately 1,000 tonnes of feed per annum, into each pen (still well below the 20,000 tonnes total for Stage 1). Each pen will therefore produce approximately 500 tonnes of fish.
c. Each set of pens will be supported by mooring lines leading to a grid system at depth which, in turn, enables tension to be kept on the nets. The pens will be laid out in a regular pattern of two lines of four pens. Each of those lines will most likely run parallel with the current.
d. Navigation lighting will be installed as required by the Harbourmaster.

[12] Above n 11, pp 5-6

Initially, the pens will be located on the area of the site plan coloured green-grey (at **Appendix A**). The initial locations selected in the attached plan will enable the enrichment created by the farm to, more or less, remain within that area.

Beyond Stage 1

Before moving to the second stage, NZ King Salmon will give 12 months' notice of this to Council. It will review all relevant scientific and technical reports and together with peer review lodge those with Council six months before any increase. New pens may be located in the green-grey area of the site plan at **Appendix A**. The pens may be located in another location, and that might be because:

a. There is a change in distribution of horse mussels and brachiopods caused by reasons unrelated to farming (for example natural cyclical changes, or commercial fishing); or
b. It may be through the monitoring undertaken by NZ King Salmon that it is established that, in this location given these currents it can sustainably farm over horse mussels without having a significant adverse effect; or
c. Further extensive areas of horse mussels are discovered in North Marlborough more generally; or
d. A policy decision is made that such farming might be appropriate and consequently, the constraint placed around the initial location of the pens will not apply to subsequent positioning.

Six months prior to additional feed going in the water, NZ King Salmon will need to update all of its scientific and technical reports with any new information gathered through monitoring and through other means. At the same time as those reports are rewritten, the Management Plans would be formally updated where appropriate to reflect whatever recommendations were made in those reports. All of that material would be provided to Council six months prior to any increase in feed discharge beyond 20,000 tonnes. Each time NZ King Salmon intends to increase the feed discharge by 20,000 tonnes, it would need to repeat this process. NZ King Salmon's current projection is that discharge at this site of up to 40,000 tonnes is possible.

There is a possibility that a trial of other types of structures might be attempted within the permit area. NZ King Salmon would assume that such operations would be relatively short term (perhaps over the course of one growing cycle, i.e. two years plus installation and removal). This pilot farm(s) would use a maximum of 4,000 tonnes of feed (included in the initial 20,000 tonnes) and be sited using the same criteria that determine where NZ King Salmon's initial placement has been located.

Summary on Site Sought

The 1,792 hectare area sought is considered to enable:

a. Flexibility to respond to unforeseen environmental issues;
b. Rotational farming followed by fallowing;

c. Designs such as Havfarm which, at 430 metres in length and 54 metres wide would require a substantial swing circle in order to operate on this site;
d. Trials of other types of structures on the site;
e. Polyculture such as the farming of macro-algae symbiotically with the salmon (addition of a new species would require an additional consent for the effects of that species); and
f. To allow for a staged approach to operations at this site.

4.2 Location

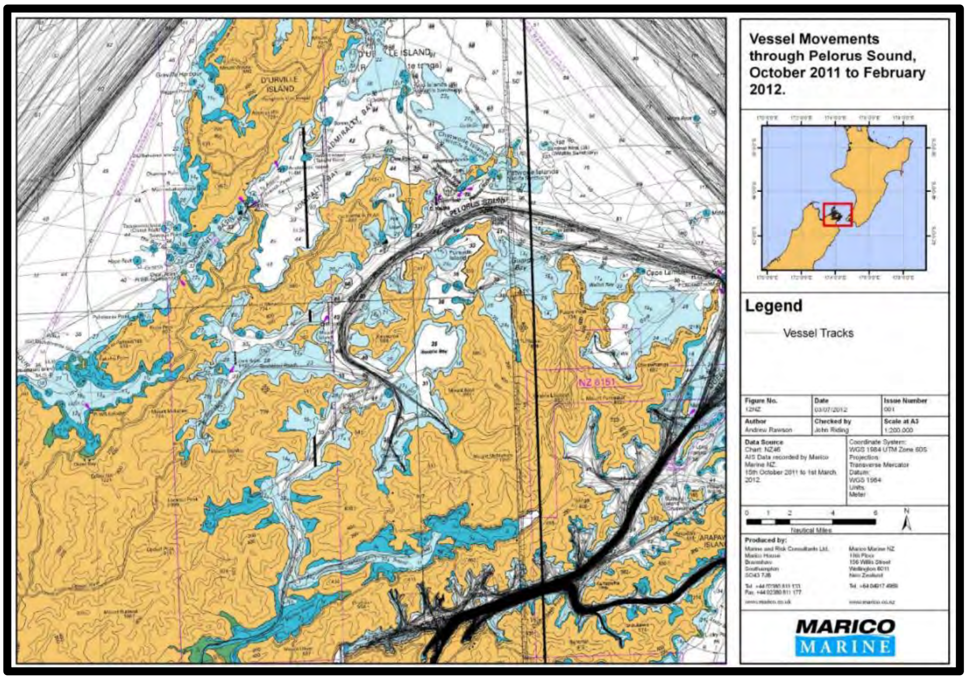
The application site is within the coastal marine area offshore of the Marlborough Sounds and is identified at **Appendix A**. The proposed area is 6 to 12km due north of Cape Lambert. It ranges in depth from approximately 60-110m[13].

Cook Strait is a high energy, high current environment. However, waves at this location are more benign than might be expected, with the probability of any wave exceeding a significant wave height of 3m being less than 2%. On average, waves are less than 2m in height for periods of 21 to 35 days at a time.[14] Mean mid-depth current speeds are approximately 0.35m/s, with a maximum recorded speed of 1.24m/s.[15]

No structures are currently located in the application site, and no resource consents have been granted to locate structures in this area. No Notice to Mariners exists within the study area warning mariners of structures.

It is an area within which a relatively small amount of fishing activity is known to occur.[16] The application site is outside commonly used navigation routes between Cape Jackson and Stevens Island, and Cape Jackson and the entry to Pelorus Sound. The relative frequency of larger vessels can be ascertained from AIS information such as this below: [17]

[13] D. Elvines, E. McGrath, M. Smeaton, D. Morrisey, "Assessment of Seabed Effects from an Open Ocean Salmon Farm Proposal in the Marlborough Coastal Area", Report No. 3317, June 2019, p 6 (Figure 3).
[14] Above n 13.
[15] Above n 13.
[16] J. Bentley, "Proposed Marlborough Environment Plan, Natural Character Recommendations", 20 November 2017, Boffa Miskell Limited. Also see the navigation assessment below in this AEE at section 6.3.
[17] Statement of Evidence of Captain Alex van Wijngaarden at Appendix 4, filed with the EPA for NZ King Salmon's 2012 Plan Change Request (proposal number NSP000002).



In addition to vessels identified who use AIS, smaller vessels may also use the application site on calm days. Navigation in and around the site of the proposed farm is discussed in detail below at section 6.3.

4.3 Dimensions

The site is 1,792 hectares in size, at approximately 3.3km wide by 5.4km long.

4.4 Structures

This application is to install salmon farming structures of an unspecified design anywhere within the proposal area. In an international sense, open ocean farming technologies are still in their early stages, and constantly evolving. Prototype and conceptual open ocean farming technologies being trialled overseas include the Beck Cage submersible offshore farming cage, Ocean Farm 1, Havfarm, and Huon's Fortress Pens in Australia. More detail on these example structures is found in **Appendix C**. It is likely that this site will use polar circles. Given this involves new technology, this application seeks flexibility in terms of the structures to be installed and the final layout of those structures within the boundaries of the 1,792 ha area. The indicative site layout is provided at **Appendix A**.

The characteristics of the proposed site are entirely different to NZ King Salmon's existing inshore farms, as are the logistics of farming in an open ocean location. As a result, the applicant has not yet determined exactly what technology it will use. In addition to the main farming structures, the site may include:

a. A barge for feed storage and staff facilities;
b. Underwater lighting to reduce early maturation of salmon; and
c. Net cleaning devices.

All structures at the site would need to comply with the consent conditions at **Appendix B**. In particular:

a. The structures must remain within the consent area at all times, other than during construction;
b. Structures must be maintained, secured, and in good working order so as not to create a navigational hazard; and
c. NZ King Salmon will take whatever steps are reasonably necessary to retrieve any non-biodegradable debris lost in or from the consent area.

Exclusive occupation is sought for the physical space occupied by the surface structures (including any barge), the moorings and any anchoring systems. In addition, consent is sought to exclusively occupy the consent area, though only to the extent necessary to undertake the activity and ensure the safety and security of the marine farm, all its structures, and staff working on the farm.

4.5 Engineering

NZ King Salmon will work closely with engineers to determine what structures would be suitable in this location. The health and safety of its staff and the welfare of its fish are also important considerations. Engineering calculations will be made with data obtained from the site. It may be necessary to install structures on a pilot basis with or without fish, prior to scaling up to commercial quantities. Engineering detail prepared by Offshore and Coastal Engineering Limited (OCEL) is provided at **Appendix R**.

The structures will meet the conditions of consent at **Appendix B**, and be consistent with specified engineering standards, which will be set out in a Structures Management Plan. In terms of the conditions:

a. The structures must be certified by a suitably qualified professional engineer with appropriate experience in marine engineering;
b. A Structures Management Plan must be prepared and lodged with the Council prior to the installation of any structures; and
c. Written notice of any significant change to the structures or operation must be provided to Council prior to that change being implemented.

The design of the structures in this open ocean environment are important. As is stated in the Navigation report[18]:

"*The infrastructure needs to be designed to withstand the most extreme weather conditions it may encounter. The NZKS methodology states that the design must be based on a 50-year return period condition, and must take in to account the through life fatigue. The methodology goes on to state that the fatigue assessment must provide the periodicity for replacement of components if required, the details must be*

[18] Below n 69.

transferred in to the maintenance routine as mandatory maintenance requirements."[19]

Additional conditions address navigational safety. These are discussed below at section 6.3.

5 Activity Status

The application area is located within the Coastal Marine Zone 2 (CMZ2) in the operative Marlborough Sounds Resource Management Plan (the Plan).

Under the Plan, many rules regulate salmon farming activities. In particular:

a. Structures which are parallel/oblique/perpendicular to the coastal marine area require consent as discretionary activities (rules 35.4.2.3 and 35.4.2.4);
b. Disturbance of the seabed associated with the anchors requires consent as a discretionary activity (rule 35.4.2.5);
c. Occupation of the coastal marine area requires consent as a discretionary activity (rule 35.4.2.7);
d. Discharges to water associated with marine farms, including greywater and feed discharge, require consent as discretionary activities (rule 35.4.2.11.1.2(g));[20]
e. Marine farms beyond 200m from the mean low water mark require consent as non-complying activities (rule 35.5);
f. Underwater lighting may require consent as a limited discretionary, discretionary or non-complying activity;[21] and
g. A term of 35 years requires consent as a non-complying activity (rule 35.5).

The applicant accepts that it is appropriate to bundle all elements of the application together and assess this as a non-complying activity. As a result, in addition to being considered pursuant to s 104, the application must pass one of the two 'gateway' tests in s 104D of the Resource Management Act 1991 ("the Act").

6 Assessment of Environmental Effects

6.1 Benthic Effects

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[19] Below n 69, at p 13.

[20] It is generally accepted that rule 35.4.2.11.1.2(g) takes primacy over non-complying activity rule 35.5.4 which relates to the deposition of material on the foreshore/seabed not otherwise regulated by any other rule. This is because Rule 35.4.2.11.1.2(g) specifically references discharges associated with marine farms.

[21] There is some uncertainty here. Underwater lighting may be a permitted activity pursuant to Rule 35.1 as an addition to a lawful structure. Lighting systems for marine farms are listed as restricted discretionary activities in Rule 35.3, but it is unclear whether this relates only to navigational lighting. As a result, lighting may be either a discretionary activity under Rule 25.4 or a non-complying activity under Rule 35.5. Consent U160039, granted on 11 March 2016, to install and use underwater lighting at the Otanerau Bay salmon farm, was assessed as a non-complying activity by Council under Rule 35.5.

Cawthron Institute has prepared a report addressing potential effects on the seabed from the proposed farm[22]. This report is provided at **Appendix D**.

This report begins by considering the suitability of the proposed location and stating that: "There are better waste dispersal capabilities at dynamic offshore locations such as the proposed site (compared to further inshore), and this is a clear advantage for mitigating seabed effects"[23].

The report considers what the potential effects on the seabed could be. The report concludes with recommendations to avoid, remedy or mitigate those potential effects.

Horse Mussels

There are horse mussel beds throughout the application area. There are also other fauna found in the area of the horse mussels habitat at the site.

Horse mussels are known as a key ecosystem engineer species that have widespread effects on ecosystem structure and functions. They are known to provide shelter and refuge for invertebrates and fish, and act as a substrata for the settlement of epifauna, such as sponges and soft corals[24]. They are considered sensitive, however actual effects on them from salmon farms are unknown. What we do know is that horse mussels are present within 300m of King Salmon's existing farms in high flow areas. Some of those observations have been of horse mussels with high abundance. In low flow areas horse mussels are observed in the vicinity of farms in low numbers. Horse mussels are also observed adjacent to, and on occasion within, mussel farms. We therefore do not have a baseline from which we can assess potential effects of the farm. Adaptive management is proposed. The predictions of potential effects on horse mussels from this proposed farm are considered below. However, before considering the potential effects on horse mussels, it is important to consider the context of these species. Having said that horse mussels are considered sensitive, there are two important considerations to have:

a. Horse mussels are a commercially fished species[25]; and
b. Horse mussels are not a rare, threatened or at-risk species[26].

Horse Mussels as a Fished Species

Horse mussels were introduced into the Quota Management System on 1 April 2004. There was a total allowable catch of 103 tonnes. The total allows a commercial catch of 29 tonnes. Customary non-commercial and recreational amounts are nine

[22] D. Elvines, E. McGrath, M. Smeaton, D. Morrisey, "Assessment of Seabed Effects from an Open Ocean Salmon Farm Proposal in the Marlborough Coastal Area", Report No. 3317, June 2019.
[23] Above n 22, Executive Summary, at p i.
[24] As discussed in MacDiarmid et al, "Sensitive Marine Benthic Habitats Defined", April 2013, at p 11.
[25] As stated above n 22 at p 19.
[26] In terms of the New Zealand Threat Classification System Lists. See Policy 11(a) of the NZCPS.

tonnes each. Fifty six tonnes was allowed for other sources of mortality. It has a deemed value of 12 cents per kilogram.[27]

Fisheries New Zealand records that "About 90% of the catch is taken as a bycatch during bottom trawling and the remainder is taken as a bycatch of dredge and Danish seine. It is likely that there is a reasonably high level of unreported discarded horse mussel catch."[28]

This application is within HOR7, an area stretching from Southern Marlborough to Northern Fiordland. HOR7 has a total allowable commercial catch of 16 tonnes, more than half the total allowable commercial catch for New Zealand. Reported catch varies. Historically, more than one tonne of horse mussels have been caught within HOR7. A catch of 634 kilograms was reported for the 12 months ending 31 March 2017. 211 kilograms was reported as being caught in the year ended 31 March 2018.

Horse Mussels are Not at Risk

The protection of horse mussel beds needs to be placed in the context of other management of Marlborough's benthic environment. The horse mussel is not a threatened or at risk species, even though it may be considered an ecologically sensitive species. As such, it is only significant effects that need to be avoided.[29] The placement of the farm may provide some protection to horse mussels by preventing bottom-contact fishing in the vicinity of the site.

The Regulatory Context for Horse Mussels

Under the Exclusive Economic Zone and Continental Shelf (Environmental Effects – Permitted Activities) Regulations 2013 ("the EEZCSR") horse mussels (as large bivalve molluscs) are defined as a "sensitive environment" in accordance with Schedule 6 of the EEZCSR when:

Living and dead specimens—

a. cover 30% or more of the seabed in a visual imaging survey; or
b. comprise 30% or more by weight or volume of the catch in a sample collected using towed gear; or
c. comprise 30% or more by weight or volume in successive point samples.

The EEZCSR provides for permitted activities to occur so long as they comply with the standards in the Schedules of the EEZCSR. That includes, when a sensitive environment is involved, either assessing the undertaking of the activity in another location (if feasible) or assessing the measures the could be taken to reduce the amount of contact with the seabed, carry out alternative lower-impact activities and change the methods of operation to lower the impact of the activity on the environment. This is a similar methodology to the assessment undertaken in this application.

[27] Fisheries (total allowable catch, total allowable commercial catch and deemed value rates) Notice 2015, Schedule 1.

[28] https://fs.fish.govt.nz/Doc/5471/HOR_FINAL%2008.pdf.ashx

[29] NZCPS policy 11(b).

Summary on Horse Mussels

MacDiarmid[30] considers that the rarer a habitat is, the more an external factor is likely to damage a significant proportion of the habitat[31]. As stated above, horse mussels are not rare. The report prepared for this application[32] finds that horse mussels are likely to be sensitive to increased organic matter sedimentation that could be caused by the proposed farm. NZ King Salmon proposes to manage potential effects on horse mussels by:

a. Adopting appropriate siting of the farm; and
b. Monitoring any effect(s) the farm has on the habitats; and
c. Adapting farm practice as required in accordance with b. above.

Brachiopods

As with horse mussels, brachiopods are classified as an ecologically important species but are not threatened or at-risk. The same level of assessment is thus required for brachiopods[33]. Potential effects are likely to be the same as for horse mussels.

Bryozoan fields/beds

The most common type of bryozoans found within this area were soft, flexible branching or bushy forms (likely Candidae and Catenicellidae) which are not considered significant in terms of ecosystem services and habitat provision[34].

Reef edge assemblages

The application area is not located within an Ecologically Significant Marine Site in the proposed Marlborough Environment Plan (MEP), nor within an ecological area in the operative Plan. The closest ecologically significant site in the operative and proposed Plans to the site is McManaway Rock[35]. The broad outline of the site of McManaway Rock (as an ecological site) is located in the fringe area to the proposed farm, but the farm does not overlap with McManaway Rocks (the farm is at its closest point is at least 1.5 kilometres from McManaway Rock proper)[36]. As such this report did not survey the entire McManaway Rock site. There is the potential for effects on McManaway Rocks. Mitigation proposed is:

a. Avoid overlap of the footprint of the farm with the McManaway Rock fringing strata;

[30] Above n 24.
[31] Above n 24, at p 9.
[32] Above n 22.
[33] That in accordance with policy 11(b) of the NZCPS it is only “significant” effects on such species that are to be avoided.
[34] Above n 22, at p 21.
[35] Discussed at above n 22, at pp i to ii of the Executive Summary and at section 2.3 (at p 6). The site is also near Witts Rock and Sentinel Rock, but these are located further away from the farm than McManaway Rock.
[36] Above n 22, at p 11 (Figure 7). At below n 114, at para 115.

b. Monitor and manage (based on any monitored effects) by adapting farming practices to minimise the risk of unacceptable effects, as the activity progresses; and
c. Adopt other operational management practices to reduce any identified effects.

See the proposed conditions at **Appendix B** for more information.

Summary of effects on the seabed

The report summarises that potential effects from the proposed farm on the seabed are those which (per Table 4 in the report[37]):

a. Could occur during the installation of the farm;
b. Could occur from the presence of the structures (once installed); and
c. Could occur from the farm operations (such as from discharges of feed: uneaten feed, and faeces).

Table 4[38] outlines the risks of potential effects on the seabed from the farm. It also outlines mitigation options ("options to reduce consequence or likelihood of effect").

Regarding potential effects on the seabed from the activity, the report concludes that there are options for avoiding, mitigating or remedying potential adverse effects. Specifically, the report states:

a. Effects from sedimentation during installation of the farm are likely to have a negligible effect on seabed communities, given high currents likely to rapidly disperse sediment. Effects by shading from the farm structures are also considered negligible, as given the depth of water here little light enters this part of the seabed[39].
b. Effects from the structures (e.g. anchors) being installed may affect habitat but will only affect a small area[40]. The recommendation to avoid significant adverse effects on the ecologically important habitats (horse mussels and brachiopods) is to avoid installation of anchors in the area of their habitat[41].
c. The effects from the structures being present once installed may have positive benefits to some organisms, due to the protection they provide from activities such as towed fishing equipment (e.g. horse mussels)[42].
d. The area of highest organic deposition during the farm's operation will most likely occur beneath the farm, as well as where the modelled footprints overlap, and in areas susceptible to accumulation such as seafloor depressions and areas of high seabed rugosity (depositional 'hotspots' both within and outside of the

[37] Above n 22, at p 44.
[38] Above n 22.
[39] Above n 22, at p 23.
[40] Above n 22, at p 24.
[41] Above n 22, Executive Summary, at p ii.
[42] Above n 22, at p 36.

modelled footprint)[43]. Increased dissolved nutrients causing increased algal growth is unlikely at this site, given the water depth.

e. The spatial extent of organic material dispersion is likely to be in the order of kilometres from the modelled footprint boundary, from transport of farm-derived organic material through sediment resuspension processes[44].
f. Seabed conditions in the most affected area will be characteristic of moderate enrichment[45]. This is because of the water depth and current speed providing for more dispersal of material.
g. Infaunal communities will grade to background conditions with increasing proximity from the edge of the modelled footprint[46].
h. Habitats of high ecological value will likely be subject to mild enrichment, and sublethal effects could also occur from chronic exposure. It is possible that small proportions of these habitats will be subject to moderate levels of deposition (depositional hotspots)[47].
i. The site is suitable for the farm proposed (as it is not anticipated to push environmental limits[48]).

The recommendations in this report will be implemented (including the adaptive management conditions). Refer to the conditions at **Appendix B**.

6.2 Water Column

Cawthron Institute have also prepared a report addressing potential effects on the water column from the proposed farm[49]. This report is provided at **Appendix E**.

The focus of the report is on assessing the following potential effects from the farm (including potential flow on effects)[50]:

a. Dissolved Oxygen (primarily associated with fish respiration);
b. Nutrient Enrichment or Loading (associated with the addition of feed and production of fish wastes and associated changes to phytoplankton species composition and abundance, such as increased algal blooms);
c. Submerged artificial lighting (on the physical environment and zooplankton communities).

For a summary of the above effects, refer to the table in the Executive Summary of the report[51].

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[43] Above n 22, "Box 2. Summary of effects from the initial proposal", at p 23.
[44] Above n 43.
[45] Above n 43.
[46] Above n 43.
[47] Above n 43.
[48] Above n 22, at p 45.
[49] E. Newcombe, B. Knight, M. Smeaton, H. Bennett, L. Mackenzie, M. Scheel, R. Vennell, C. Campos, "Water Column Assessment for a Proposed Salmon Farm Offshore of the Marlborough Sounds", Report No. 3313, June 2019.
[50] Above n 49, Executive Summary, at p i.
[51] Above n 49, Executive Summary, at p iii.

The report also looks at whether the proposed site is suitable for the farm. It concludes that it is[52]. The report states that: "we consider that this site presents lower risks of adverse water column effects when compared to inshore sites"[53].

Regarding the potential for cumulative effects on the water column from the farm, the report considers the potential for farm relocations but finds that cumulative effects would be a "worst-case scenario for the fate of nutrients from the offshore proposal, as it considers the potential for offshore farm nutrients to interact with existing nutrient pressures in a region where high phytoplankton biomass events occasionally occur and where recent HAB events have occurred"[54].

The report concludes with recommended mitigation measures for managing the potential effects on the water column.

Specific Effects on the Water Column

The report also looks at how tides and currents may be affected. This is important because "currents and bathymetry are important factors determining the dispersion and dilution of farm wastes through the water column"[55]. The summary is that there will be a large flushing of food, wastes and nutrients from the farm out of the site, and that such would not cause excessive accumulation. Nutrient enrichment will be localised[56].

Effects based on waves at the site can be managed through appropriate siting of the farm structures and suitable engineering of structures. The report finds that any attenuation effects will be localised, given the small scale of the proposed farm relative to the surrounding environment[57].

The potential effects on the water column from a farm such as the one proposed are:

a. Reduced concentrations of dissolved oxygen to levels that affect biological processes. Reductions in dissolved oxygen levels at the site is less likely to occur, given the offshore environment with substantial flushing[58].
b. Increased concentrations of dissolved nutrients. The main concern is for the creation of algal blooms[59]. This is a localised effect[60]. Effects of this nature will be greatest nearer the farm and will gradually decrease with distance as a function of mixing and dilution. The nature of this site in waters where turbulent mixing and strong currents occur increases the rate of dilution of nutrients such

[52] Such as at above n 49, pg 20, and at 8.1 on pg 59.
[53] Above n 49, at p 49.
[54] Above n 49, at p 50.
[55] Above n 49, p 13
[56] Above n 49, at p 20.
[57] Above n 49, at p 20.
[58] Above n 49, at p 6.
[59] Above n 49, at p 5.
[60] Above n 49, at p 10.

as nitrogen[61]. This reduces the risk of algal blooms occurring at this site[62]. In any event anticipated nitrogen changes from salmon farming at this site would be localised[63].

c. Phytoplankton growth. This can occur from increased nutrient levels, but as an effect it is limited in space and time and less likely to occur given the hydrodynamic conditions at this site do not favour the development of phyto-flagellate blooms (see above consideration of nature of this site). Again, given the open ocean nature of this site, risk of such occurring is reduced (as such growth most likely to occur in sheltered, enclosed waters)[64].
d. Attraction of phototaxic organisms (from submerged artificial lighting). The effect of such will be reduced by the small spatial footprint of the lights on the farm, and the inability of small organisms to maintain their position within high currents[65]. Effects of artificial lighting on benthic settlement of planktonic organisms is expected to be very small[66].
e. Vertical migration and benthic settlement of planktonic organisms. These will be highly localised and can be mitigated by positioning of the farm in high currents[67].

The report provides for recommendations regarding how to manage the above potential adverse effects (including through adaptive management proposed)[68].

6.3 Navigation

NZ King Salmon has commissioned Navigatus Consulting Limited to prepare a report to assess potential effects on navigation from the proposed farm[69]. The report is provided at **Appendix F**. The report has been prepared to adhere to the internationally established process for risk assessments as set out in AS/NZS ISO31000: 2009 (Risk management) and the associated AS/NZS HB 89 (Risk analysis). The report also incorporates the requirements and guidance in the Maritime NZ Guidelines[70].

The risks to navigation are the risks or hazards to marine craft and vessels, associated maritime activity, and the hazards to farm staff from vessels operating nearby[71].

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[61] Above n 49, at p 5.
[62] Above n 49, at p 12.
[63] Above n 49, at p 49.
[64] Above n 49, at p 40.
[65] Above n 49, at p 59.
[66] Above n 49, at p 60.
[67] Above n 49, at p 60.
[68] Above n 49, at Section 9.
[69] D. Gibbs and J. Spinetto, Navigatus Consulting Ltd, "North Marlborough Far Development Navigational Risk Assessment", 24 June 2019. This is a draft report. The final report will be sent to MDC as soon as available.
[70] Maritime New Zealand, "Marine Farm Guidelines: Navigational Safety", Wellington, New Zealand, 2018.
[71] Above n 69, at p 3.

The report begins by recognising the nature of an open ocean farm:

The key in the design requirements of the farm structures and the whole development is driven by the fact that the farms must operate in the more energetic and demanding coastal conditions versus the more traditional farm locations within sheltered inlets, bays, or sounds. This requires that the farms are able to be secured in deep water and able to withstand higher sea states than has been the norm to date. It also results in the farms being located nearer to large vessel routes and activity.[72]

The farm is located in the vicinity of three vessel transit routes. They are categorised as follows:

a. *Inshore coastal route* – The traffic following the natural transit route created by the dangers extending from Cape Jackson and the entrance to Pelorus Sound.
b. *Coastal transit route* – The traffic following the natural transit route from the North of Stephens Island and the entrance to the Cook Straight, passing to the South of Witts Rock and the North of McManaway Rock.
c. *Offshore transit route* – The traffic following the natural transit route from the North of Stephens Island and the entrance to the Cook Straight, passing to the North of Witts Rock.

The report finds that the farm provides the following benefits:

a. The farm will be a known location (with real and virtual navigational markers), so there is a benefit to mariners in identifying their location in the Strait, making the farm an aid to navigation; and
b. The farm could be fitted with an automatic radio weather reporting station and thus give significantly improved real-time navigational information to all mariners – in particular for local fishing and commercial vessels, as well as recreational traffic.

The report finds that the risks posed to navigation the farm are those risks that fit into the following categories: the farm creating a hazard for collision, allusion, and grounding[73]. These are detailed in the report at 5.1.2 (Collision)[74], 5.1.3 (Allusion)[75] and 5.1.4 (Grounding)[76].

In terms of existing vessel use at the site:

a. There is evidence of light to moderate commercial fishing in the waters in close proximity to the proposed site (the majority of commercial fishing in the general area occurs close to Port Ligar and to the North East of the site).

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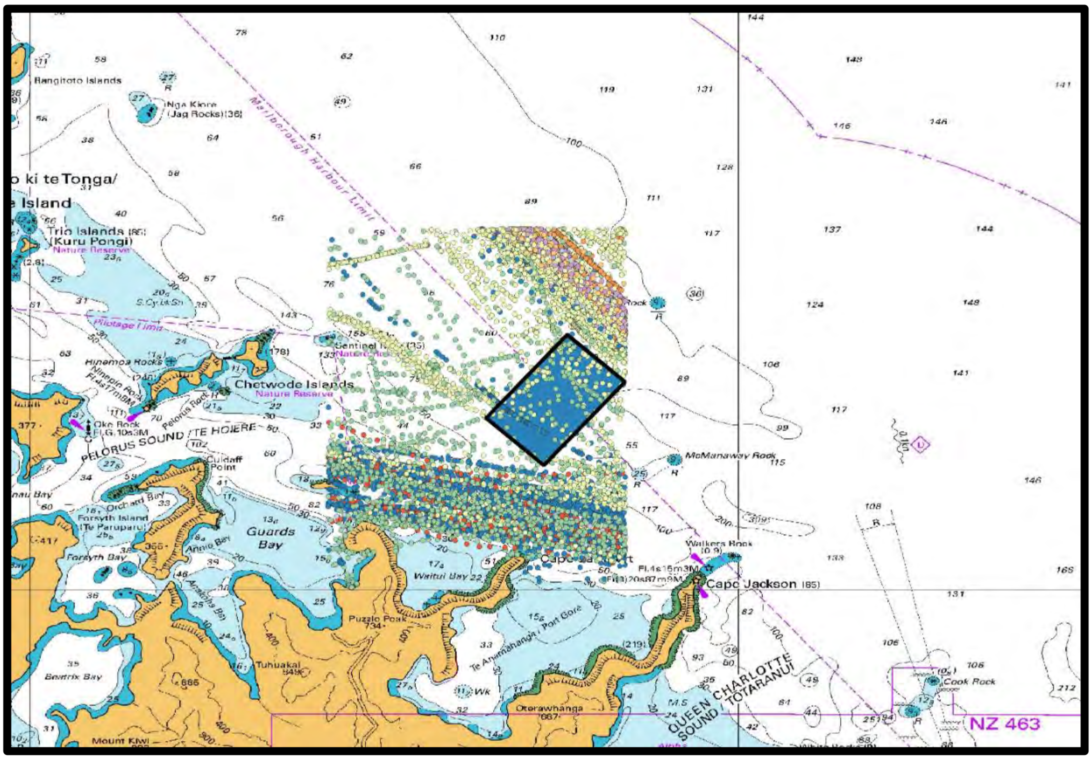
[72] Above n 69, at p 1.
[73] Above n 69, at p 24.
[74] Above n 69, at p 25.
[75] Above n 69, at p 26.
[76] Above n 69, at p 27.

b. Charter fishing vessels primarily visit the waters to the South of the site, and around Port Gore. There are fewer charter fishing vessels operating around near the proposed site compared to commercial fishing vessels.
c. There is some fishing activity in and around the proposed site, but not as much that which occurs to the north and south of the site.
d. There are many safe harbours in the area for vessel anchoring, and as such the farm is not considered to cause an effect on vessels intending to anchor in this general part of Cook Strait.
e. In terms of any anticipated future increases in traffic around the area of the site, the report finds that:
"*Any additional traffic levels over current can be expected to follow the same natural transit lines already observed in the area and so there will not be any new impact as a result of the proposed farm being in the location.*"[77]

f. Any traffic generated by the vessels servicing the site will for part of the generic vessel traffic in this area, and will not have a significant impact on the current traffic volume in the area.



The above graphic is Figure A.2 in the report[78]. It shows the existing vessel traffic (all vessel types) in and around the proposed site (that being the black-bordered parallelogram). Cargo, passenger, container, bulk, barge and working vessel movements have occurred outside the proposed site. It is mainly recreational and fishing boat uses that have occurred at the site area. These vessel movements are

[77] Above n 69, at p 22.
[78] Above n 69, at p 37.

sparser than those vessel movements around the site (particularly to the north and south). This is explained in detail at section 4.5.4 of the navigation report[79].

The report states[80]:

"*The extent of the area boundaries to the North is approximately 1200 metres from the natural large ship transit route and 500 metres from the transiting fishing vessel route, and approximately 1200 metres from the majority of traffic in the coast route to the South. There are some examples of vessels not conforming to the traffic norms and transiting as close as 500 metres to the south of the proposed area.*"

Mitigation of risk can be undertaken (and is proposed in the conditions found at **Appendix B**). One such mitigation is to make the farm visible to mariners. The farm will be lit in accordance with the Harbourmaster's requirements, and shall be installed so as to ensure that mariners can see and discern the location and extent of the farm area/structures to prevent undue navigational risk[81]. Regular maintenance of the farm and structures will assist with this. The proposed site boundaries were amended to minimise impact on known fishing operations near Sentinel Rock. Other mitigation is to factor into the design of the farm structures the reduction of risk to small vessels operating near the farm, by[82]:

a. Ensuring that all dangers to surface navigation of a vessel with a draught of 5 metres are to be marked by a special mark (in accordance with Maritime NZ Guidelines[83]); and
b. Ensuring that no dangers to surface navigation of a vessel with a draught of 5 metres outside buoyed extent, no dangers to surface navigation of a vessel with a draught of 10m within 100 metres of buoyed extent, and no dangers to surface navigation of a vessel with a draught of 20m, within 400 metres of buoyed farm extent.

Another important mitigation of navigational risk measure has been to position the proposed farm so that it runs parallel to the general direction of traffic flow.

The above are incorporated in the proposed conditions at **Appendix B**. Overall, the recommendations in this navigation report are to be implemented. A Navigation Risk Reduction and Management Plan will be prepared to minimise risks as far as is practicable at the site.

The report states that when mitigation is applied to the site/farm, there are three residual risks to be addressed. These are:

a. Vessel collision near the proposed farm (the risk being assessed as being as low as is reasonably practicable to achieve at the site);

[79] Above n 69, at pp 19 to 21.
[80] Above n 69, at p 22.
[81] Above n 69, at p 16.
[82] Above n 69, at pp 13-14.
[83] Above n 70.

b. Operational or maintenance vessel making contact with the farm (the risk to be reduced if factored into the design of the farm structures – which it will be – and as such the risk will then be as low as is reasonably practicable to achieve at the site); and
c. Vessel under control grounds and vessel not under control grounds (being reduced to a level as low as is reasonably practicable to achieve at the site).

The report concludes by finding that:

"*The risks that have been identified may be adequately managed and in doing so provide a number of benefits to mariners in the surrounding area*."[84]

6.4 Marine Mammals

The application site is not within a mapped dolphin area in the MEP.[85] It is partially within the Marine Mammal Whale area shown at MEP Map 17. The applicant has engaged Cawthron Institute to prepare a report assessing the potential effects on marine mammals from the proposed activity[86]. This report is provided at **Appendix G**.

Overall the report acknowledges that there are information gaps regarding effects on marine mammals from this type of proposed activity:

As noted in a recent global review by Price et al. (2017), there is currently very little information on how marine mammals might perceive farm structures within the open ocean environment, and even fewer data that can adequately inform the possible consequences of their responses.[87]

Given the above, the assessment of effects in the report is largely based off predictions.

The report considers that the proposed site would most likely affect the following species[88]:

a. Common, Bottlenose and Dusky dolphins;
b. New Zealand fur seals; and
c. Southern right and humpback whales.

The report finds that effects could occur for southern right and some humpback whales given the area potentially constitutes a winter habitat for such species[89]. The report acknowledges that the proposed site area "represents a very small fraction of

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[84] Above n 69, at p 35.
[85] MEP Volume 4, Marine Mammal (Dolphin) Map 18.
[86] D. Clement, D. Elvines, "Marine Mammal Assessment for a Proposed Salmon Farm Offshore of the Marlborough Sounds", Report No. 3316, July 2019.
[87] Above n 86, at p 14.
[88] Above n 86, at p 30.
[89] As above.

the total habitat available to support these marine mammal species"[90]. The report also considers effects on bottlenose dolphins, Hector's dolphin and orca.

In summary, the report considers that the most likely effects on marine mammals from the proposed farm/site are:

a. Possible habitat displacement (limited information to assess actual effects);
b. Entanglement risk (considered low risk for all species);
c. Noise (considered to have nil to negligible effect on all species);
d. Effects from artificial lighting (considered as small and localised effects);
e. Trophic flow on effects (considers that even if there are some localised effects on prey resources, they are likely to have a nil to negligible effect on the relevant marine mammal species).

To avoid, remedy or mitigate potential adverse effects above, the applicant proposes to:

a. Prepare and operate under a site-specific Marine Mammal Management Plan (MMMP); and
b. Comply with recommended best practice for the set up and operation of the farm to further reduce risk of any adverse effects on these marine mammals.

Other key points from the Cawthron report are:

a. Risk of adverse effects on marine mammals is low[91].
b. It is not certain how marine mammals will perceive and react to the proposed farm. Mitigation of risk is important[92].
c. There is no evidence that the proposed site is considered ecologically more significant in terms of feeding, resting or breeding habitats for any particular species relative to other areas of the outer Sounds or the greater Cook Strait region. The site is actually a small fraction of offshore habitats available to support the identified marine mammal species. The most likely effects will be on southern right whales and humpback whales. We do not have a complete picture on where the majority of whales tend to pass through once past the Tory Channel headlands to assess what effects the proposed farm at the proposed site might have on these species.
d. As shown in Table 2 of the report[93], any potential effect on marine mammals from the proposal are at worst less than minor (with all others being either negligible or nil).

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[90] Above n 86, Executive Summary, at p i.

[91] Above n 86, at p 30: "Based on the direct and indirect potential effects highlighted in this report, the overall effects of the salmon farms on marine mammal species within outer Marlborough Sound waters are assessed as less than minor when considered with the recommended mitigation actions."

[92] As above.

[93] Above n 86, at p 29.

e. The risks of adverse effects on marine mammals from the proposal are all able to be mitigated, remedied or avoided. The applicant will give effect to section 4 of the report ("Mitigation").

The conclusion is that potential effects on marine mammals from the proposed activity will be less than minor[94]. Proposed Conditions require the creation of a Marine Mammals and Shark Management Plan for the site (see **Appendix B**).

6.5 Seabirds

NZ King Salmon have commissioned a report on effects on seabirds from the proposed activity[95], which is at **Appendix H**. The report has been prepared by Dr Rachel McClellan of Wildland Consultants Limited.

The report addresses the type of bird species which are likely to visit/use the general location of the proposed farm, and evaluates the importance of the proposed site to those species. The report then considers the risks to those species of the proposed farm and provides recommendations (including the creation of a Seabird Management Plan). The recommendations are considered to mitigate, remedy or avoid potential adverse effects on seabirds.

Dr McClellan first identifies that (using the eBird database) the most likely seabirds to be found in the area of the proposed site are:

a. Blue penguins;
b. Albatross;
c. Petrels (including Cap Petrel) and shearwaters (including Fluttering Shearwater, Sooty Shearwater, Flesh-Footed Shearwater and Hutton's Shearwater);
d. Fairy prion;
e. Australian gannet;
f. Shags (possibly including King shag, although the site is beyond the diving range of the species);
g. Gulls and skuas; and
h. Terns.

Dr McClellan then considers the specific potential effects the proposed farm could have on those species. She finds that the potential effects on seabirds from "feed-added" fish farms are:

a. Habitat exclusion;
b. Smothering of benthos;
c. Changes/reduction in abundances of prey;
d. Provision of roosts;
e. Disturbance;

[94] Above n 86, at p 30.
[95] R. McClellan, "Potential Effects on Seabirds of Open Ocean Fish Farming, Cook Strait", Contract Report No. 4594, June 2019.

f. Ingestion of foreign objects;
g. Entanglement; and
h. Collision with farms/structures.

Habitat Exclusion

For habitat exclusion, Dr McClellan's conclusion is that there will remain the option for some seabirds to still get food from the area of the farm below the farm itself. Further, she finds that the site represents a "very small proportion of the foraging areas of seabirds that use such areas"[96]. Effects on all species identified above, in this regard, is considered negligible.

The only possible exception is for the King Shag, given that the King Shag exclusively live in the Marlborough Sounds. Potential effects of habitat exclusion on King Shags are considered limited though, given that: studies show King Shags generally forage within the Sounds and not out in the open ocean where the proposed farm will be; the site is beyond the depth that King Shags are thought to be able to dive. As the birds are thought to be species which feed generally on the sea floor, the site is thought to be outside of the feeding range of the Shag. That annotation is contentious. It is subject to a series of submissions. Those submissions have been heard but not determined by the Council. The weight which can be given to that annotation is consequently low. In summary, Dr McClellan concludes that effects on King Shag from the proposed farm "would be low to negligible"[97].

Smothering the benthos

In terms of effects on smothering of the benthos, Dr McClellan summarises that farms such as the proposed one produce waste in the form of fish feed loss outside the farm, and fish faeces. These can smother the benthos, in turn potentially changing the availability of food sources for seabirds. However, risk of adverse effects on seabirds in this regard are considered limited given:

a. The depth (and turbidity) of the water at this site is such that it is likely beyond the foraging range of most seabirds which dive for food. The King Shag may be capable of diving to such depths but given the summary above in her report, Dr McClellan still concludes potential effects are still low on the King Shag given current data shows it's most likely King Shag forage closer inshore (and this site would only be a small portion of their overall foraging range anyway).
b. NZ King Salmon records at its other salmon farms demonstrate low levels of feed loss. Low levels of feed loss means less of a potential effect on the benthos and in turn less of a potential effect on seabirds and their food supply.

Given the above assessment, Dr McClellan considers potential effects on smothering the bethos are "likely to be minimal"[98].

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[96] Above n 95, at p 19.
[97] Above n 95, at p 20 .
[98] Above n 95, at p 20.

Changes/reduction in abundances of wild fish populations/prey

Dr McClellan explains how wild fish may be attracted to the farm. If fish are attracted to the farm in any significant number, it is likely seabirds will be too. There are some positive potential effects of the farm for wild fish numbers and in turn for seabirds:

a. Studies show that wild fish presence at marine farms can significantly decrease the amount of waste food reaching the sea bed. That in turn reduces effects of smothering the benthos.
b. Farms can increase regional fish biomass and maintain fish stocks beyond the farm too. This in turn can benefit the fish themselves, and any seabirds who consume them.

There could be adverse effects to seabirds from increased wild fish at the farm, because it is likely to attract seabirds to the farm and thus potentially pose risks to seabirds in terms of collisions with structures and/or entanglement and/or ingestion of artificial objects.

Dr McClellan concludes that given low feed loss anticipated at the proposed farm, it is likely that attraction of wild fish to the farm (and with it potential adverse effects) is less than overseas farms (from which most of the data is obtained).

Provision of roosts

Dr McClellan states this is generally a positive effect for seabirds. The farm structures could provide spaces for seabirds to rest and possibly have protection from predation. However, as with the assessment of wild fish above, it is possible that potential adverse effects to seabirds could occur from the risk of collisions with structures and/or entanglement and/or ingestion of artificial objects. Effects in this regard are considered most likely limited to: the Spotted Shag, Red-Billed Gull, Black-Billed Gull, Southern Black-Backed Gull, White-Fronted Tern (and possibly the Caspian Tern and Black-Fronted Tern too) and possibly Skua species.

She concludes that buoys, markers and lights generally provide roosting sites for seabirds however that is less likely at this site given these structures/the amount of them will be limited at this site.

Disturbance

Dr McClellan then turns to consider the likelihood of general adverse effects of disturbing seabirds from the proposed farm. She finds that effects of this nature are limited by the site being remote.

Boats travelling to, from and around the farm could disturb seabirds, particularly the King Shag.

In conclusion, Dr McClellan finds that effects in this regard can be limited if boats maintain reasonable distances from coastlines, particularly where there are known seabird roosts and colonies. The site being away from the coast likely means that boats travelling around the farm will have less effect in terms of possible seabird disturbance.

Foreign objects and debris

The risk of adverse effect to seabirds here is the risk seabirds will ingest foreign/artificial objects or debris at the farm. She concludes here that:
"*It is likely, however, that small plastic debris from fish farm operations will comprise a tiny fraction of what is lost to sea from all anthropogenic sources, but it nevertheless poses a risk*[99]".

This risk is mitigated by the Seabird Management Plan to be prepared for the site including the risk and how it can be reduced in practice during operations at the farm.

Entanglement

This is considered to be a main risk to seabirds from the proposed farm. The risk is for seabirds who visit the farm to become entangled in farm infrastructure (e.g. ropes and predator nets) which could be potentially fatal. However, this risk has been considered low for aquaculture farms in New Zealand[100]. Dr McClellan reviews overseas data on seabird entanglement at aquaculture farms, and ultimately concludes that for the proposed site (based on an "above the water" farm):

a. For gull species: the risk of entanglement presents a low effect on local populations and a negligible effect on national populations for the Southern Black-Backed Gull. For the Red-Billed Gull and Black-Billed Gull, effects could be greater given their statuses as "At Risk-Declining" and "Threatened-Nationally Critical" respectively.
b. For shag species: the risk to King Shag is similar for Red-Billed Gull and Black-Billed Gull, given its status is "Threatened-Nationally Endangered)". For Black Shag, Pied Shag and Spotted Shag, effects at a national scale are unlikely. For the Little Black Shag and the Little Shag effects are low, given they are not common in Cook Strait or the Marlborough Sounds.
c. For petrels and shearwaters: the effects are considered low given they are unlikely to have national population consequences for these species, given their mostly large population sizes.
d. For Terns: risk is somewhat unknown but will depend on the rate of entanglement and ability of the local population to absorb any loss.
e. For Albatross and Mollymawks: the risk of entanglement is likely to be very low.
f. For penguins: risk needs to account for the fact that given the depth of the water at the site it is unlikely penguin would undertake benthic foraging here.

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[99] Above n 95, at p 24.
[100] Above n 95, citing Sagar (2012), Butler (2003) and Lloyd (2003) at p 25.

g. For gannets: at a local level risk of entanglement could have effects on population stability.

Overall, Dr McClellan concludes that entanglement risk can be mitigated through the type of farm structure proposed (e.g. an “above the water” fortress vs a submerged one), and management of debris and maintenance of farm structures at the site. This will all be included in the Seabird Management Plan for the site.

Collision with farm structures

Given the nature of the type of farm proposed Dr McClellan considers risk of this is lessened. She finds that:

“The extent to which an open ocean marine farm will pose a collision risk to seabirds will depend on a number of factors:

• The amount of lighting required to ensure visibility of a farm at night to boats and ships, and the brightness or lumens of the lighting.

• The degree of attraction exhibited by individual bird species to light. For example, the smaller petrel and prion species are more likely to be attracted to lights. Nevertheless, larger species can still be affected (Westland petrel have been found disorientated in the township of Westport, pers. obs.).

• Whether a seabird species will forage at night (for example, some shearwaters, petrels and gulls).

• The degree that the marine farm acts as a source of food for seabird populations.

• The structure of a marine farm, such as size, height, and visibility (for example, overhead wires are less visible than larger structures).[101]

Overall, the report concludes that the effects of the proposed farm on seabirds are generally low in probability (i.e. likely to have “minimal effect”) and able to be mitigated, remedied or avoided, such as through the adoption of a site-specific Seabird Management Plan.

6.6 Sharks

NZ King Salmon has asked Paul Duffy to comment on potential effects on sharks from the proposed farm. These comments are provided at **Appendix I**.

The most common large pelagic species in the area of the proposed farm are common thresher shark, shortfin mako, porbeagle and blue shark. There is potential for interactions with protected great white sharks in all areas, and basking sharks off the east coast South Island, particularly off Canterbury[102].

[101] Above n 95, at pp 30-31.
[102] M.P. Francis and C. Duffy, “Distribution, Seasonal Abundance and Bycatch of Basking Sharks (Cetorhinus Maximus) in New Zealand, with Observations on their Winter Habitat”, Marine Biology (2002), 140, pp 831-842.

Potential effects on sharks are also considered in the pelagic fish report prepared for the application[103] (and discussed in more detail below).

NZ King Salmon has an existing Marine Mammal and Shark Management Plan for its sites at Ngamahau, Kopaua and Waitata. A similar Plan will be created for this site. This will provide the management strategy for potential effects.

6.7 Pelagic Fish

Paul Taylor and Dr Tim Dempster, of Statfishtics and the University of Melbourne respectively, prepared a report on the effects of salmon farming on plant and fish fauna of the area north-west Cook Strait managed options for avoiding mitigating adverse effects[104]. This report is provided at **Appendix J**.

Any structure in the marine environment will aggregate fish. Typically, those effects are more marked in large shallow water sites which are close to the coast. While the site will be relatively large, it is neither in shallow water nor close to the coast, and consequently the effects of fish aggregation are predicted to be less than that experienced in initial sites.

Wild fish associated with salmon farms may be able to consume feed intended for the salmon themselves. Wild fish consume more food around fish farms than they do in their natural environments. Where food is lost from net pens that food can also be eaten by wild fish. Feed is NZ King Salmon's greatest cost. Consequently, NZ King Salmon monitors feeding in its pens closely. It has managed to virtually eliminate all feed being lost from its pens. Consequently, while this might be an issue in overseas jurisdictions, it will not be an issue on this site. Little to nil feed loss reduces attraction of sharks to the farm and in turn reduces risk of adverse effect on sharks.

Wild fish which has access to feed intended for the salmon could in theory be exposed to heavy metals and other contaminates within the feed. However, in New Zealand, feed is closely monitored to ensure that heavy metal or organohalogenated compounds do not enter the environment at anything approaching problematic levels. More detail can be found in relation to that in Appendix C of the report.

Internationally, there are examples of the transfer of parasites between wild fish and farmed fish. These issues are addressed in Appendix L of the report. Because the salmon is not a native species, such issues have not arisen in New Zealand to date.

If a fish aggregation device is fished, it is possible that wild fishery will be impacted unsustainably. The presence of the pens, barges and moorings in practical terms, prevents most forms of fishing in and around the sites. Consequently, while a formal

[103] Below n 104.

[104] P. Taylor and T. Dempster, Statfishtics and University of Melborne, "Effects of Salmon Farming on the Pelagic Habitat and Fish Fauna of an Area in North Western Cook Strait and Management Options for Avoiding, Remedying, and Mitigating Adverse Effects", July 2019.

fishing exclusion zone is not proposed, in practice the farm will prevent some form of fishing in the immediate vicinity of the pens.

Commercial and recreational fishing activity near the site is low. As a consequence, the presence or absence of the farm will make little difference to fishery (see the navigation effects assessment above at section 6.3). Farming in the way proposed will potentially displace fish from the small area in the immediate vicinity of the pens. There will, however, be a small positive benefit to a much larger area surrounding that. The overall effect of the farm will be small. That effect may be either neutral or positive.

Salmon farming may attract local resident sharks. NZ King Salmon proposes a shark management plan to minimise any attraction which the farm has for sharks and minimise the risk of any entanglement.

In theory, threatened or at risk wild fish species may be present at the site. All are endemic and diadromous (i.e. migrate between the sea and fresh water) and, according to the best available information, are found in the Marlborough Sounds. Little information is available from the marine phase of the species, but given the non-aggregation behaviour that appears to be characteristic of them during that phase, vulnerability to any marine farm is expected to be low.

The conditions of consent require the consent holder to establish a wild fish management plan. That plan provides for methods to be trialled in respect of the first set of net pens installed on the site and then a formal study undertaken in respect of the second set of net pens installed on the site. If a craft is being imported from beyond New Zealand, it is subject to the Craft Risk Management Standard, pursuant to s24G of the Biosecurity Act 1993. All vessels operating in Marlborough are subject to the Marlborough Pest Management Strategy.

6.8 Biosecurity

The applicant has commissioned a report on biosecurity effects (the biosecurity report)[105] from the proposal, which is at **Appendix K.** This report has been prepared by Lauren Fletcher of Cawthron Institute. The report provides a comprehensive assessment of the effects on biosecurity matters anticipated from the proposed farm. The assessment includes the potential for marine pest species to be introduced to, and/or spread within, the wider Marlborough region from the proposed farm. The report also provides recommendations to avoid, remedy or mitigate potential adverse effects.

The summary of anticipated effects is as follows:

"…the associated additional vessel, gear and stock movements, plus the provision of novel habitat, are expected to present a minor incremental biosecurity risk to the

[105] L. Fletcher, "New Zealand King Salmon Company Limited: Open Ocean Farm Assessment of Environmental Effects – Biosecurity", Report No. 3222, June 2019.

region. Considering the amount of vessel traffic that already occurs in the area and the management practices already in place for existing company vessels, biosecurity risk associated with vessel movements is expected to be minor.

...If the proposed mitigation measures are implemented appropriately, the residual biosecurity risk is expected to be negligible[106].”

The report acknowledges that “it is important to place risks [from the proposed farm] in the context of those that already exist”[107]. There are biosecurity risks that arise from other activities in the coastal environment which already take place, and through natural processes.

It is to be noted that the greatest risk is considered to be from non-NZ King Salmon vessels that visit farm from outside region on one-off basis. These will be subject to national regulations those vessels would need to comply with[108]; and might need to be aware of NZKS practices. This is the biggest risk from a biosecurity perspective but it can be managed or mitigated.

To manage any risk of biosecurity issues arising from the proposed activity (even though the biosecurity risk is considered to be “relatively minor”, particularly due to “the geographical isolation of the site”[109]), NZ King Salmon will adopt best management practices as recommended in the biosecurity report (including compliance with existing national regulations for hull biofouling and ballast water discharges). The best management recommendations will be tailored to the site and will be developed by a suitably qualified person to address both marine pest and disease risk.

The key mitigation measures proposed to address potential biosecurity risks are:

a. Compliance with national-level hull biofouling and ballast water legislation;
b. Compliance with a site-specific Biosecurity Management Plan (BMP) which will address both marine pest and disease risk;
c. Maintenance of vessels used to service the farm (to prevent growth of biofouling or the accumulation of sediment or debris);
d. Cleaning regime for all equipment used at the farm before moving between farm sites;
e. Standard operating procedures that incorporate industry best-practice will be development and adhered to, for transporting stock;
f. Staff working at the farm will be familiarised with pest organisms or those which exhibit unusual patterns of population growth;
g. Maintenance of farm infrastructure (e.g. pontoons and nets) to prevent the establishment of large populations of pest species;

[106] Above n 105, Executive Summary, at p i.
[107] Above n 105, Executive Summary, at p ii.
[108] Marlborough Pest Maintenance Strategy or if importing Craft Risk Management Standards, s24G Biosecurity Act 1993
[109] Above n 105, Executive Summary, at p ii.

h. Accurate records of all vessels, equipment, gear and stock movements to, from and within the farm site shall be maintained; and
i. All staff working at the site will maintain awareness of any new biosecurity guidance or requirements issued by the Ministry for Primary Industries (MPI) or Aquaculture New Zealand (AQNZ).

The above will be incorporated within the Biosecurity Management Plan to be prepared (by a suitably qualified person) for the site.

6.9 Fish Disease

Dr Ben Diggles of DigsFish Services assessed the potential changes to disease risks associated with this proposal, in his report *Disease Risk Assessment Report – Open Ocean Salmon Farms Near Marlborough Sounds, New Zealand*, dated 20 February 2019. A copy is included at **Appendix L**.

Dr Diggles undertakes a comprehensive risk analysis covering 25 infectious agents and 12 non-infectious diseases of farmed salmon in New Zealand. He concludes that the proposed location is an appropriate open ocean farming area because:[110]

a. It will allow the creation of a third biosecure area, consistent with a move towards world's best practice;
b. It will allow the company to respond to current global warming trends;
c. The increased water depth and improved water quality will reduce the risk of outbreaks of NZ-RLO[111] and other infectious and non-infectious diseases; and
d. The site is located to reduce proximity to shipping.

A minimum 16km on-water buffer zone has been empirically proven to effectively mitigate risks of spread of bacterial disease agents and viruses.[112] A farm in this location will enable the creation of three independent farm management areas: the Queen Charlotte Sound Management Area (Clay Point, Te Pangu, Ngamahau, Ruakaka and Otanerau), the Pelorus Sound Management Area (Waitata, Kopaua, Forsyth Bay, and Waihinau Bay), and the Open Ocean Management Area.

The author recognises that new endemic diseases could emerge in the future, and that "an unquantifiable risk remains that biosecurity leaks could allow exotic diseases to be introduced." As a result, he concludes:[113]

> In view of current global warming trends which are likely to increase disease risks to the industry over time, the ideal situation of 3 sufficiently large independent farm management areas with regular synchronised fallowing of each area should be

[110] Diggles, B. Disease Risk Assessment Report – Open Ocean Salmon Farms Near Marlborough Sounds, New Zealand, DigsFish Services, 20 February 2019 at p 4.
[111] A *Piscirickettsia salmonis*-like bacterial disease agent, which remains the most problematic disease issue for the industry, particularly at NZ King Salmon's inshore farming sites with suboptimal low flow conditions.
[112] Above n 110, at p 4.
[113] Above n 110, at p 4.

considered the ultimate goal for future planning arrangements for the industry in the Marlborough Sounds region.

A separate biosecurity assessment was undertaken by Lauren Fletcher at the Cawthron Institute, as outlined above. The proposed conditions require NZ King Salmon to prepare and implement a Biosecurity Management Plan.

6.10 Fishing

The coastal marine area north of the Marlborough Sounds is used for commercial fishing.

NZ King Salmon advised commercial fishers, including Sanford Limited, Challenger Scallop Enhancement Co Limited, and Southern Inshore Fisheries Management Co Ltd, of its intention to lodge this application by way of letter dated 21 March 2019.

Alison Undorf-Lay advised that Sanford considers itself an affected party, as the application might prevent access to fishing grounds and/or interfere with fishing activities.

Mark Gillard of NZ King Salmon has also met and/or spoken with a number of fishing industry representatives on behalf of NZ King Salmon to discuss the proposed application.

A report by Paul Taylor and Dr Tim Dempster (**Appendix J**) reviews the available data from recreational, charter fishing and commercial fishing vessels. The amount of fish caught in this particular location is low. There is little evidence that there will be a material effect. Certainly that evidence demonstrates that there will be no effect on the ability to catch fish. Given the distance from shore and the depth of water it is less likely that this site will be a significant fishing aggregation device.

As show above at section 6.3, fishing at this site is less frequent than fishing around the site (i.e. to the north and south of the site). That will still be retained.

6.11 Iwi

NZ King Salmon have sought to consult with iwi in the preparation of this application. All relevant iwi were sent a consultation letter and map of the site on 21 March 2019, with a follow up email to all iwi sent on 3 April. The responses received to date are summarised in the table below:

Iwi	**Contact Person**	**Response**
Te Ātiawa o Te-Waka-a-Māui	Richard Prosch	Responses unclear, talks about our potential agreement and relocation 25 March and 4 May. Also asks a range of questions which will be

		satisfied with receipt of application documents.
Ngai Tahu	Kenya Calder	Response sought clarification that the site is not within Ngai Tahu Takiwa. That confirmation was sent. Ngai Tahu confirmed that the site area is not within their takiwa.
Te Rūnanga o Ngai Tahu (MACA)	Sarah Lomaloma	Advised that they had passed the correspondence on the relevant person(s).
Ngāti Koata	Loretta Lovell	Letter passed on to trust via contact person. Letter confirming support for the application received on 3 July.
Ngāti Toa Rangatira	Te Matiu Rei	Advised they wanted to meet to discuss, but no arrangements had been made.
Ngāti Tama Ki Te Waipounamu	Narissa Armstrong	Response was said to be sent from iwi after director's meeting on 11 April.
Rangitāne o Wairau	Nicholas (Nick) Chin	Re-sent consultation letter and map on 4 April. No response received.

The following iwi were sent correspondence inviting consultation (in March 2019, and then the follow up contact in April 2019), but did provide a substantive response.

Te Rūnanga o Ngāti Rārua
Ngāti Kuia
Ngāti Apa ki te Ra
Te Runanga a Rangitane o Kautuna Incorporated

The comments of those iwi who responded have been taken into account in this application.

NZ King Salmon has also consulted with other stakeholders. This is discussed below at section 8.

6.12 Landscape and Natural Character

NZ King Salmon has commissioned a report addressing potential effects on landscape and natural character from John Hudson[114]. This report is provided at **Appendix M**.

The report is split into three parts as follows:

a. Part A provides the Design Guide for the site;
b. Part B provides the description and characterisation of the existing environment; and
c. Part C provides the assessment of landscape and natural character effects of this application.

Given the nature of this application as being for a new type of activity in New Zealand, and given that the final structures have not as yet been chosen by NZ King Salmon, this report provides for a set of performance standards to manage the potential landscape and natural character effects the farm could potentially have.

The report begins by providing the assessment methodology which the report will follow. This includes reference to the NILA Best Practice Note: Landscape Assessment and Sustainable Management 10.1. The report also uses as guidance the Landscape documentation on the Quality Planning website[115].

The nature and scale of the proposed changes (often referred to as the magnitude of change) are assessed against the characteristics and values identified in the existing environment to determine the actual and potential effects the proposed changes will have on the existing qualities of the landscape.

The report utilises a seven point scale to rate effects on landscape and natural character. This scale is a continuum which consists of negligible effects up to extreme effects. The existing environment is placed into a scale as well, at the outset, as this enables a conclusion on landscape and natural character effects. The report provides this as "Table 2"[116]. This enables the existing level of landscape character to be determined (ranging from outstanding through to negligible). Further, both the magnitude of the change proposed (i.e. the activity proposed) and the sensitivity of the landscape to change are scaled[117], from extreme to negligible. That sets the methodology or framework used in the report to assess landscape effects from.

In terms of effects on natural character, the report uses Table 4[118] to determine the existing level of natural character as that helps to inform what the extent of

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[114] Hudson Associates, "Proposed Marlborough Offshore Salmon Farm", July 2019. Please note this report is current in draft form. The final version will be forwarded to MDC as soon as it is available.
[115] For example see: https://www.qualityplanning.org.nz/node/805
[116] Above n 114, at para 16.
[117] Above n 114. Here using Table 3 in the report, at para 17.
[118] Above n 11, at para 21.

potential effects on such could be. Existing natural character could be from outstanding to negligible. As with landscape scaling, to assess natural character effects both the magnitude of the change proposed (i.e. the activity proposed) and the sensitivity of the landscape to change are scaled[119].

In summarising Part A of the report, this part provides a design guide for NZ King Salmon to use when the structures for the site are considered. This part begins with this context: "the placement of structures in an area of open ocean is, in all cases, going to appear as an incongruous element within the otherwise uninterrupted ocean setting when viewed from nearby water based locations"[120]. Separation distance of the structures from shore is important, as "visual impacts generally diminish as viewing distance increases"[121]. NZ King Salmon here propose a distance of structures from shore of at least between 6km and 12km. The report finds that the benefit of additional separation from shore diminishes at distances beyond 5km[122]. The nearest dwelling to the site is at least 8km away.

Another mitigation measure is to choose subdued and recessive colour schemes, and non-reflective materials for the structures[123]. Other measures, such as reducing the height of structures above water surface[124] are to be factored into the design of the structures at this site. Overall, NZ King Salmon will use the design guide in considering structures for the site.

Part B discussing the relevant planning documents. The application site is not located within an area of outstanding landscape value in the Operative Plan. In the MEP, the application site:

a. Is partly (around 45%[125]) located in an area of high and outstanding natural character, although the recommendation from the s 42A Officer is to make the area of high natural character (not outstanding); and
b. Is located within an outstanding natural landscape.

The report states: "While I accept the recognition of the Sounds at a national scale, I cannot accept identification of this offshore salmon farm site as an Outstanding Natural Landscape or Feature at either the District or site scale"[126], though "the outer Sounds holds high scenic qualities and high amenity value"[127]. The report also finds that the natural character of this area has been modified by "places of

[119] Above n 114, at para 22. See table 5 also at para 22.
[120] Above n 114, at para 26.
[121] Above n 114, at para 35.
[122] Above n 114, at para 35.
[123] Above n 114, at para 37.
[124] Above n 114, at para 45.
[125] Above n 114, at para 69.
[126] Above n 114, at para 81.
[127] Above n 114, at para 96.

commercial trawling and scallop dredging which have compromised the natural state"[128].

The report then goes on to consider the associations and attributes with and of this general area of Cook Strait. The summary on existing landscape value is for a general ranking of moderate and for natural character the rating is high[129].

Overall, the conclusion on landscape and natural character effects are[130]:

a. The offshore location is removed from the highly valued Sounds landform (it is "far less scenic"[131]);
b. The offshore location softens perceptual (visual) effects through isolation and placement of structures within an expansive context;
c. Views of the farm will for the most part be transitory in nature from boat traffic;
d. Visual effects reduce with distance. As the site is remote, the effect is only on passers-by; and
e. Effects of lighting at the farm "is not considered significant enough to alter the appreciation of the night sky in this location"[132].

Part C looks more specifically at the proposal itself and looks at structures. This is where mitigation methods are recommended. Conditions to manage visual effects are provided at **Appendix B** and these incorporate the mitigation measures recommended at paragraph 142 of the report.

For example, NZ King Salmon offers a condition that all surface structures should be finished in non-reflective material (see **Appendix B**). Specific colours and types of material have not yet been determined. However, the structures will be able to be non-reflective to ensure they do not act like a mirror by reflecting light over long distances. It needs to be borne in mind that the site is remote and not in any close proximity to dwellings.

The conditions will manage visual effects, and the conditions work towards having the farm structures blend into the existing environment as far as is possible.

6.13 Public Access, Recreation and Tourism

NZ King Salmon has met and/or discussed the proposal with representatives of the Waikawa and Queen Charlotte boating clubs. Both clubs have expressed that they do not have any concerns with the application, and have asked what they can do to assist in the process of seeking consent for the farm.

[128] Above n 11, at para 87.
[129] Above n 114, at para 133.
[130] Above n 114, at paras 134, 148 and 149.
[131] Above n 114, at para 150.
[132] Above n 114, at para 151.

NZ King Salmon also sought to consult with the Pelorus Boat Club, however no response was received.

Limits on public access from the proposed farm is only to the extent necessary for the safe and efficient operation of the farm. The farm placement still allows for access around the farm. In the context of the amount of open ocean in the Outer Marlborough Sounds and Cook Strait, the farm exclusive occupation area is not considered significant. There are larger farms in New Zealand[133].

The use of the site is shown above at section 6.3 in the navigation assessment. Recreational activity, and tourism activity, all around the site will be retained. Given the use of the site in the past, it is not considered to have any impact on future use of this part of Cook Strait by granting this consent. The navigation assessment above at section 6.3 also confirms that any potential navigational effects from the site can be managed.

6.14 Economic, Social and Employment

The aquaculture industry makes a significant contribution to the New Zealand economy. Salmon farming is the second largest aquaculture activity by greenweight tonnage production and export revenues. Salmon farmed in Marlborough (all by NZ King Salmon) from 2009 -2014 accounted 60 -74% of the national salmon production.[134]

King salmon is the only species farmed in New Zealand. It is a rare and premium species of salmon, accounting for only 0.7% of the world's farmed salmon population. NZ King Salmon is the world's major supplier of this species, producing just over 50% of the world's supply. The majority of salmon farmed around the world is Atlantic salmon.[135]

NZ King Salmon envisages that farming in this open ocean location will increase the company's existing production by approximately 100%. That is, it will be roughly equivalent from the combined production of salmon farms in Tory Channel and Queen Charlotte Sound, or the combined production of NZ King Salmon's Pelorus farms.

The salmon farming industry makes a significant contribution to the New Zealand economy and plays a key role in the Government's growth agenda, along with the rest of the aquaculture industry. A recent report by PricewaterhouseCoopers (PwC),[136] commissioned by MPI as part of the Marlborough Salmon Farm Relocation

[133] Larger farms are: Golden Bay (Ringroad), Tasman Bay (Ringroad), Pegasus Bay.
[134] Clough, P. and Corong, E. *The economic contribution of marine farming in the Marlborough region: A Computable General Equilibrium (CGE) analysis* (2015, New Zealand Institute of Economic Research, Wellington) at 9.
[135] See https://www.kingsalmon.co.nz/our-salmon/our-king-salmon/, accessed 20 June 2019.
[136] Kaye-Blake, B. *Marlborough Salmon Relocation – Economic Impact Assessment* (2016, PricewaterhouseCoopers, Auckland). A copy is available here: https://www.mpi.govt.nz/dmsdocument/16051-marlborough-salmon-relocation-economic-impact-assessment-prepared-by-pwc

Proposal, provides an estimate of the annual economic impact per 100 metric tonnes (mt) of salmon production for the Nelson and Marlborough region.

The analysis found that "100 tonnes of net new annual salmon production can be expected to lead to approximately $0.45 million in increased annual value add or GDP in the Nelson and Marlborough regional economy, and would support approximately 4.7 FTEs annually."[137]

A rough estimate of the expected value of open ocean farming at this location can be calculated, based on the PwC analysis. Assuming 16,000mt of feed is discharged at this site, that would equate to approximately 8,000mt of salmon production. That would lead to approximately $36 million in value add or GDP for Nelson and Marlborough, and would support 376 FTEs annually (consisting of 240 direct FTEs and 136 indirect FTEs).

Significant resources have been expended in recent years in an attempt to better understand the substantial contribution that aquaculture typically makes to the communities in which it is based. MPI has released two reports on the subject.[138] In addition, in 2015 the New Zealand Institute of Economic Research (NZIER) released a report on the economic contribution of aquaculture to Marlborough.[139]

NZ King Salmon has an active and focused sponsorship and community support programme. The company supports various community organisations, charities and events with financial and product sponsorship. Geographically the sponsorship focus is on the Marlborough region, followed by the greater Top of the South and NZ King Salmon's freshwater locations in Canterbury.

Examples include (but are not limited to):

a. Sponsorship of the Graeme Dingle Foundation's Kiwi Can programme in Marlborough;
b. Provision of Chromebooks for Marlborough Girls' College Bring Your Own Device programme, as well as the school's netball team and End of Year Prize Giving;
c. Support of the Fifeshire Foundation;
d. Promotion of food tourism in the Marlborough region, for example with the 'Salmon Sounds and Songbirds' tours with Marlborough Travel, and partnership with Destination Marlborough;

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[137] At p 6. Those impacts are a total of direct and indirect impacts. 4.7 FTEs consists of 3 direct FTEs and 1.7 indirect FTEs.

[138] Quigley, R. and Baines, J. *The Social Value of a Job* (2014, Ministry for Primary Industries, Wellington); and Quigley, R. and Baines, J. *The Social and Community Effects of Aquaculture: A case study of Southland aquaculture* (2015, Ministry for Primary Industries, Wellington). These reports are available here: http://mpi.govt.nz/news-and-resources/publications/.

[139] Clough, P. and Corong, E. *The economic contribution of marine farming in the Marlborough region: A Computable General Equilibrium (CGE) analysis* (2015, New Zealand Institute of Economic Research, Wellington).

e. Support of the Marlborough-based Kaipupu Wildlife Sanctuary and Koru Native Wildlife Centre;
f. Support to Business and Industry groups, including sponsorship of the Institute of Directors, Nelson and Marlborough Chamber of Commerce, and the Aquaculture New Zealand Ltd Annual Aquaculture Conference; and
g. Development and provision of the Marlborough Salmon Farming School Resource.

NZ King Salmon's operations support the viability of a broad range of local supply chain businesses in various sectors, including science providers, road, sea and air haulers, MPI/customs officials, warehouse operators, overseas agents, restaurants, engineering, marine and domestic electrical, marine and other mechanical services, boat yards, local fuel companies, and local equipment manufacturers.

Employment with NZ King Salmon offers several benefits, including:

a. Wages or salaries that are above average in Marlborough, at approximately $60,000 per employee;
b. Good job stability with year round employment and casual staff opportunities during busy seasons;
c. Staff discounts and medical insurance;
d. Ongoing training and development, including in Health and Safety; and
e. Succession planning and internal promotion. For example the company's Farms Manager began as a freshwater technician.

6.15 Underwater Lighting

Underwater lighting within salmon farming pens has proven very successful at reducing instances of early maturation in King salmon and associated stock losses. NZ King uses underwater lighting at its inshore sites in the Marlborough Sounds. It is possible that underwater lights will be used at the proposal site.

A number of earlier reports and letters have assessed the effects of artificial lighting on the surrounding marine environment:

a. A 2010 assessment by Dr Chris Cornelisen, Cawthron Institute, of the effects of underwater lighting at the Clay Point and Te Pangu Salmon farms;[140]
b. An expert report in 2011, and subsequent evidence in 2012 in relation to the Board of Inquiry process, both by Dr Chris Cornelisen;[141]

[140] C Cornelisen "Effects of artificial lighting on the marine farm environment at Clay Point and Te Pangu Salmon Farms," Cawthron Report No. 1851 (October 2010).
[141] C Cornelisen "The New Zealand King Salmon Company Limited: Assessment of Environmental Effects – Submerged Artificial Lighting," Cawthron Report No. 1982 (August 2011); and Evidence of Christopher David Cornelisen dated 15 June 2012.

c. Dr Cornelisen's 2013 report assessing the use of underwater lighting at the Te Pangu salmon farm;[142]

d. A 2016 letter in respect of the consent application to use underwater lighting at NZ King Salmon's Otanerau Bay site in Queen Charlotte Sound;[143] and

e. A 2016 letter from Dr Cornelisen to MPI in relation to the Marlborough Salmon Relocation Proposal.[144]

In his latest 2016 letter Dr Cornelisen concluded:[145]

> "*The potential ecological effects of artificial underwater lighting include the following:*
>
> - *Phototaxic organisms such as zooplankton and larval fish may be attracted to the lights and accumulate near and/or within the farm structures.*
> - *Vertical migration in the water column by some phytoplankton and zooplankton species may be influenced by light (moving towards or avoiding it). There may also be enhanced settlement of organisms attracted by the light onto the seabed near farm structures.*
> - *Baitfish may be attracted to the lights and aggregate near and/or within illuminated cages. Visibility of prey during night-time hours will increase. Increased aggregation and visibility of prey could in turn increase rates of predation by the farmed salmon as well as fish and marine mammals (e.g. seals) outside the cages.*
> - *Submerged artificial lighting influences the depth distribution of salmon. Increased densities of salmon at a given depth could increase risk of parasitism.*
> - *Birds flying overhead may be attracted to the lights and as a result could collide or become entangled within the farm structures.*"

Potential effects on fish, seabirds, marine mammals, disease risk and biosecurity have been assessed separately, and are discussed above. Based on the conclusions in the site swap letter, the higher currents in the application area are likely to reduce the effects of underwater lighting on attracting and concentrating zooplankton and phytoplankton.[146] Modern technology means that lighting is more targeted and results in less spillage. Overall, the effects of underwater lighting are likely to be minor and highly localised.

Conditions have been proposed addressing lighting requirements, in particular managing risk of seabirds being attracted to the site. The conditions are at **Appendix B**. The lighting proposed is similar to that of the lighting at NZ King Salmon's existing farms.

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[142] C Cornelisen, R Forrest, and A Quarterman "Effects of Artificial Lighting on the Marine Environment at the Te Pangu Bay Salmon Farm," Cawthron Report No. 2374 (July 2013).

[143] C Cornelisen, Cawthron Advice Letter 0026, dated 18 January 2016.

[144] C Cornelisen, Cawthron Advice Letter 1626, dated 16 November 2016. A copy is available on MPI's Marlborough Salmon Relocation website, under the heading "Pelagic Fish, underwater lighting": https://www.mpi.govt.nz/news-and-resources/consultations/marlborough-salmon-relocation/

[145] C Cornelisen, Cawthron Advice Letter 1626, dated 16 November 2016 at 2.

[146] C Cornelisen, Cawthron Advice Letter 1626, dated 16 November 2016 at p 3.

6.16 Noise

The site is approximately 6km from land at the nearest point (Cape Lambert). The inshore-most part of the consent area is at least 8 km from the nearest dwelling in Port Gore. As a result, it is highly unlikely that farming operations will be audible from any residences, or from the shore. Effects on passengers on passing vessels would be less than minor.

In any event, NZ King Salmon offers a condition requiring it not to exceed a noise limit of 70 dBA LA_{eq} at all times, when measured no closer than 250m from any marine farm surface structure. Certain activities would be exempt from this standard:

a. Noise generated by navigational aids, safety signals, warning devices or emergency pressure relief values;
b. Noise generated by emergency work arising from the need to protect life or limb or prevent loss or serious damage to property or minimise or prevent environmental damage; and
c. Noise ordinarily generated by the arrival and departure of vessels servicing the marine farm.

This is consistent with noise standards for industrial activities in the MEP. Noise conditions are proposed at **Appendix B**.

6.17 Historic Heritage

There are no Heritage Sites mapped in the operative Plan or the MEP in the vicinity of the proposal area. The application will not impact on heritage values.

7 Conditions

A set of conditions are volunteered by the applicant to mitigate and control the potential for adverse effects. A copy of those conditions is included in **Appendix B**.

8 Notification and Consultation

In addition to the consultation with iwi discussed above at section 6.11, NZ King Salmon has undertaken pre-lodgement consultation with several stakeholders. This consultation is summarised in the table below:

Organisation	Contact person(s)	Response
Kiwi Rail	Rebecca Beals	Stated on 26 March concerns would be limited to navigational effects (i.e. Interislander navigation route). Confirmed no concerns with application

		on 28 March 2019 via email.
New Zealand Shipping Federation	Annabel Young	NZKS met with NZ Shipping Federation in Wellington on 9 April 2019. Follow up email of 12 April 2019 confirmed no concerns.
Marlborough Chamber of Commerce	Hans Neilsen	Wants to meet in Blenheim to discuss. NZ King Salmon is to meet with Hans on 10 July.
Challenger Scallop Enhancement Co Ltd and Southern Inshore Fisheries Management Co Ltd	Carol Scott and Doug Saunders-Loder	NZKS met with Carol 24th April 2019. Was to send details to her Board. No indication when we would hear back. Agreed limited fishing occurs in the area proposed. Sent site plan to Carol and Doug by email 14 June. Requested forward to Tony Hazlett.
Waikawa Boating Club	Sue van Velzen	Met with the Club's Executive Committee on 2 May 2019. No major concerns were raised. Club asked what they could do to help with the application.
Tui Nature Reserve	Brian Plaisier	Confirmed with Brian by phone that offshore is what we need to hear their view on.
Queen Charlotte Yacht Club	Ian Gardiner	NZKS had a phone call with Ian on 17 April 2019. No concerns were raised. Ian asked what they could do to help with the application.
Department of Conservation	Lionel Solly and Andrew Baxter	NZKS met with DoC on 3 May 2019, and again on 27 June. Draft expert reports were sent for their

		perusal and comment. A list of comments was produced. NZ King Salmon is addressing these.
Sanford Limited	Ali Undorf-Lay	NZKS had a phone call with Sanford on 3 May. Agreed to meet. Emailed copy of site plan 14 June. Emailed response to request for information 18th June.
Friends of Nelson Haven and Tasman Bay Inc	Rob Schuckard	Letter to NZKS received 3 April 2019. NZKS met with Rob on 20th May 2019 at Blenheim. Rob wanted to ensure the science was done on water column and benthos effects (which has been).
TOKM/IAWG	Laws Lawson	NZKS spoke over the phone and then followed up with an email to provide a copy of site plan then copy of list of reports being prepared as at 14 June.
Royal Forest and Bird Protection Society of New Zealand	Debs Martin and Andrew John	Invitation to meet to discuss provided, and another follow up email sent to Debs on 25 June 2019. Meeting on 2 July.
Ministry for Primary Industries	Michael Nielsen	Correspondence with MPI throughout application preparation. Site plan and expert report drafts sent to Michael on 25 June.
The Environmental Defence Society	Raewyn Peart / Gary Taylor	Meeting arrangements attempted.

The following persons/organisations/companies were sent the original correspondence offering consultation in March 2019, and a follow up contact in April 2019, but no substantive response was received.

Fisheries Inshore New Zealand
Marlborough Sounds Integrated Management Trust
Pelorus Boating Club
Kenepuru and Central Sounds Residents Association
Guardians of the Sounds
Council of Outdoor Recreation Associations of NZ Inc (CORANZ)
Waikawa Fishing Company
Port Marlborough
Sea Shepherd New Zealand
Marlborough Environment Centre
Port Gore Group
Nelson Regional Development Agency Ltd
Cletus Maanu Paul
Rihari Dargaville

The comments from those persons/organisations/companies who responded have been taken into account in this application.

NZ King Salmon requests that the application be publicly notified in accordance with section 95A(3)(a) of the Act.

9 Policy Analysis

9.1 Part 2, Resource Management Act 1991

Part II of the Act is given effect through the NZCPS, RPS and MSRMP. Recent cases, and in particular the 2014 Supreme Court *NZ King Salmon* decision,[147] have cautioned against constant reference back to Part II of the Act when there is no uncertainty as to how the relevant rules and policies of the Plan should be applied. Whilst it is recognised that in a resource consent application such as this decisions are always made subject to Part II,[148] a detailed Part II analysis is likely to add little to the policy analysis in Appendices E, F, and G. A brief analysis is undertaken below.

[147] *Environmental Defence Society Incorporated v The New Zealand King Salmon Company Limited* [2014] NZSC 38.
[148] Resource Management Act 1991, s 104.

9.1.1 Section 5

In terms of the enabling provisions in s 5 of the Act the proposal is considered to be for a sustainable use of the coastal environment, which enables social, economic and cultural wellbeing and provides for people's health and safety, while:

a. Sustaining the potential of the natural and physical resources of the area of the proposed farm, to meet the reasonably foreseeable needs of future generations. Salmon farms, like other marine farms, do not permanently alter the coastal environment in which they are located. The farm could be removed in future and the environment would in time return to how it was before the farm was there. That allows for future generations to use the coastal environment for other purposes if need be.
b. Safeguarding the life-supporting capacity of air, water, soil and ecosystems. As above, because the farm would not cause a permanent change in the environment it would also not affect the life-supporting capacity of air, water, soil or ecosystems.
c. Avoiding, remedying, or mitigating any adverse effects of the activities on the environment. As the various expert reports prepared for this application have found, there are some positive effects from the proposed farm and for potential adverse effects there are best practices and measures to be taken to avoid, remedy or mitigate such effects.

In summary, NZ King Salmon consider that the proposal aligns with the purpose of the RMA in s 5.

Section 5 of the RMA is given effect through the NZCPS, the RPS, the MSRMP, and will be given effect through the MEP once it has legal effect. The application is assessed against the relevant provisions of these documents below.

9.1.2 Section 6

Matters of national importance have also been assessed under the requirements of the MSRMP and MEP. The proposal recognises:

a) The preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and development:

Section 6(a) is given effect through Policy 13 of the NZCPS, which was considered above.

b) The protection of outstanding natural features and landscapes from inappropriate subdivision, use, and development:

The site is not in an area identified as an area of outstanding landscape value in the MSRMP. It is within an outstanding natural landscape in the MEP as notified. See the Landscape Report

(**Appendix M**). The conclusion is that the development and use of the natural resources at the site are not considered inappropriate.

c) *The protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna:*

Significant habitats are protected by ensuring that the farm is located in a way which eliminates or all but eliminates adverse effects. Additionally, management plans are proposed to address effects should they arise. In that way, adverse effects will be avoided. See the assessment below on Policy 11 of the NZCPS.

d) *The maintenance and enhancement of public access to and along the coastal marine area, lakes, and rivers:*

This application proposes a limited space for exclusive occupation so that the farm if granted can be used and for health and safety reasons. No other effects on public access will occur. Access around the site will be maintained. The location has been deliberately sited to avoid main navigation routes. The navigation assessment above at section 6.3 in this AEE provides detail on effects on navigation. The conclusion is that access all around the site will be maintained.

e) *The relationship of Maori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga.*

The site is not known to be of direct importance to Maori. There are no recorded archaeological sites nearby, according to ArchSite. NZ King Salmon has sought to consult with all Marlborough iwi whose rohe is over this area. No iwi has raised any specific issue in respect of this site.

f) *The protection of historic heritage from inappropriate subdivision, use and development.*

There are no recorded heritage sites nearby the proposed site. The only site of relevance is McManaway Rock which is an ecological site in the MSRMP and pMEP. This is considered above in this AEE.

g) *The protection of protected customary rights.*

As above, NZ King Salmon has consulted with iwi in preparing this application. The proposal is not considered to have any effect on any protected customary rights. For example, fishing all around the site will be retained. The navigation information at section 6.3 in this AEE shows that the site is not frequently used for fishing: it is the areas to the north and south of the site that are, and those areas will still be used for fishing if consent is granted.

h) The management of significant risks from natural hazards.

There are no identified natural hazards in or near the areas of the proposed farm.

9.1.3 Section 7

In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall have particular regard to –

a) *Kaitiakitanga:* …
NZ King Salmon has sought to consult with the Marlborough iwi whose rohe the site is within, in preparing this application.

b) *The efficient use and development of natural and physical resources*: …
This has been assessed above in this AEE. The proposal is considered to be an efficient use and development of the resources in, and including, the coastal environment.

c) *The maintenance and enhancement of amenity values*:
Given the proposed location of the farm being remote effects on amenity values for landowners in the Sounds are considered negligible. The farms may affect the amenity of people in the immediate vicinity of the site, but only in a transitory way. There is no destination in close proximity to the site. See the Landscape Report at **Appendix M** for the thorough assessment.

d) *Intrinsic values of ecosystems*:
The only ecologically significant site (according to the operative and proposed Plans) is McManaway Rock. This is considered above in this AEE. Effects on it will be avoided. The farming of King Salmon is a farming of a non-native species. There is little evidence of transference of disease between the farmed salmon and indigenous species which protects the intrinsic values of ecosystems.

e) *Recognition and protection of the heritage values of the sites, buildings, place, or areas*:
There are no heritage sites near the proposed farm.

f) *Maintenance and enhancement of quality of the environment*:
The various expert reports support the conclusion that the environment will be maintained at its existing state as much as possible. Any changes to the natural state of this environment are reversible in future upon removal of the farm. The changes to the environment are not considered to be f

such nature which could cause unacceptable adverse effects.

g) *Any finite characteristics of natural and physical resources*:
The Cook Strait is a very large area. The farms will only occupy a very small component of that. The farms will not change the values of the place taken as a whole.

h) *The protection of the habitat of trout and salmon*:
This application is in sea water rather than fresh water. The site is not near any fresh water rivers where trout or salmon are commonly found. Most salmon caught in New Zealand is grown in much the same way that salmon destined for these sites will be.

i) *The effects of climate change*.
This application enables King Salmon to adapt to the effects of climate change which it has already experienced. Farming at scale will enable a reduction in carbon footprint when compared with smaller operations. Salmon farming is already a low carbon input form of farming due to the high feed conversion rate of salmon, the lack of a large skeleton (which requires energy to grow and maintain) and the efficiency enabled by farming a relatively small part of the sea for high value protein.

j) *The benefits to be derived from the use and development of renewable energy.*
This is not relevant to this application.

The applicant has had particular regard to the matters in s 7 of the Act in preparing this application.

9.1.4 Section 104D

As stated above in this document, the activity is to be assessed as a non-complying activity. Given this, the application needs to pass through either one of the two 'gateways' in s104D(1). The two gateways are:

a) The adverse effects of the activity on the environment (other than any effect to which section 104(3)(a)(ii) applies) will be minor.
b) The application is for an activity that will not be contrary to the objectives and policies of –
i. the relevant plan, if there is a plan but no proposed plan in respect of the activity; or
ii. the relevant proposed plan, if there is a proposed plan but no relevant plan in respect of the activity; or
iii. both the relevant plan and the relevant proposed plan, if there is both a plan and a proposed plan in respect of the activity.

The application is considered to pass both gateways, even though it need only pass through one. The adverse effects of the activity are considered to be minor. This is demonstrated above in this AEE. As shown in **Appendix N** and **Appendix O** the proposed activity is not contrary to any of the objectives and policies of the operative or proposed Plan. The conclusion is that resource consent may be granted for this activity.

9.2 Treaty of Waitangi / Te Tiriti o Waitangi

Matters of potential concern in relation to the Treaty of Waitangi have been addressed in more detail above, particularly in analysis of Policy 2 of the NZCPS. To date, consultation with iwi has not raised any concerns with the application. Ngati Koata support the application.

9.3 New Zealand Coastal Policy Statement 2010

An assessment of the application against the New Zealand Coastal Policy Statement 2010 ("NZCPS") is set out below. The policies relevant to this application are policies 2, 3, 6, 7, 8, 11, 12, 13, 15 and 18. The NZCPS is of general relevance to this application and all of its objectives and policies have been considered in the development of the proposal. Policies of specific relevance are considered below.

9.3.1 Policy 2

Policy 2 sets out a number of matters that are relevant to the taking into account of the principles of the Treaty of Waitangi and kaitiakitanga in relation to the coastal environment.

The applicant recognises that Te Ātiawa o Te Waka-a-Māui, Ngāti Apa ki te Rā Tō, Ngāti Kuia, Rangitāne o Wairau, Ngāti Kōata, Ngāti Rārua, Ngāti Tama ki Te Tau Ihu, and Ngati Toa Rangatira have statutory acknowledgements in the area of the application site. Those acknowledgements have been considered during the preparation of this application.

The applicant has also reviewed the Iwi Management Plans ("IMP") of Ngāti Kōata and Te Ātiawa o Te Waka-a-Māui.

<u>Ngāti Kōata No Rangitoto Ki Te Tonga Trust Iwi Management Plan (2002)</u>:
NZ King Salmon has reviewed the most relevant parts of this IMP for this application. In terms of this IMP, there are no known heritage sites in this area so as to cause potential conflict with the issues identified in this IMP[149]. The most relevant part of this IMP is considered to be Chapter 8. The marine mammals report[150] prepared with this application addresses potential effects on marine mammals which are considered taonga to this iwi[151]. There are no identified conflicts with this proposal

[149] I.e. the objective at 7.14.
[150] Above n 86.
[151] Section 8.13 of the IMP, and discussed at Section 10.

and Ngāti Kōata's IMP in terms of the issues around water quality[152]. There are no identified adverse effects on kaimoana beds in the area of the proposed site such as to likely cause a conflict with sections 8.22 to 8.24 of the IMP[153]. The fish report[154] prepared with this application concludes that there are no unacceptable adverse effects on fish anticipated from the proposal. Issues around fish are addressed in the IMP at 8.28 to 8.33. The two objectives of this iwi are:

a) *Maintenance or enhancement of water quality in the coastal marine area at a level that enables the gathering or cultivating of shellfish for human consumption (Class SG).*
Salmon farms require excellent water quality to be successful. This is not anticipated to be an issue with this proposal.

b) *Protection of the coastal environment by avoiding, remedying or mitigating any significant adverse effects of activities that alter or modify the foreshore or seabed.*
The various expert reports prepared for this application conclude that this will not be an issue with the proposal. NZ King Salmon will ensure all best management practices are adhered to, and the activity shall be undertaken in a way to avoid, mitigate or remedy potential adverse effects on the environment[155].

NZ King Salmon has, in the preparation of this application, considered the policies in section 8.33 of this IMP. NZ King Salmon has also undertaken consultation with iwi during the application preparation stage. NZ King Salmon considers that there are no conflicts with this IMP from the proposed activity. NZ King Salmon also considers that this application and the preparatory process leading to it align with the IMP at section 8.34 and the particular consultation methodology at section 13.

Te Ātiawa o Te Waka-a-Māui Environmental Management Plan (2014):
The most relevant parts of this IMP for this application are: section 3 (consultation), section 7.8 (sustainable management of the moana/coastal area).

NZ King Salmon considers the consultation it has undertaken with this iwi aligns with the consultation principles in section 3 of this IMP. Such is also considered to align with the objective at section 7.2. Objective 1 seeks water quality as a priority. This aligns with NZ King Salmon's objectives in operating all of its farms as water quality must be excellent for a farm to be successful. Objective 2 seeks the integrity of the coastal/marine habitats and ecosystems be a priority. This is also a priority for NZ King Salmon. Various expert reports have been commissioned during the preparation of this application to ensure such can be achieved in operating a farm at

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[152] Sections 8.14 to 8.21 of the IMP.
[153] A potential one is horse mussel beds, the effects on which are identified at length above in this AEE.
[154] Above n 104.
[155] In particular, this aligns with the general policy in this IMP at Section 8, Policy 10.

this site as proposed. It is considered that such is achievable. Objective 3 seeks that Te Ātiawa are able to feely participate in traditional and customary practices in engaging the coastal marine resources of its rohe. The limited exclusive occupation sought under this application is not considered likely to impact upon this objective. Access around the farm will be maintained.

NZ King Salmon considers that the activity proposal aligns with the objectives of this iwi at section 7.8 of this IMP. In conclusion, NZ King Salmon considers that this application does not conflict with this IMP.

Summary on Policy 2

There are no taiāpure or mataitai reserves established in the area of the application. There are also no established areas of protected customary rights or customary marine title within the meaning of the Marine and Coastal Area (Takutai Moana) Act 2011.

9.3.2 Policy 3

Policy 3 of the NZCPS requires the adoption of a precautionary approach where effects of an activity are uncertain and potentially significantly adverse. Given that open ocean farming is a new concept in New Zealand there is limited data on effects of such farms in some respects. NZ King Salmon has commissioned various reports to cover all potential adverse effects and will follow all recommended best practices within those reports. In that sense the application is to follow a precautionary approach to open ocean farming particularly as adaptive management conditions are proposed.

9.3.3 Policy 6

Policy 6 of the NZCPS is in two parts, the first dealing with activities in the coastal environment more broadly, and the second with those in the coastal marine area more specifically. This application considers the most relevant aspects of Policy 6.

Policy 6(1)(h) requires consideration of how adverse visual impacts of development can be avoided in sensitive areas (i.e. prominent headlands). There is an OLF/ONL overlay in the Proposed Plan. The Landscape Report (**Appendix M**) details how visual impacts of the proposal can be managed.

Policy 6(1)(i) requires that developments be set back from the coastal marine area and other water bodies where practicable and reasonable, to protect the natural character, open space, public access and amenity values of the coastal environment. This is an application for an open ocean farm, that is it is an application for a development set back from the coastal marine area/other waterbodies. Existing natural character will be, as far as is practicable, maintained. Several conditions are proposed to manage visual effects of the farm.

Policy 6(1)(j) requires that, where appropriate, buffer areas and sites of significant indigenous biological diversity be in place. This has been addressed in the proposed conditions at **Appendix B**.

Policy 6(2)(a) requires recognition of potential contributions to the social, economic and cultural wellbeing of people and communities from use and development of the coastal marine area. The proposed farm will contribute to the social, economic and cultural wellbeing of people and communities, particularly its employees and the New Zealand economy generally.

Policy 6(2)(b) requires recognition of the need to maintain and enhance the public open space and recreation qualities and values of the coastal marine area. The limited exclusive occupation area sought is only for that area considered necessary for the proposed farm. Access around the farm will be maintained, and therefore recreational activity opportunities in this area will be maintained. This is addressed above in this AEE at sections 6.10 and 6.13.

Policy 6(2)(c) requires recognition that there are activities which have a functional need to be located in the coastal marine area, and that the key is that they are located in appropriate places within the coastal marine area. Salmon farming has a functional need to be located within the coastal area. This application considers why the site is an appropriate area for such a farm. If marine farming such as salmon farming is to continue to grow in New Zealand options such as open ocean farming are sensible to consider given limited options for future growth closer inland in the Marlborough Sounds.

Policy 6(2)(e) requires the promotion of the efficient use of occupied space. The area sought for exclusive occupation is considered to be an efficient use of occupied space as it is the bare minimum required for the safe and efficient operation of the proposed farm.

In summary, it is considered that the proposed activity aligns with what Policy 6 is trying to achieve.

9.3.4 Policy 7

Policy 7 relates to the plan making function and not to the resource consent function. The short point to note is that strategic planning is not precluded by virtue of this application. That is because:

(a) Planning routinely needs to address existing developments and future developments; and

(b) While not a trivial exercise, it is reasonably routine for marine farms to be moved. Consequently if, in the future, a strategic planning exercise suggests that the farms should be located elsewhere, that can be achieved.

9.3.5 Policy 8

This application recognises the potential contribution of aquaculture to the social, economic and cultural wellbeing of people and communities. Policy 8 of the NZCPS requires the social and economic benefits of aquaculture, including any available assessments of national and regional economic benefits to be taken into account.[156]

9.3.4 Policy 11

Policy 11 relates to protecting the indigenous biological diversity of the coastal environment. Effects from the proposed farm on indigenous biological diversity have been considered above in this AEE.

Effects on Policy 11 are (a) seabirds, marine mammals and area identified in the plan as McManaway Rock and Witts Rock are avoided by virtue of the location of the proposed development and the conditions which are sought to be imposed. Sentinel Rock is located further away from the farm. Consequently Policy 11(a) is given effect to.

In relation to horse mussels, the assessment above confirms that as horse mussels are important but not significant, it is considered that to give effect to the NZCPS Policy 11, it is Policy 11(b) which is engaged, and therefore "significant effects" on horse mussels are to be avoided, and other (i.e. less than "significant") effects are to be avoided, remedied or mitigated. Policy 11(a) is not considered to be engaged because horse mussels and brachiopods are not indigenous taxa which are listed as threatened or at risk in the New Zealand Threat Classification Systems List, and nor do they fit into any other categories listed in Policy 11(a)(i)-(vi).

Policy 11(b) is given effect to in the conditions at **Appendix B**.

9.3.5 Policy 12

Policy 12 relates to mitigating the risk of release and spread of harmful aquatic organisms. The applicant has commissioned a biosecurity report[157] to address potential effects of the proposed farm on biosecurity in this environment. That report provides recommended best practice which will be adopted by NZ King Salmon should consent be granted.

The applicant has experience with biosecurity matters given the existing farms it operates, and the proposed conditions of consent will adequately manage the risk of spread of harmful organisms. Policy 12 is given effect to.

[156] See the above assessment in this AEE at section 6.14.
[157] Above n 105.

9.3.6 Policy 13

Policy 13 provides for the avoidance of significant adverse effects on areas of the coastal environment with outstanding natural character and the avoidance, remediation and mitigation of other adverse effects on natural character.

The application site is currently recognised as an area of high and outstanding natural character in the MEP, although the Council Reporting Officer recommended the area be made one of high natural character, not outstanding.

Overall, the effects of the proposal will not be 'significant' in terms of policy 13(1)(b).

9.3.7 Policy 15

Policy 15(a) provides for the avoidance of adverse effects of activities on outstanding natural features and outstanding landscapes in the coastal environment. Policy 15(b) provides for the avoidance of significant adverse effects and the avoidance, remediation, and mitigation of other adverse effects of activities on other natural features and natural landscapes in the coastal environment.

As outlined above, the application site is not located in an area of outstanding landscape value in the MSRMP, but is partially within an outstanding natural landscape in the MEP as notified. The Landscape Report (**Appendix M**) assesses this in detail.

Overall, adverse effects on the landscape will not be 'significant' in terms of Policy 15(b). Accordingly, this proposal gives effect to policy 15.

9.3.8 Policy 18

Policy 18 recognises the need for public open space within and adjacent to the coastal marine area, for public use and appreciation including activities and passive recreation.

The exclusive occupation area sought is limited to that necessary for the safe and efficient operation of the farm. Public access all around the farm will be maintained, and given the site is small in terms of how much open ocean space there will still be in the outer Marlborough Sounds/Cook Strait, it is considered that Policy 18 will be given effect to.

9.4 Marlborough Sounds Regional Policy Statement

The application has been considered against the relevant objectives and policies of the Marlborough Regional Policy Statement ("RPS, as outlined in the policy analysis table at **Appendix P.**

9.5 Marlborough Sounds Resource Management Plan

The application has been considered against the relevant objectives and policies of the Marlborough Sounds Resource Management Plan ("MSRMP"), as outlined in the policy analysis table at **Appendix N.**

Overall, the application is considered to be consistent with the objectives and policies of the MSRMP.

Overall, the application is considered to be consistent with the objectives and policies of the RPS.

9.6 Proposed Marlborough Environment Plan

The application has been considered against the relevant objectives and policies of the Marlborough Sounds Resource Management Plan ("MEP"), as outlined in the policy analysis table at **Appendix O.**

Overall, the application is considered to be consistent with the objectives and policies of the MEP.

10 Conclusion

This assessment of effects has shown that the activity proposed can be undertaken at the site in a sustainable way. NZ King Salmon has undertaken extensive research in preparation for lodging this application, including by engaging various experts to consider the proposal. The conditions proposed seek to manage effects of the activity. Thorough monitoring is proposed.

NZ King Salmon has sought to consult with several identified stakeholders and iwi. The comments of those who responded to that invitation have been factored into the proposed conditions and in this application generally.

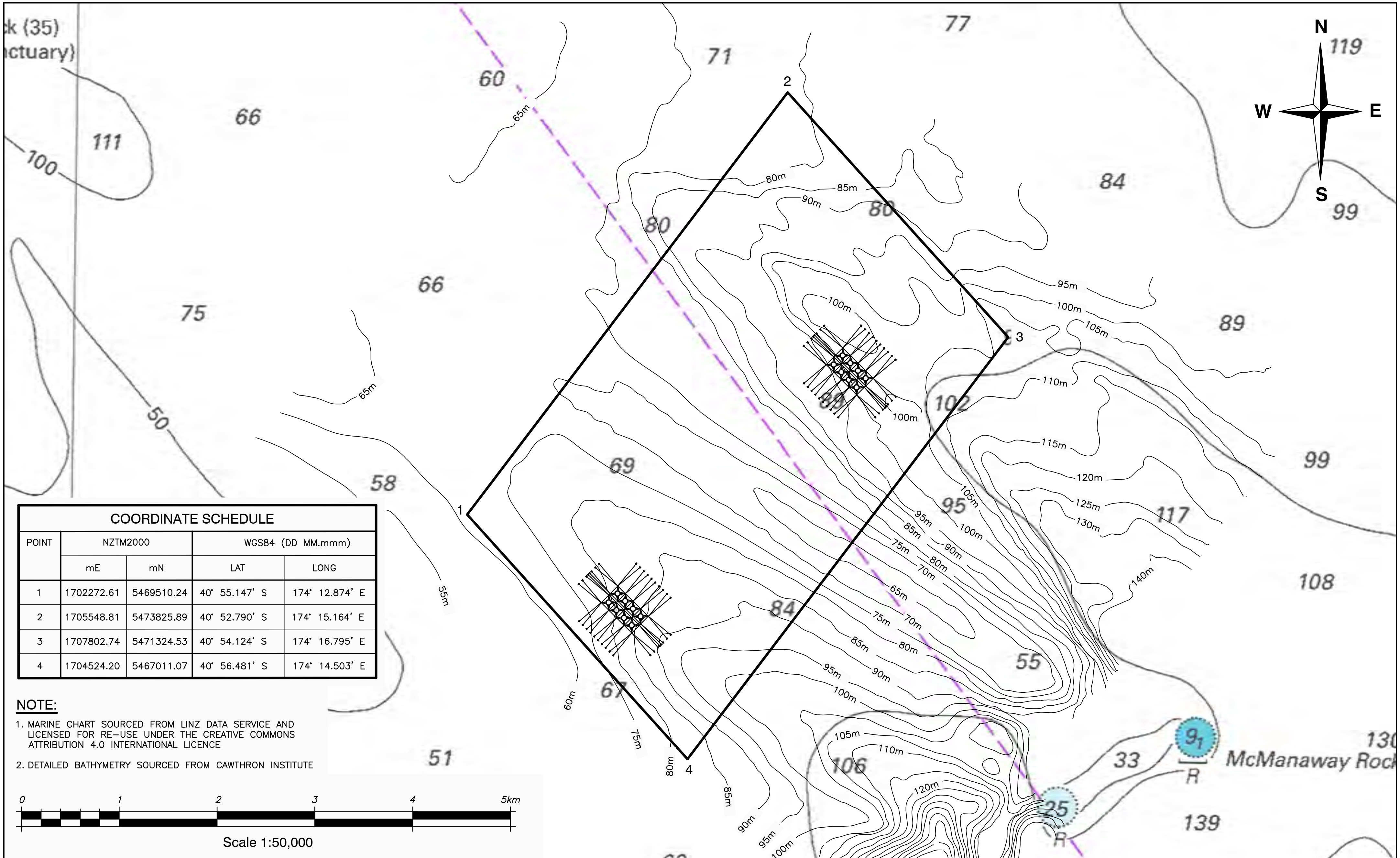
This application presents an opportunity for New Zealand. It aligns with the direction of aquaculture in overseas jurisdictions, and it acknowledges the challenges which can be faced with farming at inshore locations.

This application does not conflict with any of the objectives and policies of the MSRMP, nor the MEP or MRPS. It passes both of the two 'gateways' in s104D of the RMA.

Given this assessment, including the supporting documentation in the appendices, the conclusion is that resource consent can be granted for this application and NZ King Salmon respectfully requests that such is.

APPENDICES

APPENDIX A: Site Diagram



COORDINATE SCHEDULE

POINT	NZTM2000		WGS84 (DD MM.mmm)	
	mE	mN	LAT	LONG
1	1702272.61	5469510.24	40° 55.147' S	174° 12.874' E
2	1705548.81	5473825.89	40° 52.790' S	174° 15.164' E
3	1707802.74	5471324.53	40° 54.124' S	174° 16.795' E
4	1704524.20	5467011.07	40° 56.481' S	174° 14.503' E

NOTE:

1. MARINE CHART SOURCED FROM LINZ DATA SERVICE AND LICENSED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE
2. DETAILED BATHYMETRY SOURCED FROM CAWTHRON INSTITUTE

0 1 2 3 4 5km

Scale 1:50,000

OCEL

OFFSHORE AND COASTAL ENGINEERING LIMITED

14 Richardson Terrace
PO Box 877
Christchurch
Tel (03) 3790444
Fax (03) 3790333

49 Crown Hill Street
PO Box 151
New Plymouth
Tel (067) 512310
Fax (067) 512310

Drawn	RVE
Checked	
Traced	
Approved	
Date	06/19

NEW ZEALAND KING SALMON LIMITED

PROPOSED OFFSHORE SITES

OUTER MARLBOROUGH SOUNDS

Scale (A4)	ACAD Filename
1:50,000	051103/SK-051103-517R1
Drawing No.	Rev.
SK-051103-517	1

APPENDIX B: Proposed Conditions of Consent

Resource Consent for Open Ocean Salmon Farms

Resource consent should be granted for a salmon farm to farm King Salmon (Onchorynchus tshawystcha) within an area identified on the **attached** plan, including all activities ancillary to the farm's operations (including monitoring) for a term of 35 years, subject to the following conditions:

Lapse

1. The consent will be given effect to (in terms of s 125 Resource Management Act 1991) once the consent holder has submitted a management plan required by this consent. The consent will lapse after five years from the date of commencement if the consent is not given effect to.

Occupancy

2. The occupancy will be limited to the area illustrated on the **attached** plan at Figure 1. Structures should be confined to the area specified within the schedule of coordinates.

3. The consented area may be exclusively occupied to the extent reasonably necessary to undertake the activity and ensure the safety and security of the marine farm and all its structures. In particular, the physical space occupied by all surface structures (as they exist from time to time), including all net pens and barges may be exclusively occupied; and all mooring lines extending from the structure to the seabed and the anchoring systems within the seabed may exclusively occupy the physical space that they occupy, but not the water space above, between, and below the lines (other than is necessary to ensure the safety and security of lines and mooring systems).

Structures

4. All structures will be situated and secured so as to remain within the boundaries of the consent area at all times, other than during construction.

5. The consent holder is to maintain all structures to ensure that they are restrained, secure and in working order at all times so as not to create a navigational hazard, and take whatever steps that are reasonably necessary to retrieve any non-biodegradable debris lost in or from the permit area.

6. Written notice of any "significant change" to the structures, as defined in the Structures Management Plan (prepared in accordance with condition 15(c), is to be given to the Compliance Manager, Marlborough District Council before installation.

Visual appearance

7. All parts of any barge at the site (including its roof and ancillary features, including all associated parts such as the curtains, blinds or shutters) shall be finished in non-reflective material (except as provided for in the Structures Management Plan, Navigation Risk Reduction and Management Plan, Marine Mammal and Shark Management Plan, or Seabirds Management Plan) with a reflectivity value between 5% and 30%.

8. Except as provided for in the Structures Management Plan, Navigation Risk Reduction and Management Plan, Marine Mammal and Shark Management Plan, or Seabirds Management Plan, all other surface structures (including the barge, in accordance with condition 7) should be finished in darker non-reflective material.

9. The design and implementation of the form of the structures are to be generally in accordance with the Design Guide annexed to the landscape report and the following design principles:

   a. Surface structures other than those which are an aid to navigation are to be 5 km from shore or more;

   b. Colours of surface structures are to be recessive/subdued and will minimise glare;

   c. Surface structures to have a lower/horizontal profile;

   d. Surface structures are to be clustered and ordered;

   e. The use of surface space is to be apparently efficient with no superfluous elements; and

   f. The shape, size and colour of structures is to be consistent.

10. Where structures are proposed to be other than plastic circle type pens, supported by a nautical style feed barge then

   a. the design is to be certified by an appropriately qualified and experienced landscape architect that the design has been prepared in accordance with the Design Guide annexed to the landscape report;

   b. Where there is a deviation from the Design Guide or design principles to address an environmental issue such as that outlined in the Structures Management Plan, Navigation Risk Reduction and Management Plan, Marine Mammal and Shark Management Plan, or Seabirds Management Plan, that should be recorded in the certificate but does not invalidate it;

   c. That certificate is to be provided to the Compliance Manager, Marlborough District Council prior to the installation of the structures and

   d. No more than 20% of area of the net pens may be a different fundamental type (such as plastic circle) to the remainder of the net pens.

11. The Design Guide may be amended in accordance with Condition 70 as if it was a management plan prepared by an appropriately qualified and experienced landscape architect.

Lighting

12. The consent holder shall ensure that the submerged artificial lighting set up in each net pen will not be comprised of any more than the luminance of nine 1000W metal halide equivalent underwater lights.

13. The consent holder shall ensure that all reasonable steps are undertaken to minimise light spill, including by ensuring that:

   a. Curtains, blinds or shutters which are effective at preventing light spill at night are to be provided for all windows;

   b. All curtains, blinds and shutters on the barge(s) are to be used so that they are effective at preventing light spill at night;

c. Only external lighting that required for navigation or health and safety purposes is installed at the site; and

d. All external lights are angled downwards, except as required for navigation or health and safety purposes.

Engineering

14. All structures that may reasonably come into contact with seawater (excluding sea spray) shall be certified by a suitably qualified professional engineer with appropriate experience in marine engineering. The certificate should record that the structure is appropriate structural integrity for the intended use, as well as appropriate corrosion resistance. An engineering certificate shall be provided upon request to the Compliance Manager, Marlborough District Council.

15. Prior to the installation of any structures, the consent holder is to lodge with the Compliance Manager, Marlborough District Council a Structures Management Plan prepared by a suitably qualified professional engineer with appropriate expertise in marine engineering. The Structures Management Plan shall include:

a. A proposed Structures diagram for the positioning, layout and structure of the marine farm;

b. The maintenance and testing of the structures required, and other steps necessary to ensure that the structures remain within the design case; and

c. The engineering or design limits within which the farm will operate. Any exceedance of those limits constitutes a “significant change” to the structures or operation. Written notice of any significant change is to be provided to the Compliance Manager, Marlborough District Council before any change to the structures or operation is made.

16. Within five working days after the installation of the first structures, and within five working days after any significant change (as that term is defined in the Structures Management Plan), the consent holder shall lodge an as-built plan with the Compliance Manager, Marlborough District Council.

17. The Structures Management Plan may be altered in accordance with condition 70 below.

Navigation

18. Beyond 40 metres from the outer surface structure, no mooring line (or other structure) is to be within 5 metres of the surface of the water.

19. Beyond 100 metres from any surface structure, no mooring line (or other structure) is to be within 10 metres of the surface of the water.

20. Beyond 400 meters from any surface structure, no mooring line (or other structure) is to be within 20 metres of the surface of the water.

21. The type, design, functionality, and placement of marine farm lighting and marking must be in accordance with IALA Guidelines and approved by the Harbour Master under his or her Maritime Delegation from the Director of Maritime New Zealand pursuant to sections 200, 444(2) and 444(4) of the Maritime Transport Act 1994.

22. All lights used on the farm, including underwater lighting, floodlighting and lighting internal to the barge will be operated to ensure that they do not materially impact the ability for any vessel to maintain a proper lookout, or impact navigational safety.

23. One month prior to the initial placement of the first structures within the occupancy area specified in the plan **attached** at Figure 1, the consent holder shall notify the Harbour Master and Land Information New Zealand that the structures are to be placed within the area. The notice shall include a draft Navigation Risk Reduction and Management Plan, and a draft Structures Management Plan prepared in accordance with conditions 27 and 15 respectively.

24. Following the first placement of any structures, the consent holder shall ensure that a notice alerting mariners to the presence and location of the farm is broadcast on Marlborough Marine Radio if directed by the Harbour Master.

25. Each structure or group of connected structures is to be fitted with at least one electronic location device. That device transmission is to be monitored from a shore-base. Any deviation from normal operation will trigger an automatic response as detailed in the Navigation Risk Reduction and Management Plan.

26. The farm shall be fitted with an Automatic Identification System (AIS) that broadcasts the extent of the physical structure and dangers to surface navigation.

27. One month prior to installation of structures, the consent holder shall prepare and lodge a Navigation Risk Reduction and Management Plan with the Compliance Manager, Marlborough District Council. The purpose of the Navigation Risk Reduction and Management Plan is to reasonably minimise risks in accordance with the New Zealand Port and Harbour Marine Safety Code. That Plan is to:

    a. Identify all relevant risks in accordance with the New Zealand Port and Harbour Marine Safety Code;

    b. Detail the appropriate management of those risks;

    c. Outline the appropriate response if an AIS transponder detects a deviation from normal operation;

    d. Include a proposed structures diagram for the layout and structure of the marine farm;

    e. Include a construction plan to manage the effects of the presence of vessels during construction;

    f. Detail any initial or ongoing notification to or education of vessel users in relation to the presence of the structures;

    g. Record if and when further notice to the Harbour Master and/or Land Information New Zealand is required;

    h. Require periodic risk reviews and the implementation of any findings; and

    i. Establish an Emergency Response Plan, and require periodic drills.

28. The consent-holder may amend the Navigation Risk Reduction and Management Plan in accordance with condition 70 below.

Noise

29. The marine farm is to be conducted so as to ensure that noise arising from such activities does not exceed the following noise limits when measured no closer than 250 metres from any marine farm surface structure:

At All Times	70 dBA L_{Aeq}

30. The consent holder shall operate the farm in accordance with the best practicable option for minimising noise. Between 6 and 12 months after the first structures have been installed, and thereafter every five years, the consent holder shall obtain, from an appropriately skilled and qualified acoustic expert, a certificate confirming that this condition is being complied with. That certificate is to be provided to the Compliance Manager, Marlborough District Council and the Department of Conservation upon receipt by the consent holder.

31. Noise should be measured in accordance with NZS 6801:2008. Noise levels shall be assessed in accordance NZS 6802:2008. Any construction activities must not exceed the noise limits specified in Table 2 in NZS 6803:1999.

32. The following activities are exempt from the above noise limit and the requirement to adopt the best practicable option for minimising noise:

    a. Noise generated by navigational aids, safety signals, warning devices or emergency pressure relief values;

    b. Noise generated by emergency work arising from the need to protect life or limb or prevent loss or serious damage to property or minimise or prevent environmental damage; and

33. Noise ordinarily generated by the arrival and departure of vessels servicing the marine farm is exempt from the above noise limit.

Antifoul

34. If the consent holder wishes to use any form of copper-based antifouling on its net pens then, six months prior to use, the consent holder is to provide the Compliance Manager, Marlborough District Council and the Department of Conservation with:

    a. a Copper Management Plan;

    b. A certification by an appropriately qualified and experienced environmental scientist that the copper management plan represents the best practical option available to the company to manage fouling.

35. The purpose of the Copper Management Plan is to ensure, and appropriately verify that the use of copper-based antifouling on net pens will not breach the Australian and New Zealand Environment and Conservation Council (ANZECC) Interim Sediment Quality Guidelines (ISQG-Low) or, (where those standards are replaced by other standards), their equivalent.

36. The Copper Management Plan will be certified by an appropriately qualified and experienced scientist and will detail:

    a. Methods by which the baseline copper levels on the site are to be managed;

b. A baseline survey to enable the change in copper concentrations caused by the copper-based antifouling to be measured;

c. Sampling techniques and frequency;

d. Control sites, if required;

e. Reporting requirements for copper levels; and

f. The format of any reporting.

37. If the consent holder ceases to use copper-based antifouling on its net pens, and gives written notice of that to the Compliance Manager, Marlborough District Council and any measured copper levels for the preceding measurement are below ISQG-High (or below any replacement level), then the consent holder may cease monitoring in accordance with the Copper Management Plan.

38. If any copper levels measured exceed the ANZECC (or any revised or replacement New Zealand Standard) Interim Sediment Quality Guidelines (ISQG – High) levels for the total recoverable fraction of those metals, the monitoring and operation response identified in the decision tree in the Best Management Practice Guidelines: Benthic, shall be followed.

Benthic Standards

39. The consent holder is required to keep an internal record of the amount of feed discharged at the farm on a monthly basis. The record shall enable the calculation of the composition of the feed (percentage protein, carbohydrate, lipid, nitrogen and phosphorous) and the location of the discharge. Those records must be provided to the Compliance Manager, Marlborough District Council or the Department of Conservation upon request.

40. Prior to the installation of structures, the consent holder is to lodge with the Compliance Manager, Marlborough District Council and the Department of Conservation a Benthic Management Plan certified by a suitably qualified and experienced marine scientist. The certificate is to state that the Benthic Management Plan is consistent with relevant best practice guidelines, and is consistent with the purpose of the Benthic Management Plan.

41. The purpose of the Benthic Management Plan is to:

a. Avoid adverse effects on ecologically significant marine site 2.29 (McManaway Rocks);

b. Avoid deposition on any part of the seabed above the point of peak microfauna abundance (ES=5.0) roughly equivalent to a flux of 13kg solids/m2/yr.

c. Ensure there is to be no more than one replicate core of any sample with no taxa;

d. Avoid obvious spontaneous out-gassing of hydrogen sulphide and methane is to be observed within the consent area;

e. Ensure the coverage of the *Beggiatoa* bacteria may not be greater than localised and patchy in distribution within the consent area;

f. Avoid [significant] effects on horse mussel and brachiopod beds; and

g. To prescribe appropriate monitoring and to define the point at which further monitoring, investigation and/or management action is required to appropriately manage adverse effects.

42. At a minimum, the Benthic Management Plan is to provide for:

a. Identifying suitable locations for the initial placement of pens so as to:

i. Avoid overlap of the footprint with the ecologically significant marine site 2.29 (McManaway Rocks);

ii. Avoid [significant] effects on horse mussel/brachiopod beds and the McManaway Rock fringing strata (apart from the brachiopod or horse mussel beds which are being directly studied to better understand the effects of farm derived solids).

b. Monitoring by semi-quantitative visual means (such as an ROV) on at least an annual basis:

i. Of the benthos beneath the pens:

ii. Of adjoining areas of horse mussel/brachiopod beds; and

iii. Where relevant, ecologically significant marine site 2.29 (McManaway Rocks);

iv. Areas identified in the Plan as locations where farm derived solids might accumulate.

c. Make predictions as to what the likely effects of the farm will be and on the basis of those predictions devise a monitoring plan to ensure that the farm has the expected acceptable effects.

d. Monitoring by quantitative means every second year at locations identified in paragraph (b) above.

e. Describe a decision tree in the event of certain triggers being met;

43. In the context of benthic standards, a year means a calendar year. Any monitoring required by the Benthic Management Plan is to be undertaken between January and March in the following year.

Water Column

44. The farm should be operated at all times so as to achieve the following water quality standards:

a. To not cause an increase in the frequency or duration of phytoplankton blooms (i.e. chlorophyll a concentrations greater or equal to 5mg/m^3);

b. To not cause a change in the typical seasonal pattern of phytoplankton community structure (i.e. diatoms versus dinoflagellates) and with no increased frequency of harmful algae blooms (i.e. exceeding toxicity thresholds for harmful algae bloom species);

c. To not cause reduction in dissolved oxygen concentrations to levels that are potentially harmful to marine biota;

d. To not cause elevation of nutrient concentrations outside the confines of established natural variation for the location and time of year, beyond 250m from the edge of the net pens;

e. To not cause a persistent shift from the mesotrophic to a eutrophic state; and

f. To not cause an obvious or noxious build-up of macro algae biomass.

45. The consent holder shall not cause the total nitrogen concentration in the water column to increase above 1mg/m^3 when measured one kilometre from the site boundary. This condition will be satisfied if the consent holder produces a model prepared by an appropriately qualified and experienced marine scientist which demonstrates this.

Note: Experience and review of the scientific literature shows that it is impossible to detect the product of salmon farming in the water column at a distance from the farm. If new information comes to light, this condition can be reviewed in terms of condition 87 below.

46. Prior to the installation of structures, the consent holder is to lodge with the Compliance Manager, Marlborough District Council and the Department of Conservation a Water Column Monitoring Plan certified by suitably qualified and experienced marine scientist:

a. The purpose of that Plan is to demonstrate compliance with the water quality objectives;

b. Monitoring need not be undertaken where it can be demonstrated (through modelling or otherwise) that the farm derived effects are either below the detection limit of reasonably available scientific equipment or analytical techniques or are an order of magnitude below levels which might reasonably have any material ecological impact.

c. The frequency of any monitoring can be set with reference to the likely measurability of the impact, as well as the existence of other long term data sets and the potential benefits of being able to combine those data sets to identify long term trends.

Marine Mammal and Shark Management Plan

47. The consent holder shall prepare and lodge a Marine Mammal and Shark Management Plan with the Compliance Manager, Marlborough District Council and the Department of Conservation prior to the installation of structures.

48. The objectives of the Marine Mammal and Shark Management Plan must be to:

a. to avoid adverse effects and where it is not practicable to avoid effects to minimise those effects on marine mammals and protected sharks from the operation of the marine farm;

b. minimise the interaction of sharks with the marine farm;

c. determine how the operation of the marine farm will be managed adaptively to avoid, remedy and mitigate adverse effects on marine mammals and protected sharks;

d. ensure that the best practicable option is adopted to avoid entanglement or entrapment of marine mammals and sharks, having regard to best international practice, ongoing research and allowing for technological improvements in net design and construction;

e. establish a monitoring programme to assess the effectiveness of the Marine Mammal and Shark Management Plan; and

f. establish reporting and response procedures in the event of marine mammal and protected shark entrapment, entanglement, injury or death.

49. The Marine Mammal and Shark Management Plan will detail reasonable steps and equipment design, and shall include but not be limited to:

a. minimising the potential for sharks and marine mammals to enter the marine farm net pens through the use of (for example) predator-resistant materials in net pen construction, and/or predator exclusion nets enclosing the marine farm net pen structures and extending sufficiently high above the water around the marine farm to exclude such predators;

b. limiting the maximum mesh size of any predator netting to 200mm (the internal measurement when the net is stretched in the direction of the long diagonal of the meshes);

c. ensuring predator nets are sufficiently tensioned and maintained at all times so as to avoid entanglement of marine mammals or large sharks;

d. ensuring the twine diameter of the predator net is of a sufficient gauge to:

i. be detected acoustically by dolphins; and

ii. avoid the entanglement of marine mammals or large sharks;

e. predator net maintenance requirements, including:

i. standards and scheduling;

ii. repairing holes and tears as soon as reasonably practical;

iii. avoiding predator nets being left open over night or for extended periods of time;

iv. avoiding entrapment pockets in predator nets;

f. procedures for auditing marine farm security following any marine mammal gaining access, and taking all practical steps to correct any faults found;

g. procedures to ensure visual surface marine mammal surveys are conducted prior to major net maintenance work and that nets are not opened, removed or shifted if dolphins are observed with 2 kilometres;

h. procedures for capture and release of any entrapped or entangled marine mammal or protected shark species;

i. procedures for the retrieval, storage and transport of dead marine mammals and protected shark species for formal identification and autopsy purposes;

j. staff training requirements, including identification of protected shark species;

k. ensuring there is no feeding of marine mammals and sharks;

l. ensuring dead fish are removed promptly from the fish pens;

m. ensuring anchor warps are maintained under sufficient tension to prevent possible entanglement of cetaceans and large sharks;

n. ensuring all lines associated with the marine farm are secured at all times, and that any loose lines are secured and/or retrieved promptly;

o. ensuring that all nets are removed from marine farm structures that are left fallow, untended for more than three months or are abandoned;

p. ensuring all net and cordage debris, plastic strapping and other marine farm, domestic or other non-biodegradable waste is collected, retained and disposed of at an approved solid waste facility onshore, and that if any loose debris does enter the water around the marine farm, it is retrieved from the seabed, water column or foreshore promptly;

q. contingency plans in the event of an adverse interaction;

r. specifying what constitutes a reportable incident or an alert;

s. specifying the format for reporting a reportable incident or alert in accordance with condition 52;

t. specifying information which the consent-holder should record in the event of a reportable incident or alert;

u. specifying annual reporting requirements; and

v. stating, at a minimum, reporting requirements to the Compliance Manager, Marlborough District Council and the Department of Conservation, and in particular:

    i. annual summary reports of all incidents involving marine mammals and protected sharks becoming entangled or entrapped at a marine farm;

    ii. immediate reporting (within 24 hours) of any incident where a marine mammal or protected shark may be injured or killed; and

    iii. reporting (within one week) of timelines to remedy any unforeseen events such as a marine mammal or protected shark becoming entrapped or entangled at a marine farm.

50. The Marine Mammal and Shark Management Plan is to be certified by a suitably qualified and experienced marine scientist or scientists after reviewing the recorded information held by the consent holder.

51. The consent holder is to report each reportable incident to the Compliance Manager, Marlborough District Council and to the Department of Conservation no later than two working days after the reportable incident occurred.

52. In the event of a reportable incident or alert, the consent holder is to make a record detailing the circumstances of the reportable incident or alert, the results of the reportable incident, and any change made either to design of the structures or processes in order to minimise further interaction (as appropriate). Any further information about the reportable incident or alert recorded by the consent holder is to be provided to the Compliance Manager, Marlborough District Council or to the Department of Conservation on request.

53. In the event of an alert, the consent holder is to take the same steps as for a reportable incident. The report of the alert is to be provided to the Compliance Manager,

Marlborough District Council and to the Department of Conservation as soon as practicable, and in any event, within 24 hours of the event occurring. Within five working days of the report of the alert being provided to the Marlborough District Council, the consent-holder is to advise which appropriately qualified and experienced person that is undertaking a review of the circumstances leading up to the alert and a timeframe within which any report or recommendations (or interim report and recommendations) are due. A report by that person is to be provided to Council within the timeframe specified, or as otherwise agreed with the Compliance Manager, Marlborough District Council.

Note: An alert may trigger a review of consent conditions as provided for in condition 87.

Seabirds Management Plan

54. The consent holder shall prepare and lodge a Seabirds Management Plan with the Compliance Manager, Marlborough District Council and the Department of Conservation prior to the installation of structures. The purpose of the Seabirds Management Plan is to to avoid adverse effects and where it is not practicable to avoid effects to minimise effects on seabirds. That Plan will detail:

    a. all reasonable design and procedural steps taken to minimise interactions with seabirds;

    b. staff training required;

    c. procedures for departing and arriving vessels;

    d. contingency plans in the event of an adverse interaction;

    e. procedures for identifying seabirds;

    f. what constitutes a reportable incident or an alert;

    g. the format for reporting a reportable incident or alert in accordance with condition 57;

    h. information which the consent holder should record in the event of a reportable incident or alert;

    i. annual reporting requirements, including a requirement to report all general seabird interactions for the first year of operation (including birds roosting on pen structures, buoys and markers, or observed in the water within approximately 50 metres of the surface structures); and

    j. A requirement to report all general seabird interactions for each further year where the area of structures on the site increases by 2ha from the same day of the previous year.

55. The Seabirds Management Plan is to be certified by a suitably qualified and experienced scientist or scientists after reviewing the recorded information held by the consent holder.

56. The consent holder is to report each reportable incident to the Compliance Manager, Marlborough District Council no later than two working days after the reportable incident occurred.

57. In the event of a reportable incident the consent holder is to make a record detailing the circumstances of the reportable incident, the results of the reportable incident, and any change made either to design of the structures or processes in order to minimise further

interaction (as appropriate). Any further information about the reportable incident recorded by the consent holder is to be provided to the Compliance Manager, Marlborough District Council on request.

58. In the event of an alert, the consent holder is to take the same steps as for a reportable incident. The report of the alert is to be provided to the Compliance Manager, Marlborough District Council as soon as practicable, and in any event, within 24 hours of the event occurring. Within five working days of the report of the alert being provided to the Marlborough District Council, the consent-holder is to advise which appropriately qualified and experienced person that is undertaking a review of the circumstances leading up to the alert and a timeframe within which any report or recommendations (or interim report and recommendations) are due. A report by that person is to be provided to Council within the timeframe specified, or as otherwise agreed with the Compliance Manager, Marlborough District Council.

Note: An alert may trigger a review of consent conditions as provided for in condition 87.

Biosecurity Management

59. The consent holder shall prepare and implement a Biosecurity Management Plan with the objectives of minimising the risk of spreading marine pests and disease agents as a result of the establishment and operation of the marine farm.

60. The Biosecurity Management Plan shall include on-farm as well vector-based management measures to reduce the risk of spread, including:

a. Any vessel arriving from other regions should aim to comply with the national-level hull biofouling and ballast water legislation, and ideally operate under a Biosecurity Management Plan (BioMP) specific to the vessel.

b. Vessels associated with day-to-day operations of the farm should be properly maintained to prevent the growth of biofouling or the accumulation of sediment or debris.

c. All previously-used equipment or gear should be thoroughly cleaned, and appropriate treatments applied if necessary (e.g. disinfection), before moving between farm sites.

d. Standard operating procedures that incorporate industry best-practice should be developed and adhered to for transporting stock.

e. Farm personnel should be familiar with, remain vigilant for, and report pest organisms or those that exhibit unusual patterns of population growth.

f. Farm infrastructure (e.g. pontoons, nets) should be maintained appropriately to prevent the establishment of large populations of pest species.

g. Accurate records of all vessel, equipment, gear and stock movements to, from and within the open ocean farm site should be maintained.

61. The Biosecurity Management Plan shall also specify the parties to be notified should any new biosecurity risk from marine pests or disease agents be identified at the farm.

62. The Biosecurity Management Plan should be certified, to ensure best practice, by a person or persons appropriately qualified in marine biosecurity and aquatic animal diseases, and

provided to the Compliance Manager, Marlborough District Council and the Department of Conservation prior to the initial placement of the first structures at the marine farm.

63. The Biosecurity Management Plan may be altered in accordance with condition 70.

Wild Fish Management

64. The consent holder shall prepare and implement a Wild Fish Management Plan with the objectives of improve understanding of the size and composition of aggregations of pelagic and demersal fish beneath the marine farm as a result of the establishment and operation of the marine farm.

65. The Wild Fish Management Plan shall

    a. Specify measures to confirm the average feed Joss levels from the marine farm, including how the feed loss varies over time;

    b. Provide for testing of a methodology of surveying pelagic and demersal fish beneath and adjacent to the marine farm, including the monitoring/sampling system and the collection of test data for testing the analytical component of the methodology; and

    c. Undertaking that survey for the second set of structures placed on the site, to study the size and composition of aggregations of pelagic and demersal fish beneath the marine farm at a range of appropriate times across one year.

66. The Wild Fish Management Plan should be certified, to ensure best practice, by a person or persons appropriately qualified in the ecology of wild fish, and provided to the Compliance Manager, Marlborough District Council and the Department of Conservation prior to the initial placement of the first structures at the marine farm. The Wild Fish Management Plan shall be reviewed by the consent holder after the survey provided by condition 65(c) has been undertaken. A copy of that review is to be provided to the Compliance Manager, Marlborough District Council no later than 6 months after the survey provided by condition 65(c) has been completed.

67. The Wild Fish Management Plan may be altered in accordance with condition 70.

Management Plans Generally

68. The consent holder is to implement and comply with the Management Plans prepared pursuant to this consent.

69. Where a management plan is to be prepared or certified by someone with appropriate qualifications and experience, the consent holder may give notice in writing of that person, together with their qualifications and experience, to the Compliance Manager, Marlborough District Council. Within 20 working days of receipt of such a notice, the Compliance Manager, Marlborough District Council may give written notice to the consent holder that that person is not acceptable.

70. The consent holder may update a Management Plan from time-to-time.

    a. Any change to a management plan is to be consistent with its purpose.

    b. The consent holder is to provide 20 working days' notice to the Department of Conservation and consult with the Department of Conservation in relation to any proposed change to the Marine Mammal, Shark or Seabird Management Plans.

c. Each time a Management Plan is revised, the consent holder must provide an updated version, together with a brief explanation of any changes, to the Compliance Manager, Marlborough District Council and the Department of Conservation prior to that amendment taking effect.

d. The Marlborough District Council may require the Management Plan to be peer reviewed in accordance with condition 84.

71. Where a Management Plan is required to be prepared by an appropriately qualified and experienced person, any amendment to that Management Plan is to be prepared by a person who is qualified to prepare the original Management Plan. Where the Management Plan is required to be certified by a qualified person, any amendment to that Management Plan is to be certified by a person who is qualified in accordance with that condition. The amendments to the Management Plan does not take effect until the Compliance Manager, Marlborough District Council has had the opportunity to object to that person in accordance with condition 69.

72. Any change to any Management Plan triggers the ability of the Council to undertake a consent review in terms of condition 87.

Staged Development

73. Except in accordance with condition 74-77 and 79, the maximum mass of feed able to be discharged on this site is 20,000 tonnes per annum. The maximum number of net pens is to be 20. The maximum surface area of the net pens is to be 8 hectares.

74. Discharge of feed above 20,000 tonnes may occur if the consent holder provides twelve months written notice of their intention to do this to the Compliance Manager, Marlborough District Council, the Department of Conservation and to each iwi which has received an Iwi Statutory Acknowledgement. That notice must state the increase amount of feed proposed to be discharged. The increment must be no more than 20,000 tonnes above that previously authorised. A notice under this condition may not be given less than three years from any prior notice under this condition. The maximum number of net pens and maximum surface area is to be increased pro rata.

75. Six months after giving that written notice, the consent holder is to provide to the Compliance Manager, Marlborough District Council, the Department of Conservation and to each iwi which has received an Iwi Statutory Acknowledgement reports from appropriately qualified and experienced scientists updating its assessment of environmental effects in relation to the following topics:

a. Benthic effects;

b. Water column effects;

c. Effects marine mammals and sharks;

d. Effects on wild fish;

e. Effects on seabirds;

f. Biosecurity; and

g. Disease.

76. Those updating reports are to:

a. Incorporate any monitoring results and other relevant information;

b. Where appropriate, undertake further modelling to assess the effects of discharging up to the amount of feed specified in the notice; and

c. Make recommendations as to any alterations that ought to be made to Management Plans provided for by this consent.

d. Be peer reviewed by the Peer Review Panel, and any comments which the Panel has on the reports are to be responded to.

Note: If the peer reviewed reports are provided more than six months after giving notice in condition 74, the consent holder is to amend the notice giving six clear months from when the reports are all provided.

77. At the same time as providing the scientific reports, the consent holder is to provide updated Management Plans to the Marlborough District Council and to each iwi which has received an Iwi Statutory Acknowledgement, consistent with the recommendations in the updated reports. These Management Plans are to be referred to the Peer Review Panel, and any comments are to be responded to.

78. Conditions 74 to 77 shall apply to each successive increase of 20,000 tonnes of feed discharged per annum.

79. If notice is given in accordance with conditions 74 and 75 which would see an the maximum number of net pens exceed 60, then

a. The consent holder will additionally provide to the Compliance Manager, Marlborough District Council and to each iwi which has received an Iwi Statutory Acknowledgement reports from appropriately qualified and experienced landscape architect updating its assessment of landscape, natural character and amenity environmental effects.

b. The report will review and update the landscape assessment and the Design Guide

c. That report is to be peer reviewed by an independent Fellow of the New Zealand Institute of Landscape Architects. The identity of the peer reviewed is to be agreed between the consent holder and the Compliance Manager, Marlborough District Council. In the event of a disagreement, the peer reviewed is to be selected by the President of the New Zealand Institute of Landscape Architects or his or her delegate.

Iwi Statutory Acknowledgements

80. The consent holder shall:

a. Record any comments, advice and other information provided by iwi to the consent holder and shall attach that as an appendix to the Annual Monitoring Report. Information that iwi does not wish to be presented in this way need not be presented; and

b. The consent holder must record the response of the consent holder to comments, advice and other information provided by iwi.

Annual Monitoring Report

81. Any Monitoring Report required by this consent is to be provided to the Compliance Manager, Marlborough District Council and the Department of Conservation no later than 15 June each year, unless this consent or a monitoring plan prepared under this consent states otherwise. The Monitoring report shall contain

    a. A statement as to the tonnage of feed and nitrogen discharged each month over the previous year;

    b. The results of all the monitoring undertaken in the previous year;

    c. A comprehensive analysis of the results of that monitoring, including

        i. Whether the monitoring information obtained is fit for the purpose of determining the effects from the operation of the marine farm

        ii. Whether there are any evident trends in terms of effects from the operation of the marine farm.

        iii. An assessment and conclusions as to whether compliance with conditions 35 (if notice has been given pursuant to condition 34), 40-42 and 44-46 is met.

    d. Where identified as a result of the monitoring, any recommendations for other actions to be undertaken to address potential effects from the operation of the marine farm, including to avoid, remedy or mitigate any significant adverse effects from the operation of the marine farm. This may include additional monitoring; and

    e. Any other recommendations for amendments to the monitoring programme or Management Plans for the following year.

82. The Marlborough District Council may require any monitoring report to be peer reviewed in accordance with condition 84.

83. At the same time a Monitoring Report is submitted to the Marlborough District Council, all iwi who have received a Statutory Acknowledgment shall:

    a. By provided with the Annual Monitoring Report; and

    b. Be invited by letter to provide any comments, advice or other information they may determine appropriate. The letter is to invite comment within three months. The letter is to indicate to whom iwi should respond. The letter will record the steps anticipated by the consent holder leading up to the preparation of any revised Management Plan.

Peer Review

84. The Compliance Manager, Marlborough District Council may require an independent peer review of any Annual Monitoring Report or Management Plan received from the consent holder. Any peer review will be undertaken in consultation with and at the cost of the consent holder.

85. Where an independent Peer Review Panel has been established by virtue of a different consent, held by the same consent holder, then, where the issue relates to a matter within the expertise of that Peer Review Panel, the peer review shall be undertaken by that Panel.

86. If no such Peer Review Panel has been established, it is to be established in accordance with the process outlined in Consent U140294 as that consent stood on 13 March 2013 (at the conclusion of the Board of Inquiry process).

Review of Consent Conditions

87. In accordance with the provisions of s 128 and 129 of the Resource Management Act 1991 (or any provision in substitution thereof) the Council may, at the time(s) specified in Table 1 below, review the conditions of consent by serving notice of the intention to do so for one or more of the purposes in Table 1.

Table 1: Purpose and Times of Potential Review of Conditions of Consent

Purpose(s)	Times of Service of Notice
To deal with any adverse effect on the environment which may arise from the commencement of the consent and which cannot be adequately avoided, remedied or mitigated by any term or condition incorporated within the consent, pursuant to the provisions of s 128(1)(a)(iii) of the Act.	On the first day of any month.
To require the consent holder to adopt the best practical option to avoid, remedy or mitigate any adverse effect on the environment relating to the activity.	On any anniversary of the granting of this consent.
To address any matter which might be incorporated or absent in any Management Plan prepared in accordance with this consent.	Within 90 days of being provided with a Management Plan or revised Management Plan.
To address matters relating to the environment identified by information, advice and comments from iwi provided pursuant to condition 80 above.	Within 90 days of receiving that advice pursuant to condition 80.
To address issues arising from an alert issued pursuant to conditions 53 and 58 above.	Within 90 days of receiving an alert pursuant to conditions 53 and 58.
To deal with any adverse effect on the environment which may arise from increase discharges of feed pursuant to conditions 74-79.	Within 12 months of receiving a notice pursuant to condition 74 or within the period specified on any amended notice pursuant to condition 76.
To address environmental effects arising from a transfer of ownership of farms within a biogeograohic region to different owners	Within 6 months of a notice of transfer being received by the Marlborough District Council
To address issues arising from a review of Best Management Practice Guidelines relevant to this consent	Within 6 months of revised best management practice guidelines being adopted by the Marlborough District Council

Removal of Structures

88. Unless a replacement consent is applied for and granted, the consent holder, at the consent holder’s expense, must remove the all structures associated with the farm from the site and provide written confirmation of this to the Compliance Manager, Marlborough District Council, within three months of any of the following events occurring:

  a. The term of the consent for marine farm structures has expired and the consent holder has not lodged an application to renew the consent for those structures, or if such an application has been lodged the consent has been refused and all rights of appeal exhausted;

  b. The consent being surrendered or cancelled; or

  c. The structures becoming redundant or derelict.

Other Matters

89. Pursuant to section 36 of the Resource Management Act 1991 and the Marlborough District Council's Schedule of Fees, the consent holder will be responsible for all actual and reasonable costs associated with the administration, monitoring and review of this resource consent.

90. The consent holder will in the future be required to pay coastal occupation charges if they are imposed through Council’s resource management plans.

APPENDIX C: Open Ocean Farm Structures Examples

HUON AQUACULTURE

HUON FORTRESS PEN SYSTEM

OFFSHORE PROTECTION FOR YOUR FISH & STAFF

huonaqua.com.au

A FISH FARM PEN FOR THE FUTURE

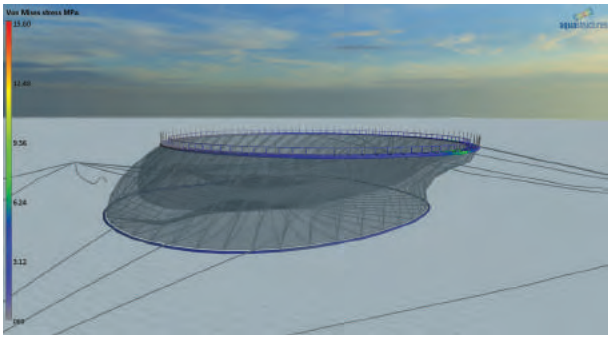
The Fortress Pen System was developed in Tasmania by our team at Huon Aquaculture in response to a need to keep seals out, provide a safe platform for our staff to work on and allow us to farm further offshore. There was nothing available on the market, so we underwent a 2-year, new pen development project with funding support from the Australian Government's Fisheries Research and Development Corporation (Atlantic Salmon Aquaculture Subprogram: trial of a stock protection system for flexible oceanic fish pens). The project began in 2012, with the first prototype pens in the water during 2013.

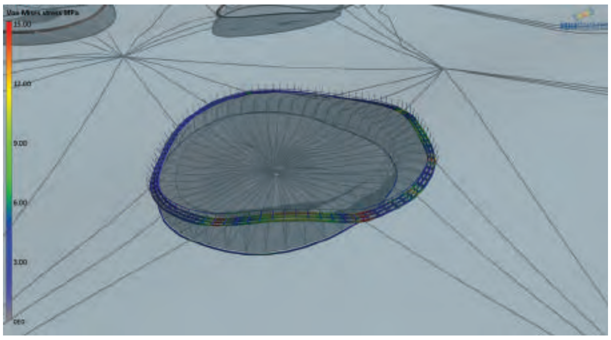
One of the key features of these pens was a patented, wide-style stanchion with flexible seal fence posts in an angled socket to allow an outer predator net to be set around the inner net while keeping a minimum distance of 2m separation between the nets. This outer predator net was connected directly to the sinker tube to reduce rigging and keep it tensioned at all times and in all weather. We then developed a unique tensioning system for the inner net that allowed it to flex with the pen, the predator net and the sinker tube. The end result is a pen that is easy for our staff to work on, keeps seals and other marine predators out and allows us to focus on the performance of our fish.

We've been using our Fortress Pens in some of the roughest farming conditions in the world for over three years and our fish have never grown better.

DESIGNED AND TESTED FOR THE TOUGHEST CONDITIONS IN THE WORLD

Huon's Fortress Pens have been designed for, and now tested in, some of the toughest Australian conditions at Storm Bay, Tasmania and Providence Bay, New South Wales. These sites are high energy, exposed sites, frequently receiving storms swells and gale force winds. Modelling by Aquastructures AS, Norway show the Fortress Pens are capable of withstanding these tough conditions and Farming these pens at these locations over the last few years have shown them to be able to withstand storm events.





HUON FORTRESS PEN

EMPLOYEE SAFETY

- Tapered walkway plates with stud grip, drainage holes and walkway spacers provide a perfect fit for every pen
- Outer predator net above water keeps staff safe from menacing seals and from being washed off the collars
- Staff access areas for easy entry on and off the pen
- Huon's Fortress Pen System recieved the Innovation in Safety award from the 2015 Tasmanian Community Achievement Awards

ON WATER MANAGMENT

- Endless rope net-tensioning systems allow the inner nets to be easily released and tensioned
- Stanchions made from impact modified Nylon provide the strength of steel, but with durability and flexibility
- Huon's Fortress Pens contain no steel parts to damage boats or chaff through nets and ropes

FISH PROTECTION

- Outer seal-fence poles and predator-proof netting to keep seals off the pen above-water
- Flexible bird poles keep bird nets supported so birds cannot get near the fish or fish feed
- Underwater the predator net provides an impenetrable barrier that keeps seals and sharks away from the fish

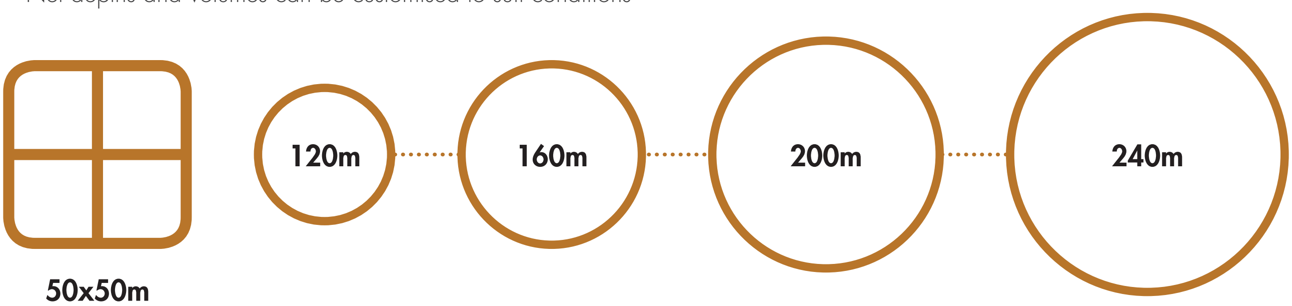
FISH PERFORMANCE

- Light-weight, super-strong nets allow excellent water flow, reducing drag and improving in-pen DO's
- Keeping seals, sharks and birds away from the fish allows them to grow without disturbance
- Nets are optimised for use with mort collectors, so any dead fish can be retrieved as required

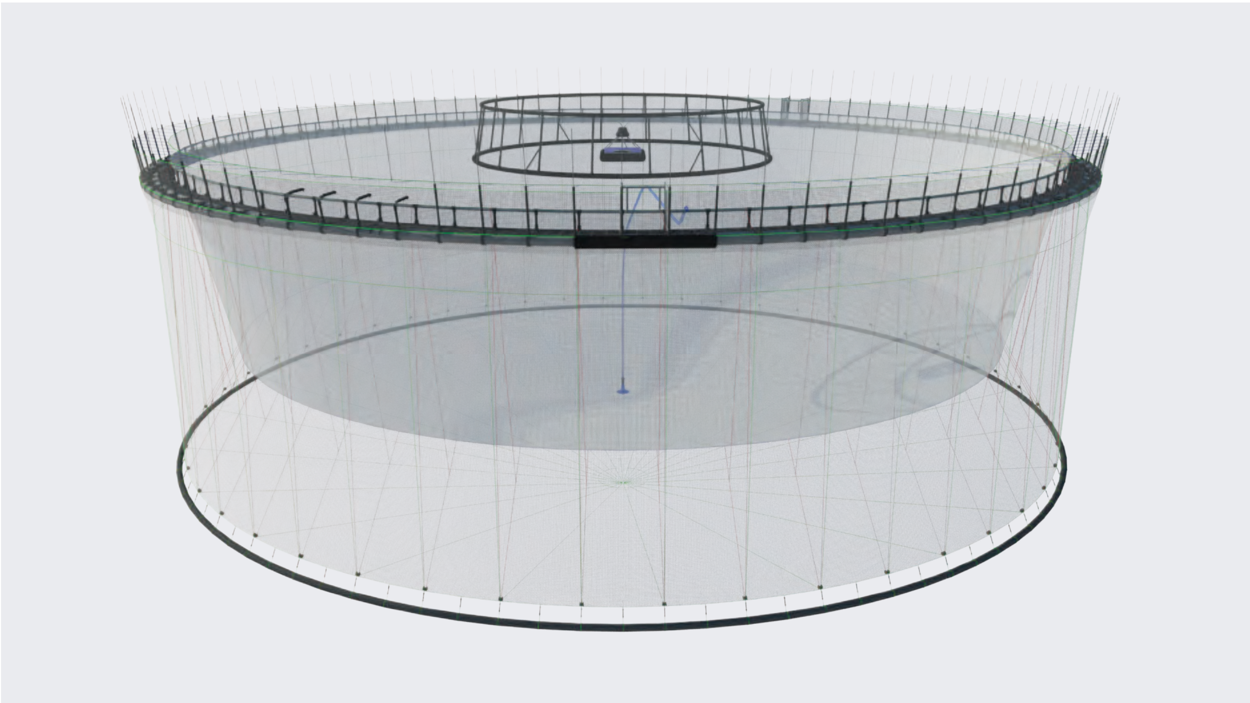
FORTRESS PEN SPECIFICATIONS

System Name	Overall Pen Circumference/Size	Collar Pipe Diameter*	Predator Net Depth†	Fish Net Depth†	Fish Net Volume†
Square	50x50m	450mm	20m	16m	40,000m^3
F120	120m	450mm	16m	13m	10,000m^3
F160	160m	450mm	22m	17m	25,500m^3
F200	200m	560mm	28m	22m	48,000m^3
F240	240m	560mm	32m	26m	72,500m^3

* All pens have 3 collars
† Net depths and volumes can be customised to suit conditions

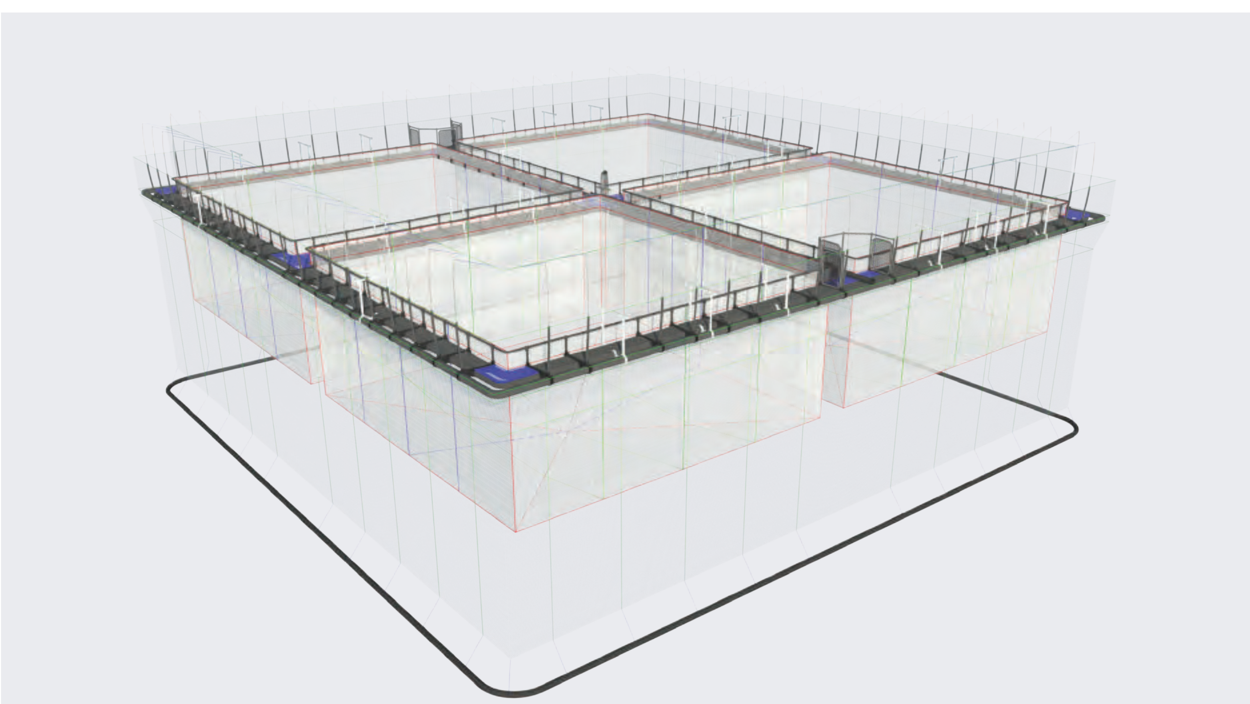


HUON FORTRESS PEN - ROUND



F240m circular pen with LiftUp, bird net stand and feed spinner

HUON FORTRESS PEN - SQUARE



Square pen with 4 pods and dual staff access points

FORTRESS PEN COMPONENTS

Moulded HDPE or Nylon pen compnents include: **1** Handrail/Seal Pole Plug **2** Pin Locker **3** Rope Tension Pulley **4** Handrail T **5** Walkway Plate **6** Walkway Spacer **7** Stanchion Block **8** Stanchion

A LITTLE BIT ABOUT US ...

We've been farming top quality salmon in the pristine waters of Tasmania for over 30 years and in that time we've learnt a thing or two about the best way to raise some of the highest quality salmon in the world.

We have built a reputation based on quality and innovation with a proud history of leading the way in aquaculture developments both in Australia and internationally. A constant desire to put the health of our marine environment, our fish and the safety of our staff at the forefront of every business decision has led to innovation across all aspects of our business. Recognition that the future of fish farming looks very different to that of today continues to drive significant change in our global aquaculture industry as companies like ours move to offshore, deeper oceanic sites and look to adopt technology such as the Huon Fortress Pen Systems that can withstand these more beneficial, but equally challenging, new farming locations.

This focus on continual improvement and innovation in the way we farm has set the foundations for Huon Aquaculture to continue to grow sustainably into the future.

Peter and Frances Bender
Co-Founders

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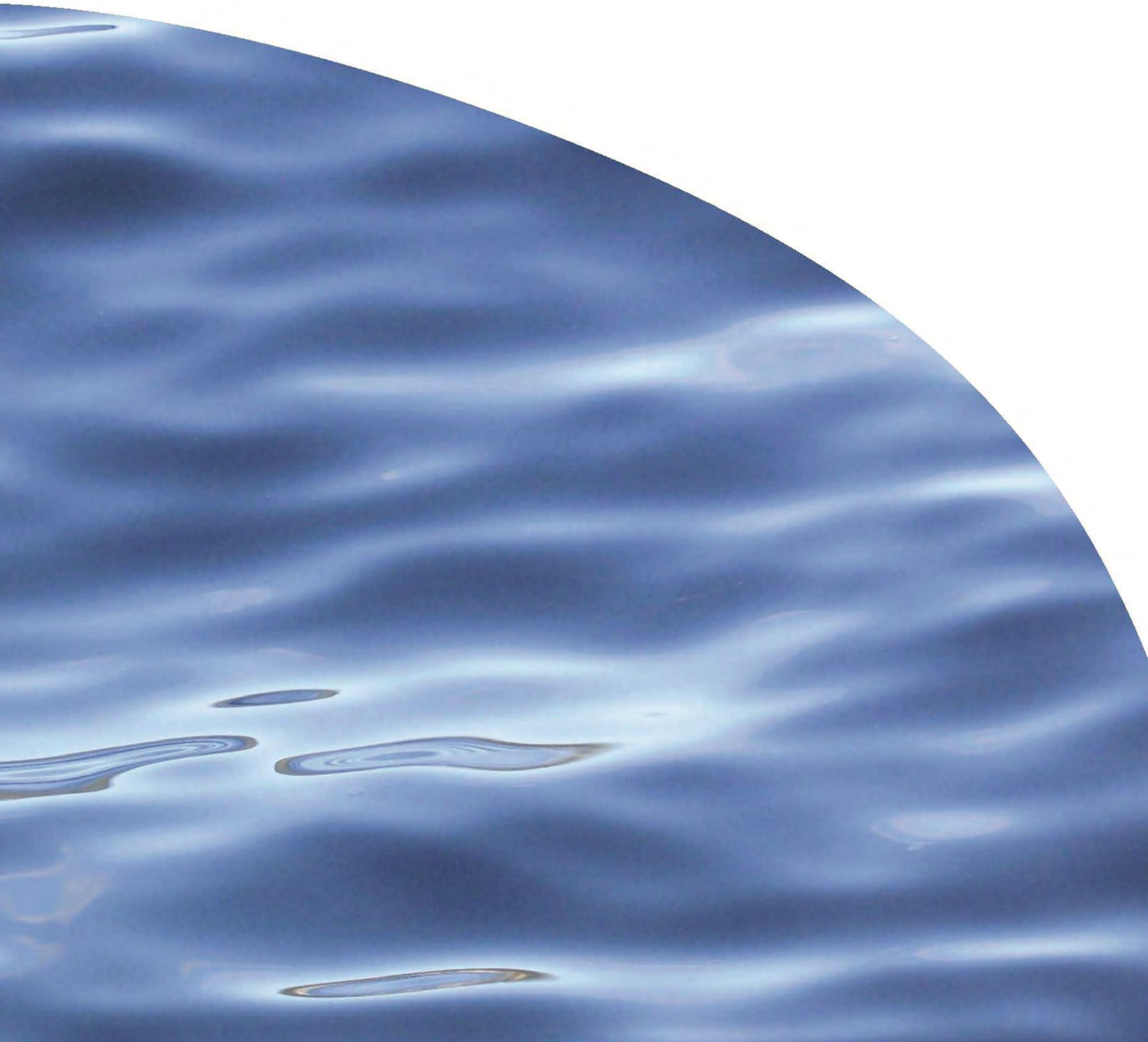
YOUR LOCAL SUPPLIER

huonaqua.com.au

APPENDIX D: Benthic Report

REPORT NO. 3317

ASSESSMENT OF SEABED EFFECTS FROM AN OPEN OCEAN SALMON FARM PROPOSAL IN THE MARLBOROUGH COASTAL AREA



ASSESSMENT OF SEABED EFFECTS FROM AN OPEN OCEAN SALMON FARM PROPOSAL IN THE MARLBOROUGH COASTAL AREA

DEANNA ELVINES, EMILY MCGRATH, MALCOLM SMEATON, DON MORRISEY

Prepared for The New Zealand King Salmon Co. Limited

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REVIEWED BY:
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APPROVED FOR RELEASE BY:
Grant Hopkins

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EXECUTIVE SUMMARY

Cawthron Institute was contracted by the New Zealand King Salmon Co. Limited (NZ King Salmon) to provide a report describing effects on the seabed arising from a proposal to develop an open ocean site for salmon farming. The proposal area is 1,800 ha of water space in total and is located offshore of the Marlborough Sounds, due north of Cape Lambert, and east of the Chetwode Islands. Compared to existing water space operated by NZ King Salmon for coastal salmon aquaculture (16.95 ha of surface structures, and 139.7 ha of total water space), this would be a substantially larger, and more exposed, farming area. There are better waste dispersal capabilities at dynamic offshore locations such as the proposed site (compared to those further inshore), and this is a clear advantage for mitigating seabed effects.

The initial level of production of the proposal is 10,000 tonnes of fish (approximately 20,000 tonnes of feed), with further staged increases beyond this. This assessment describes what the seabed effects would look like under a range of theoretical scenarios that are expected to encompass the proposal's magnitude.

The main findings of our seabed assessment are as follows:

- A range of sediment types were observed at the study area, grading from sandy-mud through to coarse sand and gravels with high amounts of shell debris. Bathymetry and sediment type within the area appeared to be influenced largely by scouring from water movement around McManaway Rock on the edge of the survey area. The sediment was well oxygenated with low organic content (2.4–4.5%). Rich infaunal communities were present within sediments across the area, and are typical of those present at deep high-flow areas within the Marlborough Sounds. There were also distinct habitat classes (strata) based on the visual seabed biological characteristics. The strata were: biogenic habitat (horse mussels [and/or horse mussel debris/biogenic clumps]) and brachiopod mixed communities, soft bryozoan fields, reef-edge assemblages, and areas where epifauna were sparse. The reef edge communities flanked McManaway Rock, an area of which is classified as a significant marine site in the Marlborough coastal area.
- The proposed site has water depths of 60 to 165 m. Water current velocities at the site are strong (mean and maximum near-seabed currents of 31 and 86 cm/sec, respectively; mean and maximum mid-water, 35 and 110 cm/sec) and the predominant axis of flow is southeast/northwest. The proposal area is a high-flow environment where wastes will be readily dispersed and assimilated, but the trade-off is a larger, more diffuse footprint. Our depositional modelling shows that the site has capacity to support a large salmon farm development.
- At the initial proposed production level of 10,000 tonnes per year (20,000 tonnes of feed discharge) depositional modelling indicated that the maximum depositional flux within the primary footprint would be on the order of 2.44 kg solids/m^2/yr (moderate enrichment), with a total footprint area of 453 ha. Scaling up the production to 40,000

tonnes of production resulted in depositional flux of up to 9.0 kg solids/m^2/yr, with a total footprint of 658 ha. Fine farm waste material will also be dispersed, through water column transport and sediment resuspension processes, to the far field (e.g. outside of the total and primary footprints). Through these processes, dispersal is estimated to be on the order of kilometres beyond the primary footprint modelled in this assessment, although accumulation will be at low levels that may not be easily discernible.

- Based on the initial production level, in the most intensely affected area (moderate enrichment conditions), more tolerant and opportunistic taxa will begin to dominate infaunal communities, and sensitive taxa will be displaced. As a result, taxa richness will be reduced from background conditions, and total abundances may increase. There will be slight changes to sediment chemistry (total free sulphides and redox potential) due to increased microbial activity, and patches of bacteria may be visible. Some more sensitive (sessile suspension feeding) epifauna may show reductions in density, while more tolerant taxa may increase (e.g. mobile deposit feeders may aggregate in these areas). It is highly unlikely that levels of copper and zinc will reach an adverse biological threshold at this level of production. With increasing proximity to the edge of the footprint (~1.5–2 km downstream of the pen edges), infaunal communities will grade to background conditions, with a large proportion of the footprint containing communities with enhanced taxa richness and abundances, akin to a 'fertilisation' effect.
- The tolerance of horse mussels and brachiopods to farm-related deposition is not known, but it is likely to be low. Thus, depending on the location of the structures within the proposal area, epifaunal communities may show sub-lethal effects, or be displaced, even at relatively low depositional levels (mild to moderate enrichment). The significant marine site and reef-edge assemblage areas also contain taxa likely to be sensitive to deposition.
- Far-field waste dispersal, and possible associated effects are difficult to predict, but are an important consideration in monitoring at this site, due to the dispersive nature of the site and the potentially large farming area that it may be able to support.
- Two key considerations to reducing the likelihood and consequence of ecological effects are:
    - avoiding overlap of the footprint with sensitive horse mussel and brachiopod beds, and the McManaway Rock fringing strata,
    - monitoring and effects-based management whereby the potential effects of concern can be monitored, and farming practices adapted to minimise the risk of unacceptable effects as the activity progresses.

  In addition, there are other operational management practices that can help to reduce some of the effects.
- A robust, long-term management plan should be prepared prior to any structure installation. This should include clearly defined limits on 'effect acceptability', intervention framework and feedback pathways for adaptive management and monitoring, and details of a well-designed monitoring programme that measures

effects. Additional depositional modelling is recommended to inform the monitoring design, once the final farming configuration is known. This modelling should include a higher number of released particles, and particle resuspension.

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1. INTRODUCTION

Cawthron Institute (Cawthron) was contracted by The New Zealand King Salmon Company Limited (NZ King Salmon) to provide a report describing effects on the seabed arising from a proposal to develop an offshore, open ocean site for salmon farming. The proposal area is 1,800 ha, northeast of the Marlborough Sounds, due north of Cape Lambert, and east of the Chetwode Islands (Figure 1). The total area surveyed as part of this assessment is approximately 5,000 ha.

1.1. Scope of the proposal

NZ King Salmon want to install salmon farms in open ocean areas due to improved environmental conditions for farming and reduced biosecurity risk. With a total water space of about 1,800 ha, the proposed site could potentially support a large-scale salmon farm development. The total area occupied by surface structures at any one time would be considerably less than the total proposal area (1,800 ha), and NZ King Salmon want flexibility to move the farm structures within the site.

There are physical operational constraints at sites with high water currents and wave action that must be considered when selecting pen technology. In addition, pen technologies for such exposed environments are relatively new, and the details of the pen structures and mooring design used in the proposal are yet to be confirmed. Options include multiple polar-circle style pens serviced by an onsite barge system, and pens that can be submersed to afford protection from unfavourable oceanic conditions. Screw anchor systems are likely to be used to fix the structures to the seabed.

The initial level of production of the proposal is up to approximately 10,000 tonnes of production (20,000 tonnes of feed), across two blocks of pens, each serviced with an onsite barge. Further staged increases beyond this initial level could reach an aspirational 40,000+ tonne production level (80,000+ tonnes of feed). By way of managing any uncertainty of effects associated with the proposal, NZ King Salmon propose a planned process is followed before feed levels discharged at the site progress beyond 20,000 tonnes per annum. This process would comprise (and increased production levels would be contingent on) an independent assessment of effects (and review of new knowledge[1]) measured as a result of production levels of < 10,000 tonnes.

[1] In both published literature and relevant monitoring information collected at the proposal site, and also other salmon farm sites within the Marlborough Sounds.

2. SITE CHARACTERISATION

2.1. Site scoping

The total area included in the survey was approximately 5,000 ha, determined by an 'Index of Suitable Locations' (ISL; provided by MetOcean Solutions Ltd) and by cursory depositional modelling from a salmon farm scenario. The ISL used LINZ (Land Information New Zealand) depth sounding points, and modelled ocean currents from MetOcean Solutions Ltd to identify the most suitable farming locations. In addition, a depositional modelling scenario was run (DEPOMOD; Cromey et al. 2002) using the ISL depth and ocean current data, to approximate the spatial extent of the depositional footprint (results not provided). The footprint boundary was then buffered in each direction (by approximately ~1.5 km) in primary flow directions. The boundaries of the buffer area delineated the edge of the area put forward for survey for seabed characterisation.

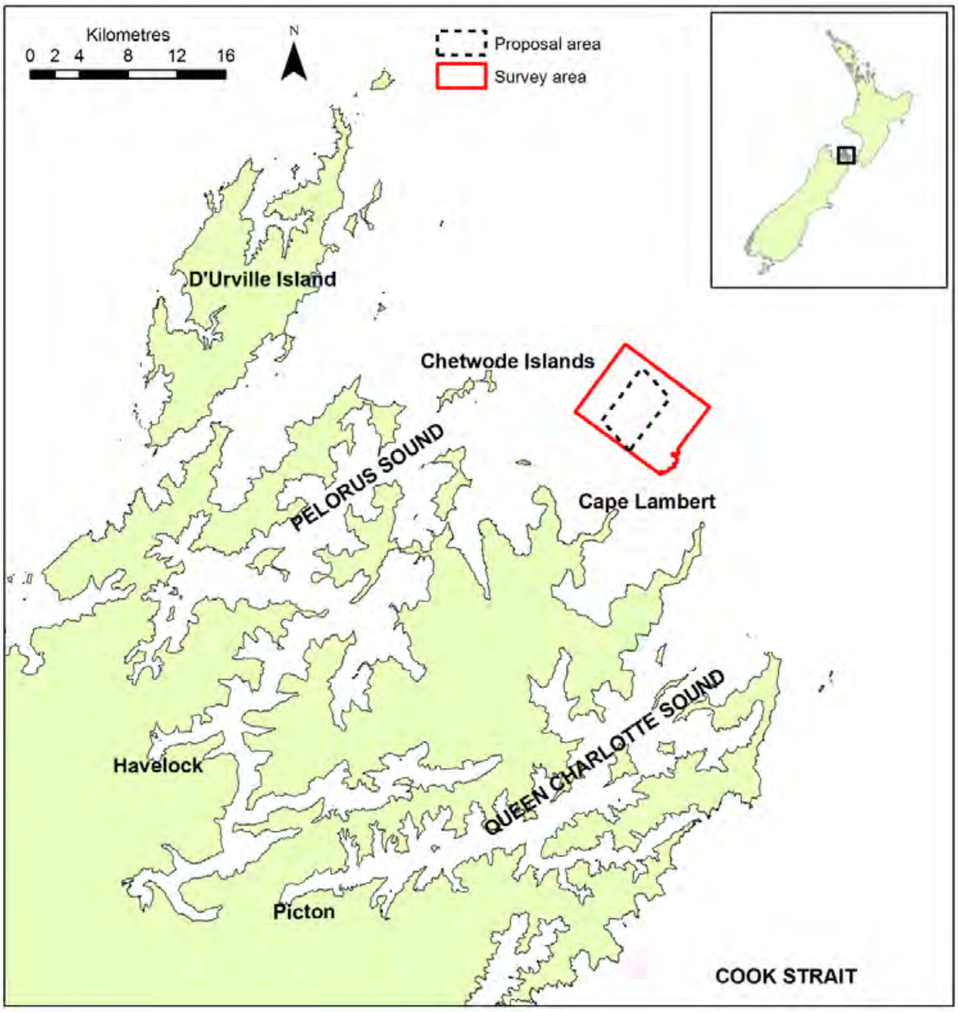

Figure 1. Total area (5,000 ha) of seabed surveyed for the seabed assessment (red line) in relation to the Marlborough Sounds. The irregular boundary on the southwest corner is a result of the survey being extended toward McManaway Rock.

2.2. Methodological approach

Due to a lack of existing bathymetry and seabed ecology information for the survey area, and the large total area that needed to be surveyed, a multibeam echosound (MBES) survey was performed. Following the MBES survey, imagery was obtained from ‘classes’ (defined by MBES data; see Section 2.2.1) within the survey area using drop camera and towed sled video. Sediment sampling was carried out across the survey area. The purpose of the video and sediment sampling was to validate the sediment properties inferred from the backscatter data, and characterise the infaunal communities present within the area. Further detail on sample collection is provided in the following sections.

2.2.1. Multibeam echosound (MBES) survey

The MBES survey gathered high resolution (0.25 m^2) depth and backscatter information. Full details of the MBES survey are provided in Appendix 1. Depth data were used to provide an accurate picture of seabed bathymetry and were also used in the depositional modelling (Section 3.2.2).

Backscatter intensity infers physical seabed characteristics, using sound signal reflected from the seabed. Specific parameters that can be inferred from backscatter data include sediment grain size, composition and microtopography (depending on the cell size, this can include features formed by biological processes; for example, bioturbation). Lamarche et al. (2011) define backscatter classes that can infer substrate type. Although a quantitative method, we apply these three ‘classes’ to our backscatter tile data in a qualitative sense to infer substrate type in a given area. A quantitative analysis of the data was not considered necessary for the purposes of site characterisation. The three classes defined in Lamarche et al. (2011) are in bold below, and described further in the text that follows:

- **Homogenous weak-to-moderately reflective (dark grey on the map).** This likely indicates softer, more homogenous sediments (i.e. mud to sand).
- **Homogenous, highly reflective (light grey on the map).** This likely indicates coarse substrate that is reasonably homogenous. For example, substrate comprising sand and shell hash.
- **Highly heterogenous reflective (light grey on the map, with irregular dark patches within).** This likely indicates rock, whereby there is a high reflectance from the hard surface but the irregularities of bedrock and boulder/cobble type seabed scatters the incident energy. This scattering results in a high level of variability in the signal, thus creating an apparent ‘shadow’ effect in the mapped backscatter image.

In this study, backscatter was used to indicate the presence of any previously unknown areas that might support diverse epifaunal communities (e.g. rocky reef habitat). The data were also used to inform the design for more in-depth sampling techniques, by allowing targeted arrangement of video sampling to obtain a good representation of the habitats present, minimising the risk of not capturing the full range of habitat types within the area.

2.2.2. Seabed imaging

Seabed imaging was undertaken on 8-9 January 2019 to ascertain seabed characteristics (primarily epifaunal communities) that may not be evident in the MBES survey. Imaging was performed using towed video sled technology, as well as a video camera attached to a drop frame (drop camera), both with external, battery-powered lights. A towed video sled is suited to epifaunal communities that are patchy or sparse in nature, whereas a drop camera provides only a snapshot of a small seabed area but is useful in areas of variable seabed relief, (which may snag a towed sled), and when conditions preclude effective sled towing or footage collection (i.e. strong wind/currents, low water visibility).

The 28 stations surveyed for seabed imagery (Figure 2) were targeted to capture each 'class' of MBES backscatter characteristic. At most locations, a video sled was towed along a transect typically 100 to 200 m in length. The start and endpoint of transect were marked as the position of the vessel when the video sled made contact with, or left, the seabed. The position of the transect therefore reflects the position of the vessel during the transect survey, not the position of the video sled. It is difficult to calculate the position of the video sled due to the influence of deep water, strong currents and variable video cable layback along any given transect. The start/end locations therefore have an error of up to ~200 m based on the length of cable paid out[2] and the water depth. The entire transect was viewed via live feed to the vessel, and recorded on a PC, as well as being recorded on a closed-circuit camera system.

Where video sled tows were not feasible, a drop camera was used. This system involved a weighted steel frame with a fixed downward-facing camera being lowered to the seafloor. There was a smaller positioning error associated with this method as compared to the video sled method. For the drop camera array, two cameras were used: closed circuit camera and live feed camera. Generally, this footage was of poorer quality than the towed video sled footage, and would likely have underestimated patchy communities, but it did provide a small, but useful, snapshot of the seafloor.

Seabed habitats were characterised qualitatively during post-survey review of the recorded footage. A narrative was provided with respect to substrate type, biogenic features and epifauna. Relative abundance[3] estimates were assigned for notable

[2] the error will be less at the start point when less cable was paid out.

[3] For abundances, rare = present in < 5% of the video frames, occasional = present in 5-20%, uncommon = present in 20-50%, common = present in 50-80%, abundant = present in 80-100%. Percent cover was assessed as an average across several video frames from different points of progression along a given transect.

taxa, based on qualitative density estimates averaged across the entire video transect.

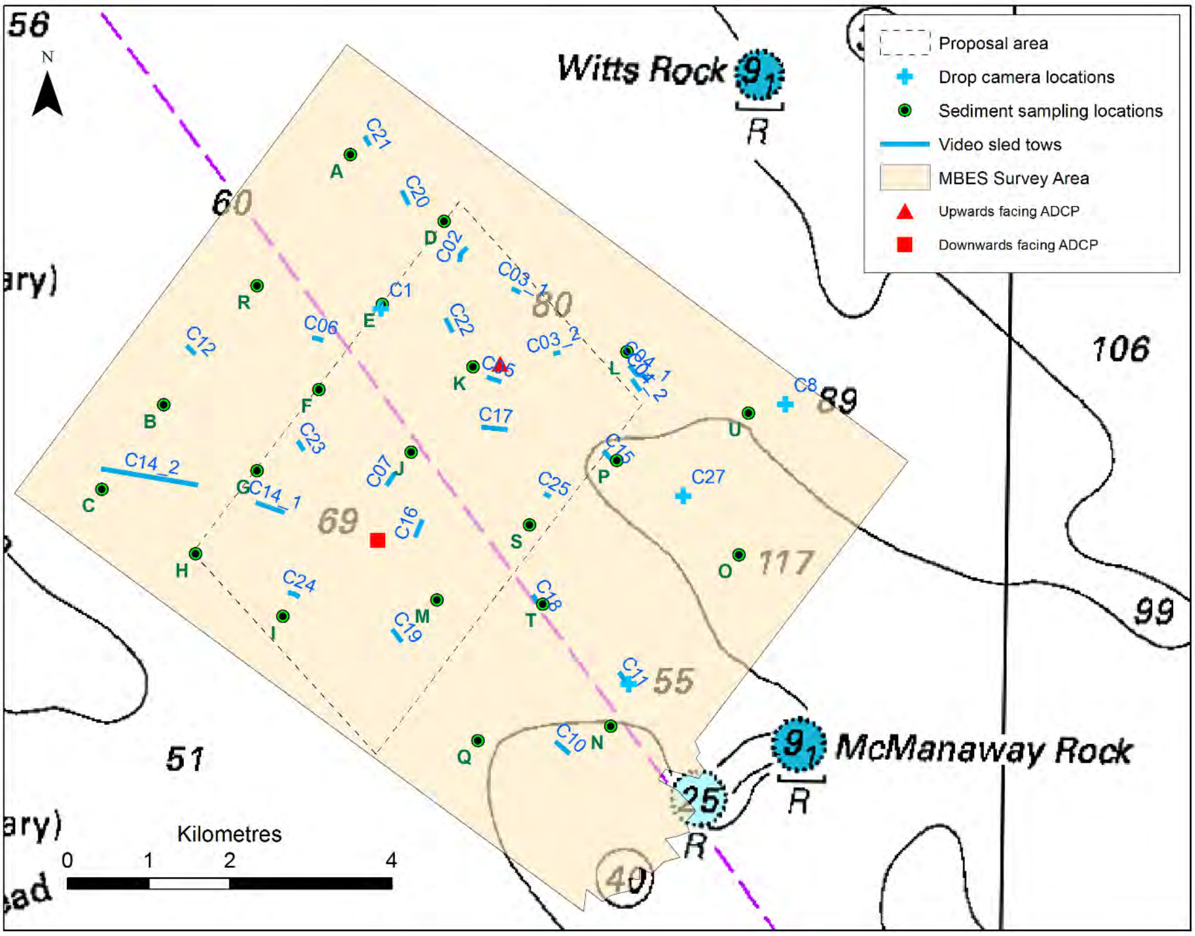

Figure 2. Map of sampling locations within the survey area. MBES = multi beam echosound. ADCP = acoustic Doppler current profiler.

2.2.3. Sediment sampling and analysis

Single replicate sediment samples were collected on 25 January 2019 from 21 sampling stations (Appendix 2). Sampling stations were arranged to provide a good representation of the different backscatter classes (see Section 2.2.1). Full methodologies for sample collection and data analysis are provided in Appendix 3. In summary, each sample was assessed for sediment grain size, organic content (as % ash free dry weight), redox potential, and infaunal community metrics. Multivariate analyses were performed on the infaunal data and Enrichment Stage scores were calculated for each sampling station (methods and data provided in Appendix 4).

2.3. Site bathymetry

Depths in the survey area ranged from 45 m within a part of the McManaway Rock complex[4] (in the SE corner of the survey area), to 165 m deep 'holes' on either end of McManaway Rock complex (Figure 3). In the middle of the area, running on a northwest/southeast axis, the seabed forms a relatively shallow 'ridge' of approximately 60 m depth. Either side of this ridge, and along the same axis, the seabed deepens variably, notably toward the holes present either side of McManaway Rock, and to a lesser extent at the NW end of this axis. The bathymetry is more homogenous near the NW boundary of the survey area, with depths of 60 to 75 m along this edge.

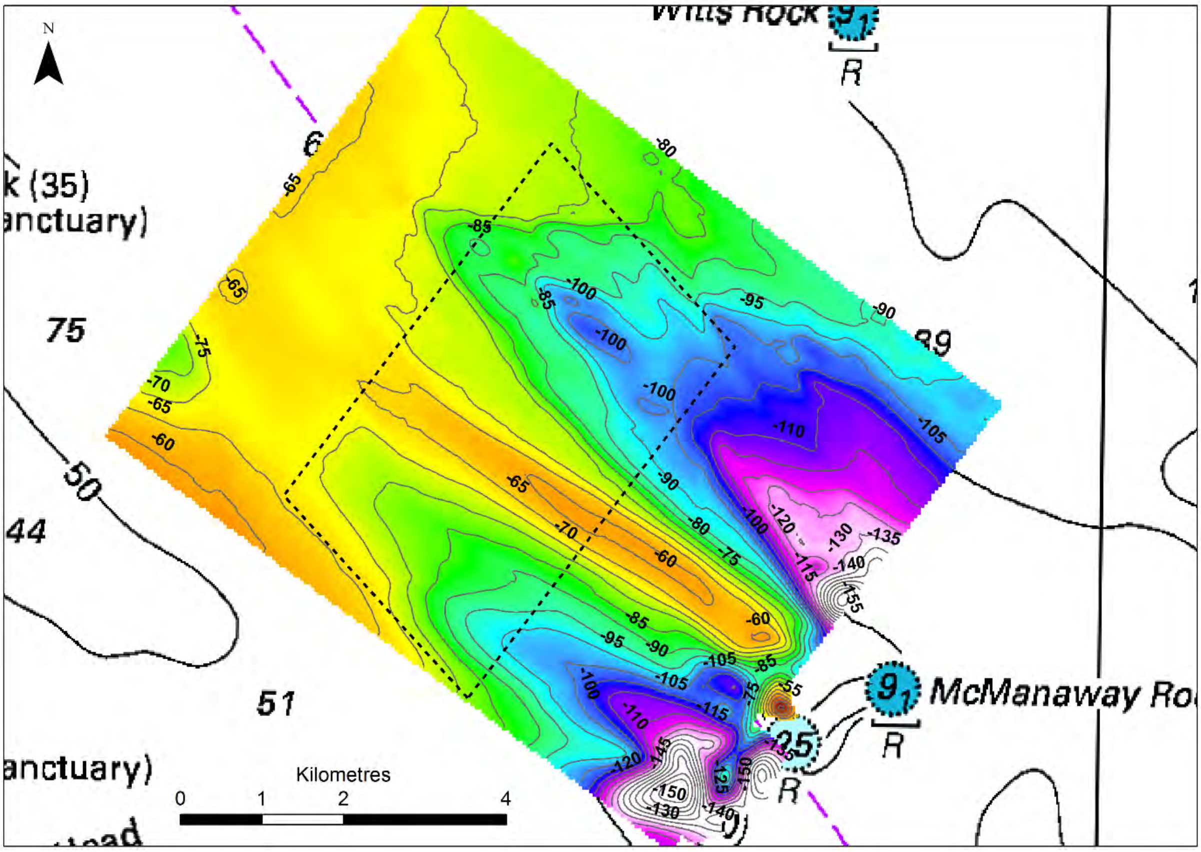

Figure 3. Bathymetry data from the multi-beam echo-sound (MBES) survey overlaid onto chart NZ46. Contours are at 5 m depth intervals. Black dashed outline is the proposal area.

[4] The entire McManaway Rock complex was not surveyed.

2.4. Sediment physical and chemical properties

The sediment was well oxygenated with redox values of 84–329 Eh_{NHE}, mV, and a low, but variable, organic content (2.4–4.5% AFDW) (Appendix 4). Backscatter data from the MBES in the present study are displayed in grey-level mosaics at a grid resolution of 0.5 m (Figure 4). The lighter shades indicate high backscatter intensity (reflectivity; i.e. harder substrate), while the darker grey indicates lower reflectivity (i.e. softer substrate).

Soft sediment comprised an estimated 20–25% of the area, while sandy/gravel sediments comprised 60–70%. The remainder of the area (~10%) was hard substrate, likely rocky outcrop or cobble type substrate. Generally, the more rocky, gravelly areas were to the southeast end of the site, nearer to McManaway Rock.

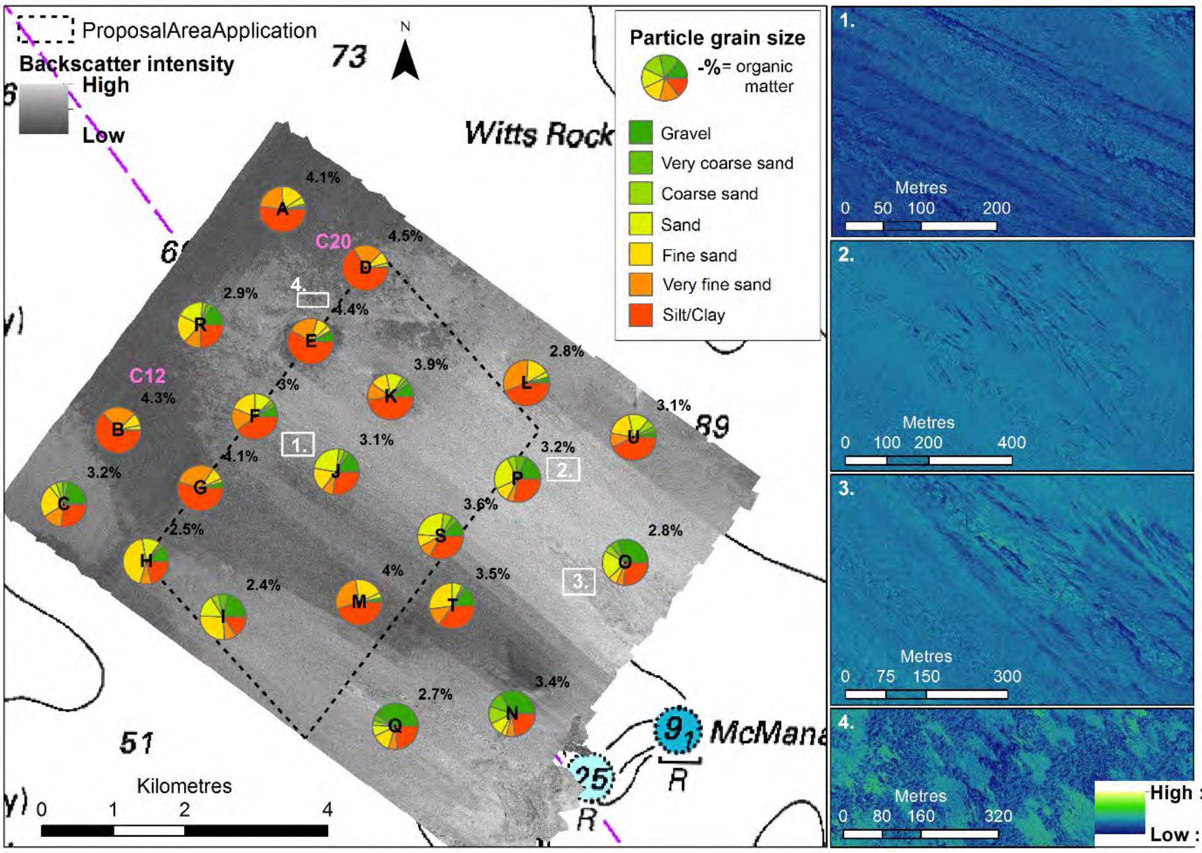

Figure 4. Overview of sediment properties from the backscatter data, with charts showing particle grain-size at each grab sampling location. Panels on the right highlight the nature of backscatter intensity of several distinct features (e.g. 1. rock outcrops, 2. undulating seafloor, 3. gravel/rock deposits, 4. biogenic features); panel locations are the boxes marked in the main map panel. C20 and C12 video sled areas are marked for reference to Figure 5.

The distinctly lighter grey areas evident in Figure 4 comprised coarser sediments and rock and were largely associated with deeper areas within the site. They were probably created through sediment scouring from high currents inundating around the McManaway Rock complex. Conversely, muddier/sandier sediments were apparent primarily at the north-western end of the area, but also extending through the mid-section (southeast) toward McManaway Rock.

Smaller areas of irregular backscatter were also apparent within the survey area (e.g. Figure 4 [insets 1-3]). These could be rock outcrops covered with surficial sediments (i.e. not apparent in video footage), deposits of large rocky material, or undulating seafloor topography (e.g. sediment 'waves').

The northern part of the area also showed a high level of patchiness in the backscatter (e.g. Figure 4 [inset 4], Figure 5) similar to that seen in other MBES surveys where clumps of epifauna were present (e.g. bryozoans; Grange et al. [2003]). Video analysis confirmed the signal was due to large patches of biogenic habitat (horse mussel and shell debris; see Section 2.5.1). The patches were also evident in bathymetry as small raised areas (< 1 m in height from the seabed; Figure 5).

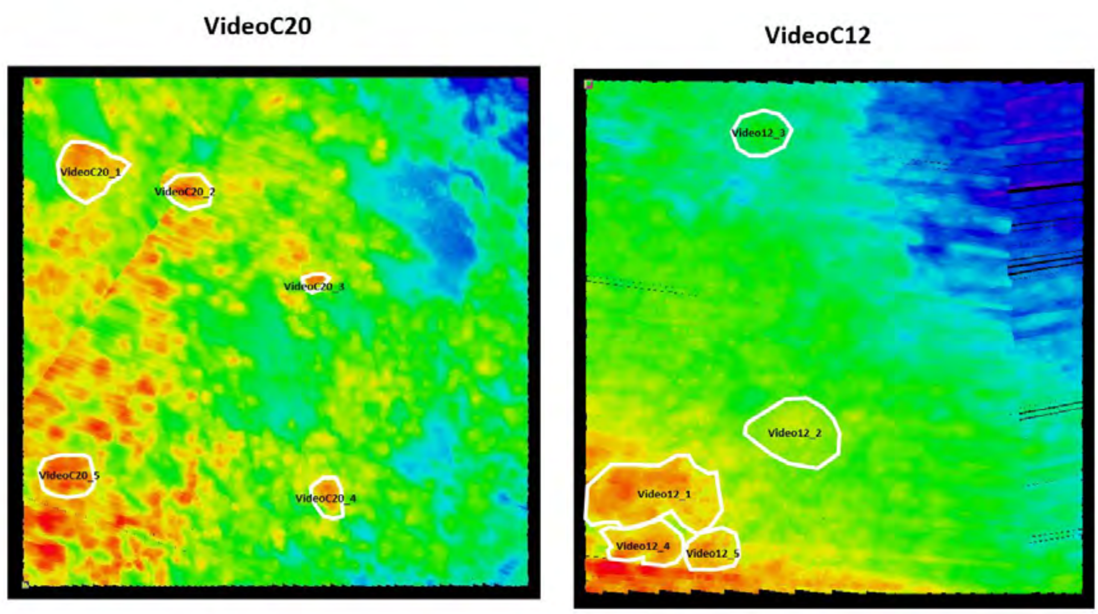

Figure 5. Bathymetry examples from an area where biogenic habitat was seen in video footage (video sled C20 and C12—see Figure 4). Discrete raised areas circled in white are thought to be biogenic habitat patches. Each panel is 200 m^2.

2.5. Biological communities

2.5.1. Infauna

Infauna refers to communities living within sediments. Most samples contained moderate numbers of taxa, typically between 20 and 45 taxa per core. Three samples contained fewer than 20 taxa (14, 17 and 19 taxa per core for stations R, B and H respectively, located on the western edge of the survey area), while one sample had a very high number of taxa (59 taxa per core, site Q, nearby to McManaway Rock). Total abundances were variable, ranging from 44 to 293 individuals per core, with an average of 130 per core (full dataset provided in Appendix 5). These statistics and the level of variability are reasonably comparable with communities commonly found in deep, high-flow areas within the Marlborough Sounds (e.g. Tory Channel; Clark et al. 2011).

Results of the multivariate analysis on infaunal assemblage shows the relative similarity of the samples across the survey area. There are two distinct groups at a 40% level of similarity. Group 1 sites generally had lower taxa richness and total abundances (Appendix 4). In terms of community composition, the strongest distinguishing factors between these two groups were the absence of maldanid and syllid polychaete worms, oligochaete worms and *Aricidea* sp. from Group 1, and the dominance of nematode worms, *Prionospio* spp., *Spiophanes kroyeri* and ampharetid polychaetes in Group 2. The abundances or presence/absence of a variety of other invertebrate taxa were also influential in distinguishing these groups. The infaunal communities appear to be largely influenced by particle grain size (as would be expected), based on the vector overlay for the sediment properties (Figure 6).

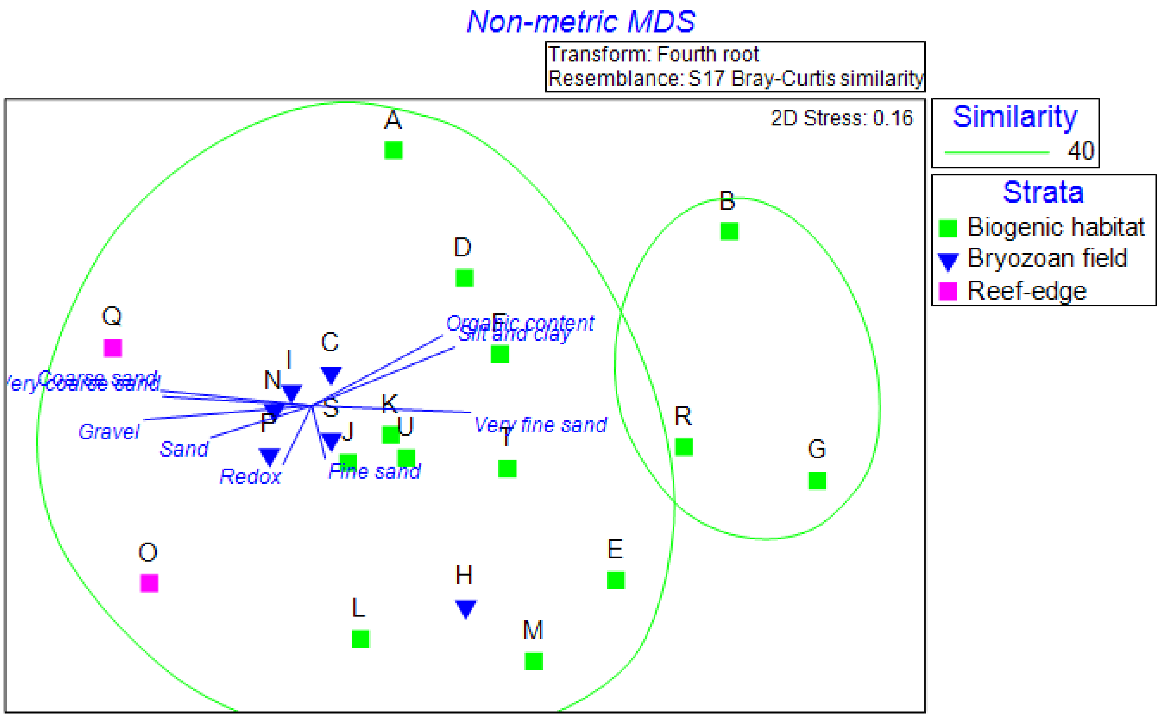

Figure 6. Similarity (%) of the offshore infaunal assemblages as shown by multivariate analyses. Non-metric multi-dimensional scaling plot of similarities between infaunal assemblages (clustered at 40% similarity), overlaid with vectors of sediment properties (particle grain size, organic content, and redox). Symbols denote seabed strata assigned through video footage review (Section 2.5.2). Analysis was performed on the basis of Bray-Curtis similarity resemblance matrix of fourth-root transformed count data.

2.5.2. Seabed epibiota

Overview

Four primary epifaunal ‘strata’ (or habitat ‘classes’) were seen within the area (Figure 7). In summary, these strata were biogenic habitat, bryozoan fields, and reef edge assemblages, with the remainder of the area (~10%) comprising sparsely populated mud communities (Figure 8). Strata were assigned within the survey area based on epibiota characteristics seen in the video footage, inferred using continuous substrate characteristic data and high-resolution bathymetry layers from the MBES survey. Some ‘transitional’ habitat will exist between the delineated strata (in particular, between the bryozoan field and reef edge strata) that is not well depicted in Figure 8. These strata are discussed in more detail in the next section.

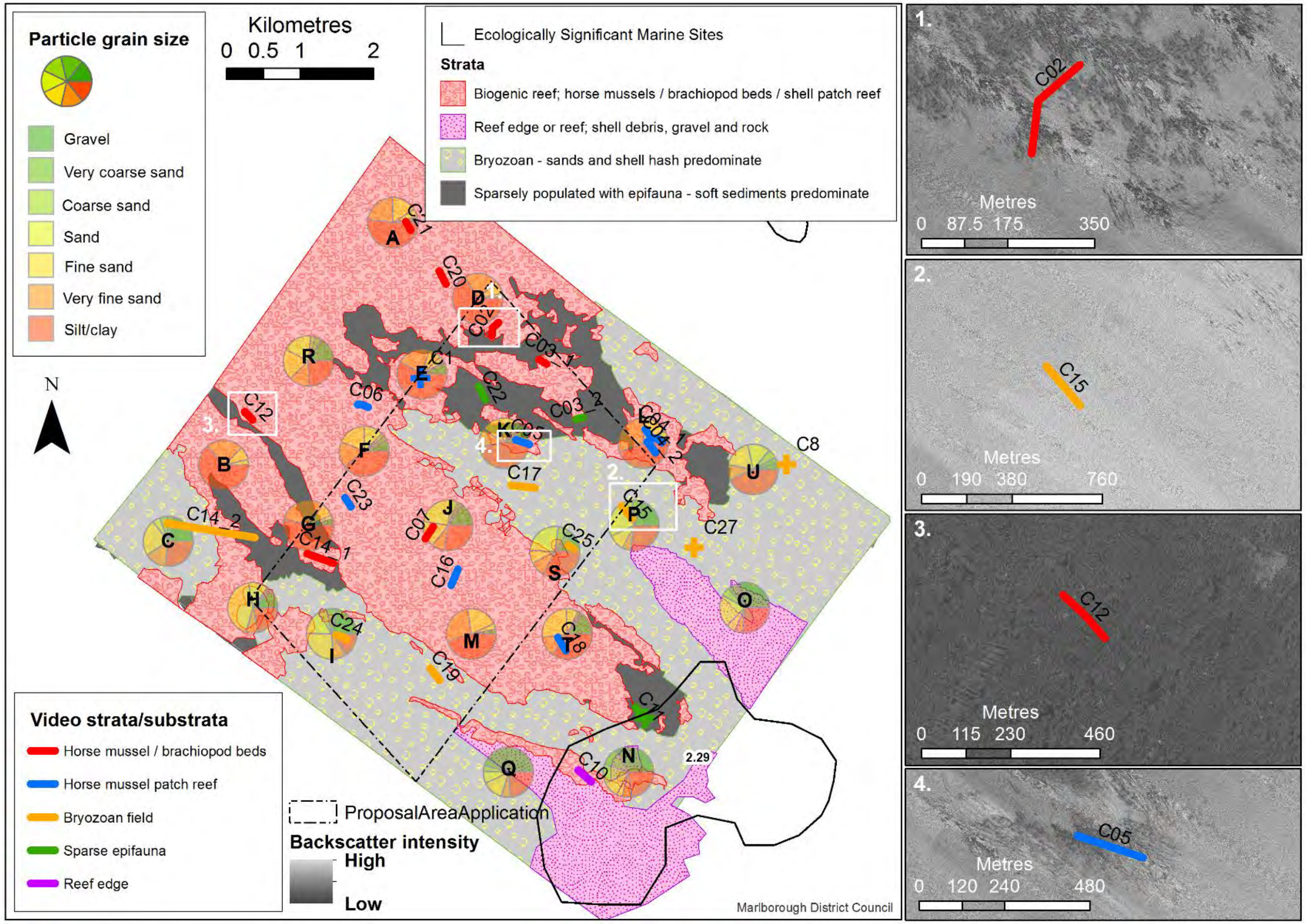

Figure 7. Approximated habitat map overlain with sampling locations, sediment grain size, backscatter data, and video transects/drop camera locations. The boundary of Ecologically Significant Marine Site 2.29 is shown in relation to the proposal area (lower right).

Description and ecological significance of strata

A detailed description is provided for each stratum found in the seabed survey below. Examples of taxa seen in the video footage are provided in Appendix 6.

Biogenic habitat

These strata comprised over 45% of the surveyed area, and within this, there were two substrata:

a. **Horse mussel/brachiopod beds** (Figure 8), which comprised ~70% of the biogenic habitat strata. Within this habitat type there were patches (up to 20 metres across) of dense epifaunal communities comprised primarily of horse mussels (*Atrina zelandica;* density of living animals ~40% per m^2, and density of non-living ~40% per m^2), and in most areas, brachiopods (density up to ~70 per m^2, including but not limited to incidental species found in grab samples; *Notosaria nigricans* and *Terebratella sanguinea*) (Figure 9). Based on the qualitative video footage observations, approximately 50% (20–80% depending on transect) of this substratum was characterised as 'horse mussel/brachiopod beds'. Other fauna associated with the horse mussel patches included occasional snake stars (*Ophiopsammus maculata*), sea cucumbers (Holothuroidea), gastropods (notably *Astraea heliotropium* and *Maoricolpus roseus*), large anemones (unidentified), fanworms (Sabellidae), feather hydroids (Aglaopheniidae), fan shells (Pectinidae) and bryozoans (primarily bushy and flexible branching forms). Other, mobile fauna included cushion stars (Valvatida), long-armed sea stars (possibly *Cosmasterias dyscrita*), crabs (unidentified), and sea slugs (Pleurobranchaea). Sponges (various morphologies; encrusting, arborescent, globular, tube clustered), solitary (including *Styela clava*) and colonial ascidians (various). Tube-dwelling anemones (Ceriantharia) were also common to abundant.

   There were often quite large (up to 10s of metres) stretches of barren seafloor between the patches of dense epifauna. These 'bare' areas comprised an estimated 50% (20–80% depending on transect) of this sub-stratum. This stratum appeared to be associated with soft muddy sediments.

b. **Horse mussel debris patch-reef** (Figure 9), which comprised ~30% of the biogenic habitat stratum, and predominantly occurred on the edges of the horse mussel/brachiopod beds. These communities were characterised as patches (up to ~ 20 metres in length) of large broken shell debris (often non-living horse mussel shell, density ~80%), in areas of muddy soft sediments (Figure 8). Total coverage of the area by shell debris patches was ~50% (20–80% depending on transect). Brachiopods (typically < 1 per m^2) and horse mussels (live, ~10 %) were seen occasionally in these areas. Encrusting communities and mobile fauna were associated with the increased habitat complexity provided by the shell debris, which acted as hard attachment substrate. Conspicuous encrusting and mobile taxa were very similar to those in the *horse mussel/brachiopod beds* (see (a) above).

Between the patches of shell debris and biogenic structure, there were large (10s of metres) stretches where epifauna was sparse (50% bare; 20–80% depending on the transect) (Figure 10). Here, the seafloor had reasonably homogenous, muddy sediments with burrow holes and few to no epifauna visible (Figure 10). The most prevalent species seen in the sparsely populated areas was tube-dwelling anemones. Occasionally, small clusters of shell debris with encrusting organisms were seen, as well as a fine green algal-like growth at C11 (only).

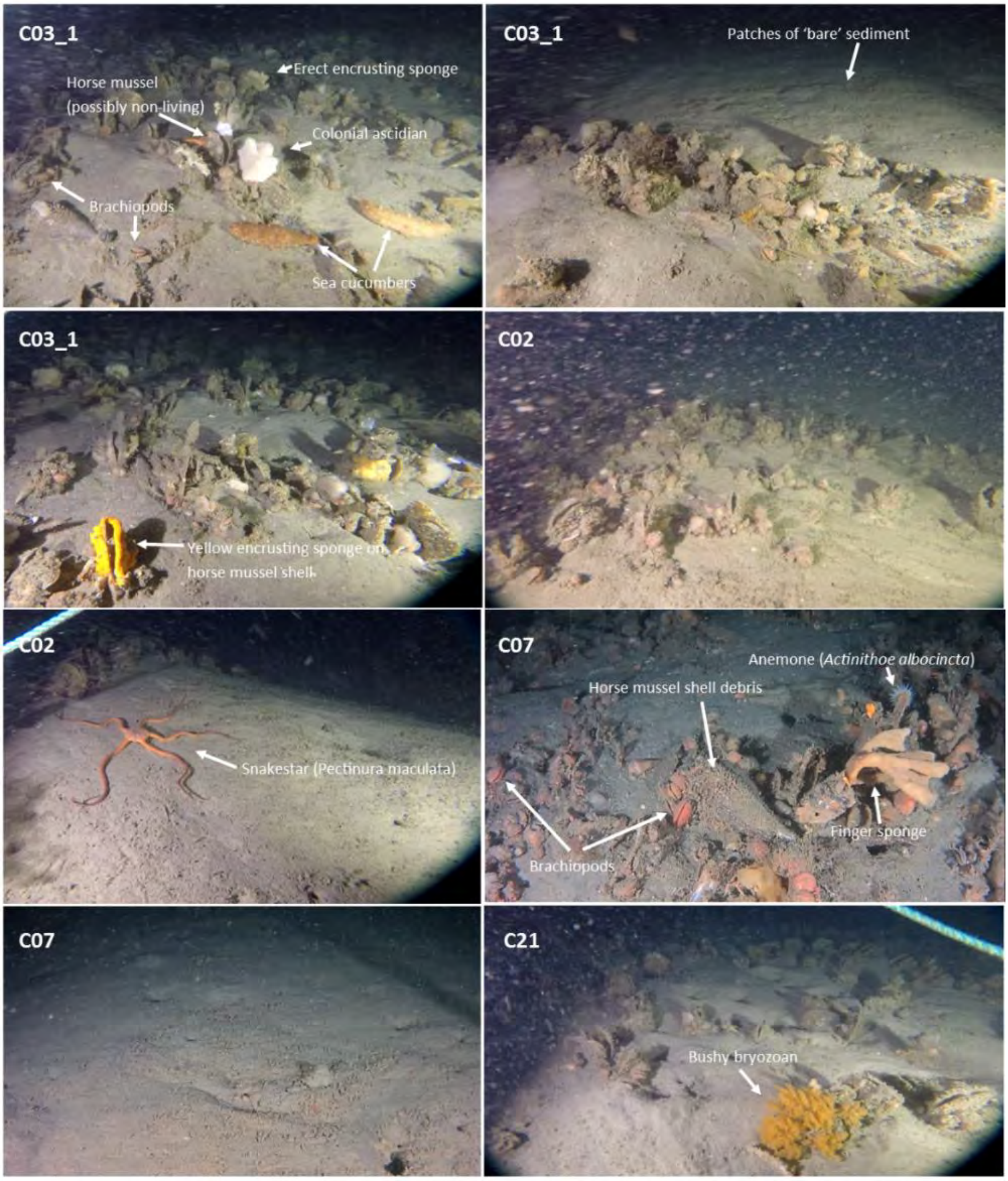

Figure 8. Representative images from areas characterised as horse mussel/brachiopod beds. Identifier in the top left indicates the transect the images was taken from. Barren seafloor patch between biogenic habitat patch is also shown (i.e. from transect C07 & C02).

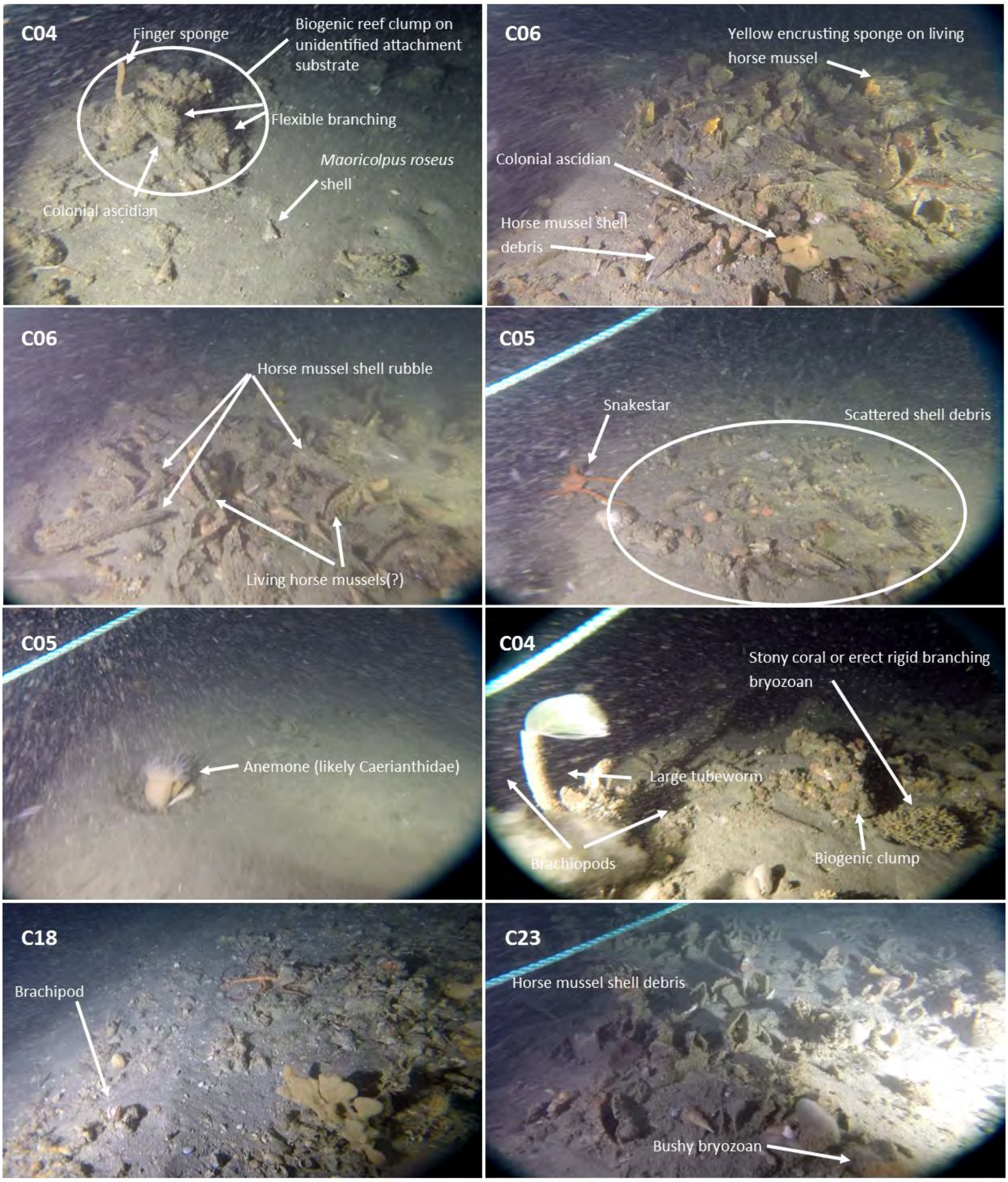

Figure 9. Representative images from areas characterised as horse mussel patch reef. Identifier in the top left indicates the transect the images was taken from.

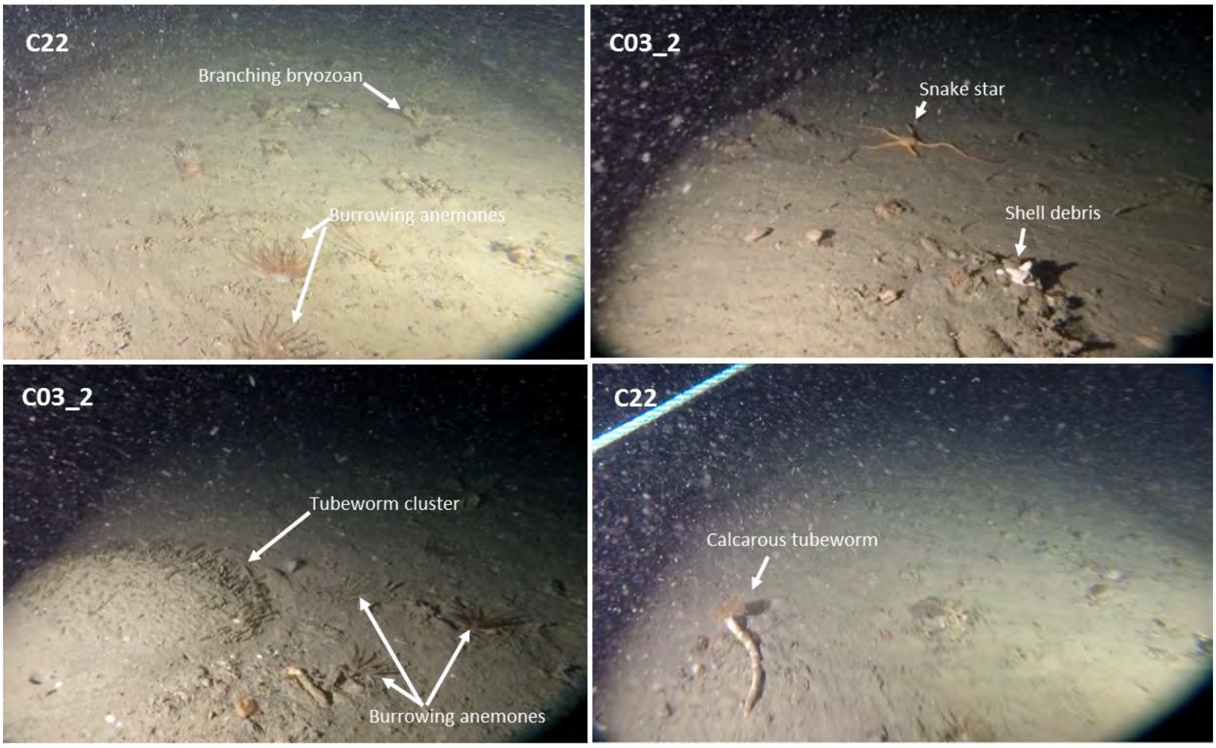

Figure 10. Representative images from areas characterised as having sparse epifauna. Identifier in the top left indicates the transect the images was taken from.

Bryozoan fields

In this stratum, small bryozoans were the prevalent epifauna. These ‘fields’ comprised ~35% of the total area surveyed. Within this area, the coverage of bryozoans was generally very sparse (~2%) (Figure 11). In some parts there were smaller areas where bryozoans were more common (density up to ~5% per m^2), but these ‘patches’ were rare.

The bryozoans seen were of various forms (flexible branching, solid branching, bushy, encrusting), but flexible branching (most likely Candidae) and bushy forms (likely Catenicellidae) predominated (i.e. soft bryozoans). Growths were attached to shell material when it was present on the seafloor, thus they were associated with sediments that comprised fine shell hash and larger shell debris. Generally, these were sandy sediments that appeared reasonably hard and consolidated. Where larger shell debris was more prevalent (i.e. in transition to the reef edge assemblage stratum), there was typically more diverse and abundant epifauna, including increased soft bryozoan coverage. Soft bryozoan abundances were an estimated average of 2% coverage throughout this habitat type.

Other encrusting taxa in these communities included sponges of various forms, feather and strand hydroids (Appendix 6), and colonial ascidians. Other fauna included cushion stars, long-armed sea stars, gastropods (e.g. *Calliostoma* sp., *Maoricolpus roseus*), fanworms, snake stars, sea slugs, large anemones, tube-dwelling anemones, crinoids (or crinoid-like forms; rare), scallops (*Pecten novaezelandiae*) and variegated scallops (e.g. *Chlamys* sp.). There were very few observations of horse mussels or brachiopods seen in video taken from this habitat, and large biogenic clumps were very rare.

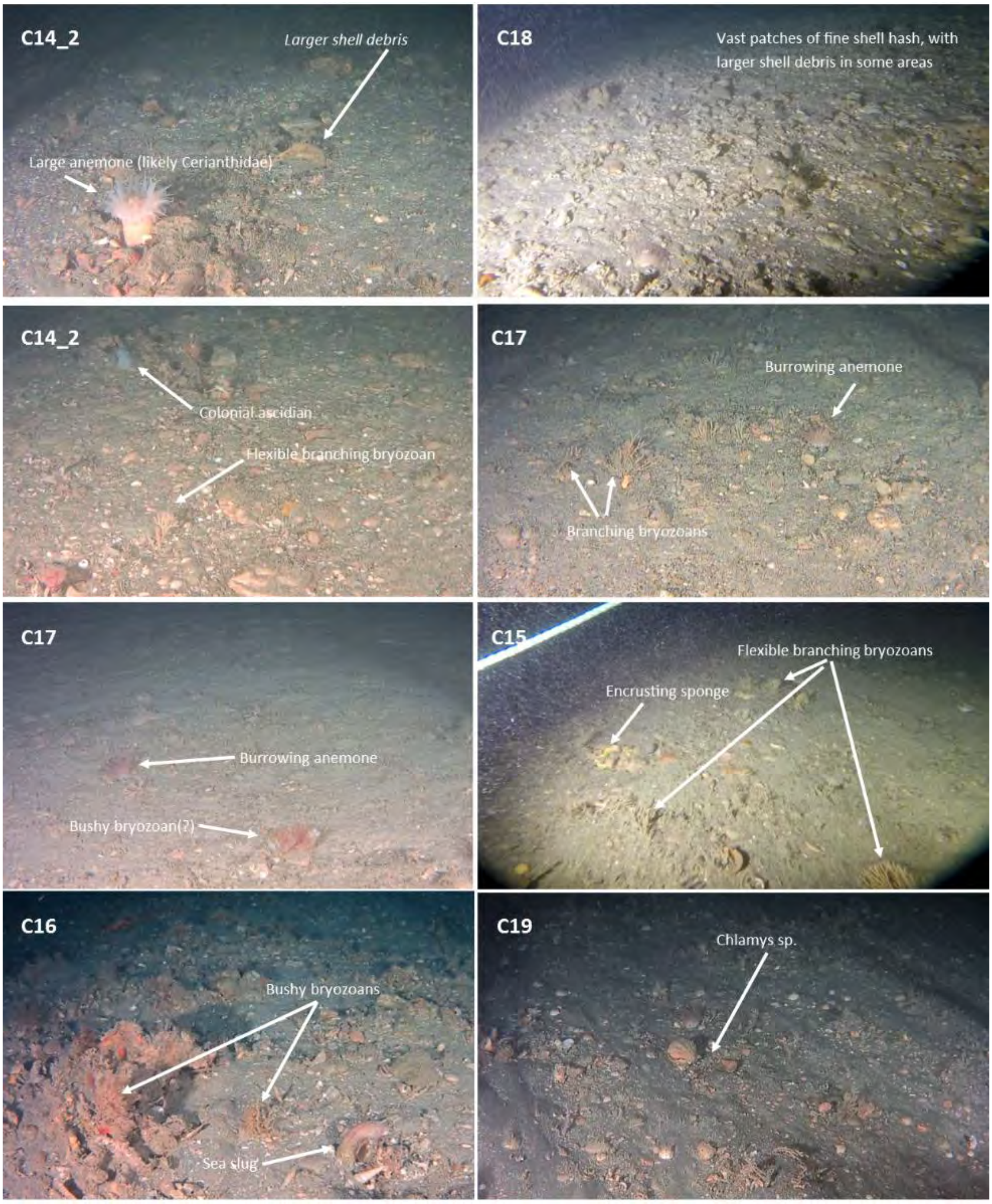

Figure 11. Representative images from areas characterised as bryozoan communities. Identifier in the top left indicates the transect the images was taken from.

Reef-edge assemblages.
The substrate within this stratum was dominated by shell debris, with whole shells and finer shell hash, gravel and cobbles, as well as underlying bedrock substrate in some areas. This type of habitat comprised ~10% of the survey area. Aggregates of shell material (biogenic clumps) were common in the footage (Figure 12), though very little video footage was collected in this stratum in total. There was a gradual transition from the bryozoan field stratum to these areas. Epifauna (including nudibranchs, large parchment worms, tree hydroids, colonial ascidians, large sponges, bryozoans [soft and rigid], brachiopods) were more common in areas where rocks and other large hard substrate became more available nearby to known rocky reef-type habitats (i.e. McManaway Rock). Horse mussels were seen, although rarely. McManaway Rock is considered an 'ecologically significant' habitat within the Marlborough Sounds (Davidson et al. 2011; Figure 8).

Figure 12. Representation of images from areas characterised as reef edge assemblages. Identifier in the top left indicates the transect the images was taken from.

Ecological importance of habitats

The biogenic habitat stratum contains habitats (biogenic patch-reef, hard substrate) and taxa (horse mussels, brachiopods and some within the reef-edge assemblage) classified as 'sensitive' (MacDiarmid et al. 2013). In this context, sensitive refers to:

- the tolerance of the species or habitat to damage from an external factor
- the time taken for its subsequent recovery from damage sustained as a result of an external factor.

Furthermore, although neither horse mussels or brachiopods are endangered or at risk, they are considered ecologically important (DOC 1995; MacDiarmid et al. 2013; Davidson et al. 2010), and this is discussed in the following sub-sections. The ecological importance of soft bryozoan fields and reef edge assemblages encountered within the areas is also discussed.

Horse mussels and patch-reef

Dense, stable beds of large bivalves such as horse mussels are important contributors to benthic ecosystems and support a variety of epibenthic associates (Morrison et al. 2014), including brachiopods seen in this study. Bivalves fulfil a variety of functional roles integral to ecosystem functioning (Jackson et al. 2001; MacDiarmid et al. 2013; Anderson et al. 2019). For example, emergent shells can alter water boundary flow. Slowing water movement allows fine sediments to settle, thereby affecting sediment composition and subsequent infaunal communities (Coco et al. 2006; MacDiarmid et al. 2013). Boundary flow modification can also provide refuge from predators reliant on chemical cues for prey detection (e.g. sea stars and gastropods, Zimmer et al. 1999). Large emergent structures provided by horse mussels also provide physical refuge from visual predators, and provide substrate for mollusc egg deposition (Hay 1990). Bivalves can also influence water quality through the process of filter feeding (Rothschild et al. 1994), act as a food source to predators (usually micro-predators, Cranfield et al. 2004), process nutrients (Hewitt et al. 2006; Herman et al. 1999), and fix carbon and provide nutrients through suspension-feeding and the production of pseudofaeces (Hewitt & Pilditch 2004).

Young horse mussels grow completely buried and grow out of the sediment as they mature, protruding about 1/3 of their bodies above seabed as adults (Hay 1990). Both living animals and dead shell matter create habitat and increase complexity in what might otherwise be unsuitable habitat for a variety of organisms (MacDiarmid et al. 2013; Anderson et al. 2019), including the provision of habitat for juvenile fish species. For example, they provide nursery habitat for juvenile blue cod in the Marlborough Sounds (NIWA's 2017 MBIE-funded juvenile-habitat surveys; unpublished data) and juvenile snapper in the Kaipara Harbour (Usmar 2009).

The definition of a 'significant' large bivalve bed or community is the presence of > 30% of both living and dead specimens in imaging surveys covering 100 m^2 or more (MacDiarmid et al. 2013). In DOC (1995), the trigger level is 20% per m^2. Based on these descriptions, the horse mussel strata within the survey area could be considered significant (~50% coverage on average in the video footage from this strata). We note that within these zones there were occasional large areas where no horse mussels were seen (including video transects C3_2, C22 and C11 in their entirety). Despite being classified as an ecologically important species, horse mussels are not a threatened or at-risk species, and are also a fishery under the Quota Management System (Box 1).

Horse mussel beds are known from seven locations in the Marlborough Sounds (Davidson et al. 2010), and around 70 locations New Zealand-wide, in waters up to 80 m deep (Jones et al. 2016). The Marlborough/ Tasman Bay and Fiordland areas are relative hotspots for known habitat of this type on New Zealand's continental shelf (MPI 2016). Closest to the proposal site are the horse mussel beds in Port Gore and Wainui Bay (Davidson et al. 2010). Patch-reefs (mixed assemblage biogenic clumps) are known to occur in at least 14 other locations within the Marlborough coastal area, primarily near offshore islands (Trio, Chetwode and Titi islands) and in Tory Channel (Davidson et al. 2010). With one exception, these are typically in shallower areas (< 40 m). As such, the patch-reef at the proposal site may contain comparatively more distinct assemblages.

Box 1. Horse mussel fishery information.

Since 2004 horse mussels have been managed under the New Zealand Quota Management System with the majority (90%) being caught as bycatch though bottom trawling, dredge and Danish seining (Fisheries New Zealand). According to Fisheries New Zealand the total allowable mortality from fishing in the Challenger fishing area (which encompasses the Marlborough Sounds) is 49 tonnes per annum (tpa); 16 tpa for commercial fishing, 1 tpa for customary and recreational fishing, and 32 tpa for 'other fishing-related mortality'. In 2017, the reported annual catch was 634 kg, while 211 kg was reported in 2017; a reasonably high level of horse mussel catch is also suspected to be unreported (https://fs.fish.govt.nz/Page.aspx?pk=8&tk=41&ey=2017).

Horse mussels are known to have value as customary kaimoana and taonga species for local iwi in some areas (Anderson et al. 2019). There are no current estimates of recreational or Maori customary catch for horse mussels, nor are there any existing estimates of baseline biomass for any horse mussel stock. It is also unknown whether horse mussel stocks in New Zealand are at, above, or below their maximum sustainable yield (the maximum use that a resource can sustain without reducing its renewability through reproduction or natural growth).

It is unknown what proportion of the Challenger horse mussel catch is taken from horse mussel populations that occur within the survey area.

Brachiopods

Brachiopods, or lamp shells, superficially resemble bivalve molluscs but are part of an ancient phylum that have been largely unchanged for 500 million years (MacDiarmid et al. 2013). They occur throughout New Zealand at all depths and are primarily associated with hard substrates (gravel or shell debris), areas of higher current flow, with low suspended sediment load (Lee & Smith 2007; MacFarlan et al. 2009). Similar to bivalves, brachiopods support a variety of epibenthic associates such as provision of substrate for encrusting organisms, or shelter (both live brachiopods and empty valves) for recruiting individuals (Gordillo et al. 2019). A significant brachiopod bed is considered present if one or more specimens of any species occur per m^2 of sampling

(MacDiarmid et al. 2013). In addition, DOC (1995) provide guidance around the 'trigger levels' for brachiopod densities. These are species-specific (*Neothyrus lenticularis*; 'one seen', *Magasella sanguinea* and *Waltonia inconspicua;* both > 20 per m^2 in a distinct zone).

Brachiopods were commonly seen in the horse mussel/brachiopod beds at densities that would constitute the stratum being considered a 'significant' brachiopod bed. Brachiopods were far less prevalent within the horse mussel patch reef substratum, and based on their abundances in the video footage, would be at a density of < 1 per m^2. Despite being classified as an ecologically important species, brachiopods are not threatened or at risk. It was not possible to identify the species of brachiopods seen in video footage, and the presence of those listed in DOC (1995) within the proposal area cannot be ruled out.

Bryozoan fields

Bryozoans are colonies of very small filter-feeding animals which can form complex three-dimensional structures. When this structure is rigid it can provide a multitude of ecosystem services. For example, these rigid bryozoans provide habitat on a micro- and megafaunal scale for a multitude of sessile organisms, including ophiuroids, annelids, decapods, sponges, ascidians, and bivalve molluscs, generating and maintaining local biodiversity (Wood 2005; MacDiarmid et al. 2013). As bryozoans are slow-growing animals, recovery from widescale impact can take decades (Batson & Probert 2000).

Bryozoan beds, or thickets, are considered 'significant' if large frame-building bryozoans (> 50 mm in three-dimensions) form > 4% mean cover over large areas (10-100s km^2) OR dominate the seabed in small areas (> 50% per m^2) (MacDiarmid et al. 2013). The density threshold in DOC (1995) is > 5% cover. The most common type of bryozoans seen within the survey area were soft, flexible branching or bushy forms (likely Candidae and Catenicellidae), rather than the rigid frame-building bryozoans. As such, the soft bryozoan growth seen within the survey area is not considered significant in terms of ecosystem services and habitat provision.

Reef edge assemblages

McManaway Rock is a subtidal (13.5 m depth at its shallowest point) rock complex just outside of the survey area. This area (see Figure 8) is classed as ecologically significant, based on the high species diversity and distinction of assemblages that it supports, as well as the low occurrence of offshore rock stacks within the Marlborough region (Davidson et al. 2011).

There were zones within the proposal area that fringed McManaway Rock, and had higher diversity and sediments punctuated by hard substrate. Although these zones were not surveyed comprehensively by video footage, it is likely that species diversity and the presence of hard substrate would likely become more common nearer to

McManaway Rock proper. Some taxa within this reef edge assemblage have density thresholds beyond which are considered significant (DOC 1995). The taxa that exceeded the thresholds (based on the limited video footage) are hydroid trees (*Solandaria racemosa*; > 3 per m^2 in a distinct zone). In addition, brachiopods were present in some areas of this stratum at densities that may constitute a significant brachiopod bed).

3. ASSESSMENT OF SEABED EFFECTS

The seabed could potentially be affected by the proposed activities both during initial development (e.g. the installation of anchors, warps and pen structures) and from discharges (uneaten feed and faeces, operational discharges) associated with operation once the farm is installed (Box 2).

Box 2. Summary of effects from the initial proposal

- *The initial proposed anchor installation may disturb and / or remove ecologically important habitat. The generation of diffuse sedimentation may also occur but is likely have a negligible effect on seabed communities.*
- *The area of highest organic deposition during the farm's operation will be most likely occur beneath the farm, as well as where the modelled footprints overlap. Accumulation of organic material in areas susceptible to accumulation such as seafloor depressions and areas of high seabed rugosity (depositional 'hotspots' both within and outside of the modelled footprint) is also possible.*
- *The spatial extent of organic material dispersion is likely to be on the order of km's from the modelled footprint boundary, from transport of farm-derived organic material through sediment resuspension processes.*
- *Seabed conditions in the most affected area will be characteristic of moderate enrichment.*
- *Infaunal communities will grade to background conditions with increasing proximity to the edge of the modelled footprint.*
- *Habitats of high ecological value will likely be subject to mild enrichment, and sub-lethal effects could also occur from chronic exposure. It is possible that small proportions of these habitats will be subject to moderate levels of deposition (depositional hotspots).*

3.1. Seabed impacts associated with anchor installation and presence of structures

Effects arising from the installation of anchoring structures and the presence of pen structures could include the destruction and/or displacement of species and habitats, the short-term resuspension of sediments, and an increase in the surface area available for colonisation by fouling organisms (and increased drop-off of this biomass). The effect of shading by farm structures is considered to be negligible at this site because of the limited light penetration to the seabed due to its depth.

Anchor installation

Physical disturbance and resuspension of sediments during mooring installation could affect seabed communities by: crushing/direct removal of species immediately in the area, burial by sediment, and smothering or sedimentation-induced reductions in feeding efficiency immediately surrounding the farm installation area (Clark et al. 2011; Anderson et al. 2019).

While anchor installation is likely to generate increased sedimentation that risks smothering epibiota, the disturbance is only likely to occur during installation and shortly thereafter (hours to days). Effects from resuspension will be minimised by the high currents that will rapidly disperse the sediment. Displacement and sedimentation effects associated with mooring installation will be affected in a small area (~2 m^2) immediately around each of the anchor sites. Recolonisation of the disturbed seabed around the moorings will ensue from communities nearby immediately following installation, but destruction of biogenic clumps or habitat-forming species could take months or years to re-establish.

Presence of structures

Increased surface areas provide more opportunity for colonisation of fouling organisms. Drop-off of fouling biomass may exacerbate enrichment effects, or smother/directly damage epibiota (Keeley & Taylor 2011; MacDiarmid et al. 2013; Anderson et al. 2019). Epibiota may also scavenge fallen fouling biota that have originated from farm structures; this could alter epifaunal community composition, favouring scavengers and may increase predation on existing epifaunal communities (Crawford et al. 2001). Depending on the type of fouling taxa, biofouling drop-off may increase habitat complexity and available attachment substrate for seabed epifaunal organisms. Once established, the presence of farm structures may also be beneficial for some organisms, due to the protection they provide from destructive activities such as towed fishing gear.

The significance of marine pest colonisation is addressed in Fletcher (2019).

3.2. Seabed impacts arising from organic enrichment during farm production

3.2.1. How do impacts manifest?

Deposition of farm-derived organic material is the primary driver of seabed impacts associated with salmon farming. The physical characteristics of the farm site and attributes of the farms themselves[5] influence the accumulation of this organic material (Keeley & Taylor 2011; MacDiarmid et al. 2013; Anderson et al. 2019). The flushing potential and environmental assimilation of farm wastes at a given site are largely dictated by water depth and current speed, and to a lesser extent, seasonal factors such as water temperature (Keeley & Taylor 2011). Increased flushing not only reduces local biodeposition and sedimentation, but also increases oxygenation of sediments (Findlay & Watling 1997).

[5] Including fish stocking density, the settling velocity of fish faeces, the type of feed and feeding system, the type of pen structure utilised and the amount of flow reduction caused by the pen system, if any (Keeley & Taylor 2011).

Sites in deep water (> 30 m) with strong water current velocities (> 15 cm per second), such as the proposal site, will feature a more dispersed depositional footprint with less organic enrichment than shallower sites with lower flushing ability (Pearson & Black 2001; Aguado-Gimenez & Garcia-Garcia 2004). This is due to increased levels of particle resuspension, and the greater range of dispersal of fine particles and flocculent material (Keeley & Taylor 2011; Law 2019). Resuspension occurs when current speeds near the seabed exceed a critical velocity threshold. Given the site characteristics (see Box 3), resuspension/dispersion of deposited particles is likely to be significant at this site. Thus, the dispersal of particles outside of the primary footprint, into the far field, through particle resuspension processes is likely to be more substantial than it has been for salmon farm sites located in less dispersive sites.

Sediment properties

Microbial decay of waste material can dramatically alter the sediment chemistry of the seafloor, i.e. depleted oxygen levels, elevated free sulphides, reduced redox levels. Visible bacterial cover may occur even at moderate levels of deposition. For example, at the Te Pangu farm, patches of bacteria are sometimes visible on the seafloor at 300–500 m from the pen edge.

Excessive accumulation of organic waste on the seabed can also result in anoxic conditions in the overlaying water, which can cause oxygen stress to biological communities (particularly epifauna). The accumulation of organic matter can also result in increased dissolved nutrients in sediments, from nitrogen and phosphorus in farm waste and resulting remineralisation through benthic processes. Increased dissolved nutrients can affect the seabed biology by increased algal growth, but given the depth of the site, this is unlikely.

Box 3. Oceanographic summary of the site with respect to seabed deposition and particle resuspension.

Waves

A 10-year high resolution SWAN wave hindcast model was commissioned from MetOcean Solutions Ltd for five locations over the site (see Newcombe et al. 2019). Waves propagate from the NW and SE direction through Cook Strait and the majority (> 84%) have significant wave height lower than 1.5 m. Larger wave events are predominantly of NW origin as the North and South Island landmasses shelter the area of interest from southerly swell. The probability of any wave exceeding a significant wave height of 2 m is 6–13% depending on distance from shore, and the probability of an exceedance of 3 m is < 2%. The area is deep enough that wave motion will likely have negligible impact on particle resuspension and burial with wave velocities being an order of magnitude less than current velocities at the seafloor (Appendix 7).

Currents

Overall, this is a high flow site due to the near 180-phase difference in tidal elevation between the west and east coasts of New Zealand, which drives tidal currents through Cook Strait. Currents measured at the site* were in excess of 120 cm/s with mean mid-depth speeds of the order of 35 cm/s. Current speeds increase with distance offshore and are higher near the surface due to wind effects. Mean current velocities show a NW directional bias at pen depth but below this, currents tend towards the SW. Velocities remain high near the seabed—the mean and maximum velocities recorded at the lowest depth bin by the upwards-facing ADCP (acoustic Doppler current profiler) were 31 cm/s and 86 cm/s, respectively. These values are almost consistently higher than reported critical velocity threshold values (0.9–9.5 cm/s) required for resuspension**. Accordingly, we should assume that all particles deposited beneath the farm can be resuspended and dispersed.

Both ADCPs generally showed a good agreement in water current profiles. The farther offshore ADCP showed higher current speeds, and a NE/SW direction in currents, while the more inshore ADCP showed currents with NNE/SSW tendencies (see Appendix 8).

*Two ADCPs were deployed at the site to collect water column profile data, one upwards facing, and one downwards facing. A summary of deployment details can be found in Appendix 8, and deployment locations are marked in Figure 2. For full deployment detail, readers are referred to Newcombe et al. (2019).

** Values for this threshold vary between studies: Cromey et al. (2002) use a hard-coded value of 9.5 cm/s while Law (2019) propose individual values of 0.9 cm/s and 1.5 cm/s for faeces and food pellets, respectively. Keeley et al. (2013b) state that choosing an optimal velocity threshold beyond which particles resuspend is a contentious problem.

Infauna

Infaunal communities are likely to follow a reasonably predictable succession in relation to increased organic deposition from the farm. This succession has been well described at dispersive sites by Keeley et al. (2013a). Although the work done by

Keeley et al. was inside the Marlborough Sounds, the infaunal communities at the proposal site are much the same as those in Tory Channel where three farms are currently in operation (see Section 2.5.1). Major differences between the proposal site and Tory Channel are the increased depth (60–90 m depth vs. < 40 m depth), and the higher water current velocities[6] (~35 cm/sec vs. ~22 cm/sec) at the proposal site. The greater depths and current speeds mean there will be differences in the depositional footprint, but this is accounted for by site-specific depositional modelling[7]. The higher current speeds at the proposal site means that resuspension of deposited particles may play a larger role than they do at the Tory Channel farms. The successive response of benthic infaunal communities to increasing farm waste is unlikely to differ appreciably to that described by Keeley et al. (2013a), except that there may be lower 'effects' per unit of modelled flux at the proposal site compared to that in Tory Channel, due to the likely greater effect of particle resuspension (which was not accounted for in our modelling).

Based on the likely substantial influence of resuspension at this site, the accumulation of organic material within the sediments is likely to be minimal. Nonetheless, even at dispersive sites there can be significant changes to infaunal communities. New Zealand and overseas studies at high flow sites have shown that benthic effects tend to be most evident directly beneath the pens, and exhibit a strong gradient of decreasing impact with increasing distance (Figure 13). However, at some dispersive sites with complex bathymetry, there can be substantial patchiness in deposition and associated effects (Broch et al. 2017).

Typical changes in infauna along an enrichment gradient from a finfish farm are depicted in Figure 13 and described in Table 1, and range from pristine natural conditions (Enrichment Stage [ES] 1) to extremely enriched conditions (ES 7). An important feature along the gradient is the stage of greatly enhanced seabed productivity, which defines ES 5 and is evidenced by extreme proliferation of one or a few enrichment-tolerant 'opportunistic' species such as the marine polychaete worm *Capitella capitata* and nematodes. ES 5 has traditionally been the recommended upper level of acceptable impacts in New Zealand for infaunal communities (see the best management practice guidelines (benthic) immediately beneath salmon farms in the Marlborough Sounds; MPI 2015). This is because the benthos is still considered biologically functional and has the greatest possible biomass, thus thought to have greatest waste assimilation capacity. Stages beyond ES 5 are characterised by extremely impacted sediments and the probable collapse of the infaunal population[8], at which point organic accumulation of waste material is thought to greatly increase.

Previous work in the Marlborough Sounds shows that farm-related enrichment becomes discernible at ~ES 3, given the baseline ES of the Marlborough Sounds is

[6] Mean mid-water average
[7] With the exception of resuspension effects.
[8] These conditions have not yet been encountered at a dispersive site.

around 1.5-2.5 (MPI 2015). At the proposal site, baseline ES scores (1.4–2.4) were very similar to within the Marlborough Sounds.

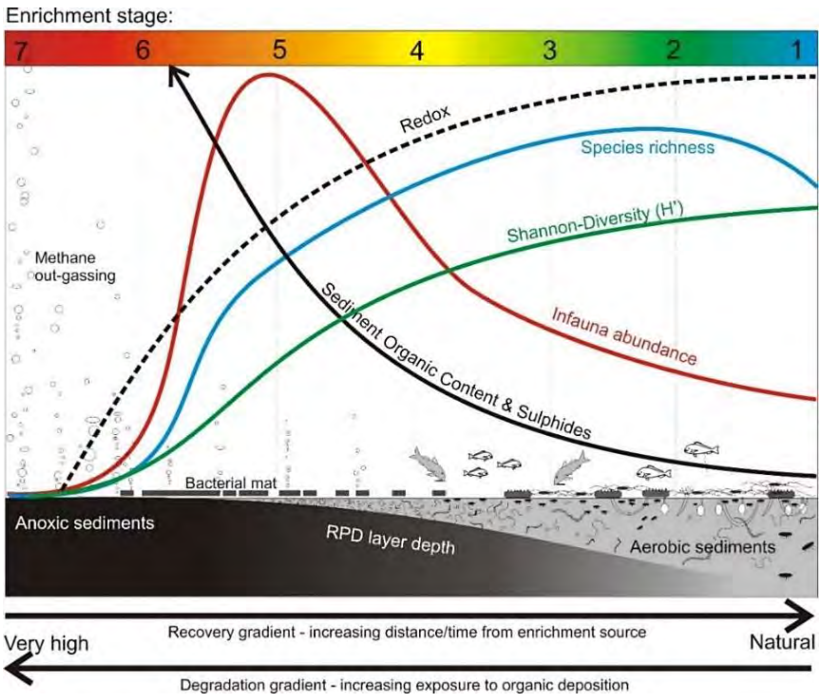

Figure 13. Graphical representation of typical enrichment gradient indicating approximate boundaries of the seven Enrichment Stages, that vary with the intensity of enrichment (MPI 2015).

Table 1. General description and main environmental characteristics of Enrichment Stages (ES) 1-7.

ES	General description
1	***Natural/pristine conditions*** – Environmental variables comparable to unpolluted/ un-enriched pristine reference site.
2	***Minor enrichment/enhanced zone*** – This can also occur naturally or from other diffuse anthropogenic sources. Taxa richness usually greater than for reference conditions. Minor increases in animal abundance possible.
3	***Moderate enrichment*** – Coupled with a significant change in community composition. Notable abundance increase, richness and diversity usually lower than reference. Opportunistic and tolerant species (e.g. capitellids, dorveillids) begin to dominate. Sediment chemistry may show slight deteriorations, and *Beggiatoa*-like bacteria may be visible in patches.
4	***High enrichment*** – A transitional stage between moderate effects and peak macrofauna abundance. A major change in community composition is evident. Opportunistic species dominate, but other taxa may still persist. Major sediment chemistry changes (approaching hypoxia), patches of *Beggiatoa*-like bacteria likely to be visible.
5	***Very high enrichment*** – Sediments are highly enriched and macrofauna are at peak abundance. Total abundances can be extreme. Diversity usually significantly reduced, but moderate richness can be maintained. Sediment organic content usually slightly elevated. *Beggiatoa*-like bacteria may form visible 'mats', and sediment out-gassing is possible.
6	***Excessive enrichment*** – Transitional stage between peak abundance and azoic conditions (no infauna present). This has not previously been observed at high-flow salmon sites in the Marlborough Sounds.
7	***Severe enrichment*** – Anoxic and azoic; sediments no longer capable of supporting macrofauna. Organic material accumulating in the sediments. This has not previously been observed at high-flow salmon sites in the Marlborough Sounds.

Epibiota

Most research has focused on the ecological impact on infaunal communities as indicators of farm effects, due to farms typically being sited over soft sediment habitats that have no notable epifaunal communities. As a result, impacts on infaunal communities are reasonably well understood. By contrast, depositional effects on epibiota are poorly documented (Keeley & Taylor 2011) as these are typically site- and species-specific. There is limited information on the effect of farm-related organic enrichment deposition on horse mussels, brachiopods and other less prevalent but potentially sensitive epibiota seen at the proposal site. If the organisms consume waste, there may be positive effects (e.g. increased growth) due to food supplementation (George & Parrish 2015; Bergvik et al. 2019), which may lead to increased densities. Equally, there may be sub-lethal effects (e.g. reduction in food quality leading to reduced growth, or reduced reproduction [White et al. 2016]), possibly leading to an eventual reduction in densities. Smothering may also directly displace some organisms. Adverse consequences are likely to be species-specific. The response of epifaunal taxa found in the proposal area to organic deposition is discussed in further detail in the following sections, with an emphasis on the ecologically important taxa like horse mussels and brachiopods as these occupy a large proportion of the proposal area.

Mobile deposit feeders

Mobile deposit feeders are likely to be tolerant of moderate to high levels of deposition. For example, snake stars aggregate (or increase in abundance) in a 'halo' around the Clay Point and Te Pangu salmon farms in Tory Channel, but are rarely observed beneath the pens. Urchins (White et al. 2018), sea stars (*Coscinasterias muricata*; Crawford et al. 2001) and snake stars (*Ophiosammus* sp.; D. Elvines, personal observation; Govier & Bennett 2007) have been noted to increase in abundance in response to increased bio-deposition within the primary footprint. Mobile deposit-feeding taxa within the area included snake stars, long-armed sea stars and sea cucumbers, and these taxa were reasonably consistent throughout the softer/sandier sediment areas, but were not densely distributed.

Sessile epifauna

Bryozoans, encrusting organisms, hydroids and other sessile organisms were generally patchy in their distribution (associated with shell debris [horse mussel areas] or rocky substrate) or were very sparse within the area. Bryozoans and burrowing anemones were reasonably consistent throughout the softer/sandier sediment areas, but were not densely distributed. These taxa are more sensitive because they are immobile, and are suspension feeders[9], thus are more likely to be displaced at high levels of deposition, and may reduce in density in response to moderate deposition levels depending on the life history traits. We do note that for the past decade rocky-reef community monitoring has been undertaken adjacent to salmon farms sited in

[9] Suspension feeders are unable to filter particle intake. Rather, they excrete unwanted particles, which is energetically demanding (Ellis et al. 2002).

dispersive environments in the Marlborough Sounds. These habitats are known to contain sensitive taxa, and results of this monitoring to date shows there have been no discernible changes in abundance for individual groups or taxa (including tree hydroids) attributable to the farms (Dunmore 2019).

Horse mussels

As discussed above, scavengers and/or predators such as sea cucumbers, crabs, cushion stars and snake stars can aggregate beneath or around the perimeter of pens, sometimes in association with bacterial mats (Govier & Bennett 2007). These aggregations may result in consumption of sensitive species, particularly those in the juvenile phase. Juvenile horse mussels are known to be key prey items for large sea stars, resulting in high mussel mortality rates (Hay 1990). Increased predation may also occur if predators are attracted to the site by increased biodeposition.

Horse mussel beds are considered sensitive habitats but no research has directly examined the effect of salmon farm deposition on these organisms. Based on other information for other filter-feeding organisms, we can expect that the placement of salmon farm infrastructure above or adjacent to established horse mussel beds may lead to enhanced food supply at very low levels of deposition, and reductions in density or complete exclusion at higher levels of deposition (through a variety of mechanisms).

There will be a ‘threshold’ beyond which horse mussels will be displaced directly beneath salmon farms due to farm-related enrichment. At present, this threshold is unknown, however, we can provide context around this by examining the life history of horse mussels, and what is known about their distribution in relation to aquaculture-derived organic matter sources.

Horse mussels feed on organic matter (phytoplankton, zooplankton, seston), have low clearance rates compared to other bivalves (0.15–1.1 L/hr; Ellis et al. 2002), and are selective of particle size (Hewitt & Pilditch 2004). Particle sizes for food of suspension feeding bivalves is 2–12 µm (Jorgensen 1990) and rejected particles are expelled via mucous (called ‘pseudofaeces’) (Miller et al. 2002). Horse mussels are known to be sensitive to excess siltation. Previous research has described signs of stress and significant drop in condition (biomass) in response increased suspended sediment concentrations (Ellis et al. 2002). Increased suspended sediments can result in increased respiration (Gibbs et al. 2005). Observations of increased stress was, however, attributed to the reduced quality of food intake (Ellis et al. 2002), and was associated with energy demands of increased filtering requirements from higher levels of non-food particulates. It is worth noting that horse mussels occur in other areas of New Zealand’s coast that typically have much higher suspended sediment loads (e.g. Mahurangi Estuary, Ellis et al. [2002]; Firth of Thames, Cameron et al. [2018]) than a baseline approximated for the proposal site based on limited sampling (1–4 g/m^3;

Newcombe et al. 2019). Therefore, they are likely to be tolerant to some level of increase in suspended solids.

Horse mussels (and other sensitive taxa) have also been found in proximity to existing, operational salmon farms in the Marlborough Sounds:

- Horse mussel beds were found 230 m offshore of the Te Pangu Bay salmon farm in Tory Channel, supporting a variety of encrusting species (Taylor & Elvines 2016). While these beds are outside of the primary depositional footprint, they are subject to a low-level of farm-related organic enrichment (< 1 kg/m^2/yr) (Keeley et al. 2013b).
- Sparse assemblages of horse mussels have also been seen in the within 70-145 m of the Otanerau Bay salmon farm in Queen Charlotte Sound (Hopkins et al. 2004).

It is important to note that the incidental presence of horse mussels adjacent to these farms to does not tell us anything about their condition (e.g. if they are healthy and/or reproductively active). Nonetheless, given that the Te Pangu farm is a dispersive site where resuspension processes are known to redistribute farm waste, the persistence of horse mussels after almost a decade of the farm operating at a high production level indicates that they can tolerate at least a low-level of exposure to farm-related organic deposition.

Green-lipped mussel (*Perna canaliculus*) farms also provide enhanced levels of suspended and deposited organic material (albeit to a lesser extent than typical salmon farms), and horse mussels have been reported to exist along (Wong 2009; Cawthron unpublished data) and within the boundary of some of these farm areas in the Coromandel (Cawthron unpublished data). In the Marlborough Sounds region, there are many encounters of horse mussels immediately adjacent to, and under, active mussel farms (Inglis & Gust 2003; Hopkins et al. 2004, 2005a, 2005b), albeit mostly at low densities. The survey by Inglis and Gust (2003) reported that horse mussel distribution was not affected by the presence of farms. The depositional rate of organic material from green-lipped mussel farms in the Firth of Thames (a non-dispersive site) was estimated to be on the order of ~0.7 kg solids/m^2/yr (0.22 kg C/m^2/yr; Cameron et al. 2018).

Before displacement of horse mussels occurs, chronic ‘sub-lethal’ effects (e.g. compromised reproduction and growth) are likely to first take place. The ‘sub-lethal’ threshold is unknown, but will likely be related to a change in filtering requirements dependent on food quality (e.g. particle size of farm-derived organic material, food to sediment ratio). By contrast, if the horse mussels are presently food limited, then small increases in organic matter in the particle size utilised by horse mussels may have a beneficial effect. Horse mussels are not continuous feeders, and their ability to cease feeding may play a role in their tolerance to increased suspended organic matter (Hewitt & Pilditch 2004). Nonetheless, caution should be applied in transferring any estimate of tolerance from another context to the proposal area, due to different site characteristics such as bathymetry, currents (and resuspension properties), depth, and potential population level differences in susceptibility to effects.

The general lack of understanding of mechanisms that may result in adverse effects at a species-specific level and the limited available information on the exact tolerance of horse mussels to farm-related organic enrichment means that we cannot reliably estimate at what level of organic flux horse mussels would become adversely impacted at the proposal site. Based on their sensitivity to siltation, their sensitivity to increased organic matter sedimentation is likely to be high.

Brachiopods

Brachiopod beds are considered 'sensitive' habitats but, as for horse mussels, there have been no studies examining their response to salmon farm deposition. Brachiopods are filter feeders, drawing in suspended particles which are either retained or rejected (larger particles). Rejected particles are expelled typically using filament movements, with or without the assistance of mucous production (filament transport across an existing mucous membrane or increased production of mucous for 'mass expulsion', the latter usually in conjunction with cessation of feeding) depending on the abundance of rejected particles (Rudwick 1962). Predation by drilling has been shown for brachiopods (Gordillo et al. 2019), and this likely includes predation by carnivorous bivalves such as whelks.

Very little information can be found on brachiopod sensitivity to organic enrichment, or siltation. It is likely that effects from increased organic matter will manifest as for horse mussels: possible enhanced food supply at very low levels of deposition, to reductions in density (through lower feeding efficiency and associated stress, or recruitment effects) and complete exclusion at higher levels of deposition. Increased predation may also occur if scavenging predators are attracted to the site by the increased biodeposition.

3.2.2. Effects on the seabed in the context of the initial proposal

Depositional modelling and background to approach

Particle tracking models have become an accepted and useful tool to predict and manage the extent of farm biodeposition (Henderson et al. 2001). For this assessment, SMTOMOD (solid material transport (offshore) model) was used to predict deposition from waste to the seabed. The modelling did not include the effect of particle resuspension. Resuspension will act to reduce the intensity of the footprint while at the same time, increasing the dispersion area. Model scenarios provided in this assessment therefore represent a one-way flux to the sediment (i.e. more conservative with respect to footprint intensity, but less conservative with respect to spatial extent of footprint (see Box 4).

Previous assessments have used DEPOMOD (Cromey et al. 2002), a tool that is widely used and published, and designed specifically for managing fish farm wastes, (e.g. Cromey & Black 2005; Magill et al. 2006). The limitations of DEPOMOD rationalised the use of an alternative model. Full model details, including comparison to DEPOMOD can be found in Smeaton and Vennell (2019-draft). A summary of methods is provided in Appendix 9. Note that the number of particles released in the modelling was reduced to decrease the model runtime. The implications of this are a coarser depositional footprint in the model outputs.

Footprints are depicted as 'additional' solids flux to the seabed, with the '**primary footprint**' defined as enrichment that is likely to be discernible using indicators used for routine monitoring (e.g. in MPI 2015). We do note that at such a dispersive site with low background enrichment (Appendix 4), farm-related enrichment may become discernible at a lower level, thus the '**total footprint**' area should also be considered.

Box 4. Modelling limitations.

As discussed already, the modelling scenarios do not account for the effects of resuspension, thus the scenarios provided in this assessment underestimate the spatial extent of the footprint.

In addition, we note that both the large distance across which the primary footprint occurs, and the variation in bathymetry across the area, make it likely that the currents will not be uniform across the area. Accordingly, the modelling described in this report should be treated as an informative exercise to approximate the intensity and minimum spatial extent of waste dispersal, rather than a close depiction of the likely footprint shape.

A spatially explicit dispersal model could be used to account for the variation in currents and complex bathymetry in some areas of the site. However, these models require higher resolution current data (either collected from multiple locations across the area, or from existing models), are computationally demanding, and inherently have their own limitations. As such, a spatially explicit modelling approach was not taken here. In any case, limitations of modelling are best addressed at an early stage of development by an empirical footprint mapping exercise as done with inshore salmon farming sites.

Due to these limitations, and because the farming configurations are not yet confirmed, we recommend additional modelling specific to the final farming layouts are performed to inform sampling design and to later compare predicted vs. observed results. This additional modelling should include particle resuspension.

The modelling for this proposal is presented in two parts:

- the initial proposed production level of 20,000 tonnes of feed, with pens sited to minimise depositional impacts to ecologically important and significant areas (Section 3).

- depositional modelling that encompasses a range of farming locations, configurations (pen sizes, feed intensities and block layouts), pen spacings and production levels (presented in full in Appendix 10).

The initial proposed production level (20,000 tonnes of feed per annum) was modelled in two blocks of 8 pens, with each block of 8 pens comprising two rows of four, arranged perpendicular to the main flow axis (Figure 14). The blocks were separated from each other by a distance of 500 m (measured between both internal edges), and are located in an area where bryozoan fields predominated within the depositional footprint. The blocks are also located within each other's depositional footprint; i.e. there is some overlap of deposition.

The primary footprint is 3,271 m long (in the main flow direction) (SE/NW), and 663 m wide (perpendicular to the current; Figure 14), with an area of 139.4 ha. The total footprint is 535 ha. The highest deposition occurs in the middle between the two pen blocks, where footprints overlap. Here, the maximum solids flux is 2.56 kg/m^2/yr, which is approximately equivalent to an ES of 3.4 (moderate enrichment), grading to 'background' within 1.5–2 km from the downstream pen perimeter. Outside of the primary footprint, there is a large area subject to low level (0–1 kg solids/m^2/yr) deposition of organic waste from the farms (as shown in the total footprint). In addition, beyond the total footprint, the seabed will likely be subjected to waste particles dispersed by resuspension (not accounted for in the model), on the order of km's from the total footprint boundary.

Accumulation of solids may also occur in some areas, both within and outside of the total footprint. This is most likely to occur in seafloor depressions, areas with higher rugosity (surface roughness), such as rocky substrates, and bivalve beds. In these areas, lower shear velocities encourage deposition of particles, and the variable seabed relief shields them, to some extent, from resuspension. Relevant to the survey area, these 'hotspots' of deposition are the fringing reef edge areas, seafloor depressions (in particular the 'holes' on the eastern side of the area nearer to McManaway Rock), and the biogenic habitat containing horse mussels and patches of shell debris, which promote deposition of particles, and reduce the likelihood of resuspension through higher seabed rugosity.

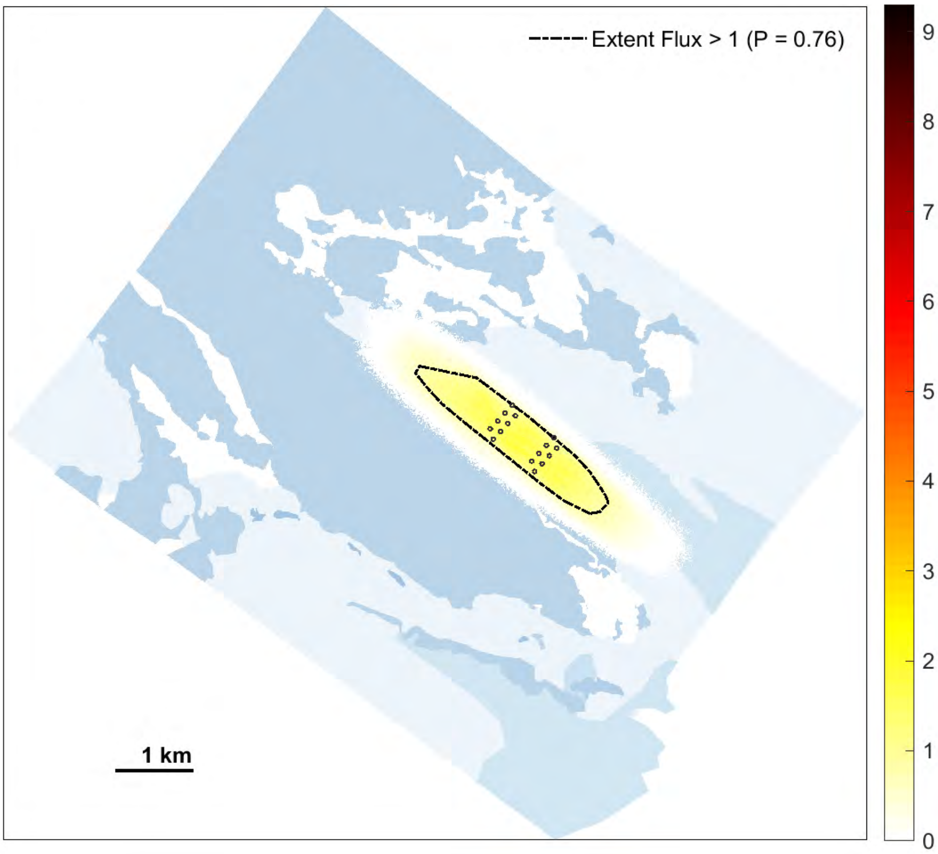

Figure 14. Modelled output from depositional modelling for the initial production level. The dashed line indicates the boundary of the area where solids flux is > 1 kg/m^2/yr. P = the probability of encountering solids flux of > 1 kg/m^2/yr within that area. The background delineates the epifaunal strata described in Section 2.5.2. Dark areas contain biogenic habitat. The scale shows mean annual solids flux (kg/m2/yr).

Ecological implications of the proposal

Each block of pens will have approximately 36 moorings[10], and each mooring is expected to directly disturb a maximum area of 2 m^2 per pen. For the initial proposed development, this equates to a total area of 144 m^2 (for 2 blocks of pens), with a larger (~10s of metres) area downstream of the disturbance affected by short term, diffuse sedimentation that will likely have a negligible effect on seabed communities.

Seabed conditions in the middle of the footprint will have slightly altered sediment chemistry (elevated total free sulphides and reduced redox potential) due to increased microbial activity from waste decay. In addition, patches of visible bacteria may be present. Infaunal communities will be highly functional, however they will be substantially altered from 'background' conditions, with notably increased abundances of more tolerant and opportunistic taxa (e.g. nematodes, *Barantolla lepte*,

[10] Information provided by NZ King Salmon. Note that moorings per pen will be dependent on block layout and orientation, with up-current pens, subject to stronger currents, having more moorings than pens in the middle of the block where they are somewhat protected by the up-current pens.

oligochaetes), and the total number of taxa and community diversity may be reduced (i.e. some more sensitive species may be displaced; paraonid and maldanid polychaetes for example). Some more sensitive (sessile suspension feeding) epifauna noted from within the 'bryozoan fields' in this area may also show reductions in density, while more tolerant taxa may increase in density (e.g. mobile deposit feeders may aggregate in these areas), possibly increasing predation pressure to some pre-existing taxa. It is highly unlikely that levels of copper and zinc will reach a biological threshold of possible effect (ISQG-Low; ANZECC 2000) in this area. Approximately 1.5 ha area will be affected in this way (see Section 3.3).

Outside of the most intensely affected area (i.e. the majority of the primary and total footprint area; ~452 ha), only a slight increase in microbial activity is predicted to occur, to the extent that it may not be discernible in sediment chemistry indicators. Infaunal communities may have a noticeable increase in taxa richness, and total abundances, which may both be above reference/background conditions, somewhat akin to a 'fertilisation' effect. In addition, particle resuspension into the far field (outside of the total and primary footprints) may result in a similar effect. Biological effects will manifest rapidly for infauna, but may take several years to stabilise. Although not well known, possible chronic effects to larger organisms may manifest more gradually, and could worsen with increased duration of exposure.

In far-field areas that are susceptible to accumulation (i.e. where dispersal of re-suspended waste may accumulate), moderate enrichment effects (such as those occurring within the most intensely affected area), may occur from a higher accumulation of farm waste material. These susceptible areas are the seafloor depressions on the southeast edge of the survey area, and areas with high seafloor rugosity (biogenic habitats and rocky substrates) where waste particles are less likely to be resuspended.

Based on the farm siting in the modelled scenario, habitats of high ecological importance are likely subject to only mild enrichment. At this level, it is unlikely that displacement of even sensitive taxa (suspension feeding) will occur, and they may even benefit from the supplementary food supply (discussed in full in Section 3.2.1). Equally, adverse subtle sub-lethal effects are possible from chronic exposure, and such effects (should they occur) may lead to eventual decreases in density. However, we note that the area of biogenic habitat affected in this way is likely to be only a portion of the total biogenic habitat that exists within the surveyed area.

It is also worth noting that benthic fishing often targets biogenic habitats (e.g. such as bryozoan thickets and horse mussels; even if they are not the target species) due to their known association with commercial fish species. Accordingly, placement of structures and exclusion of destructive benthic fishing activity may afford these sensitive communities with some level of protection.

3.3. Effects on the seabed from operational additives

Secondary to organic enrichment effects, which are the primary seabed impact from the proposal, there are also potential impacts associated with additives in feed (i.e. feed has high levels of zinc), from antifoulants (which are often copper based), and the introduction of therapeutants used to treat stock (e.g. antibiotics, lice control agents).

Potential effects from copper (from antifouling) and zinc (from salmon feed) were assessed comprehensively for recent applications for salmon farms in dispersive sites in the Marlborough Sounds (Sneddon & Tremblay 2011). This assessment was largely based on available national and international literature, with data from existing NZ King Salmon farms used to interpret research in the context of conditions expected at those proposed sites. For our assessment, below we provide an extract of relevant discussion from Sneddon and Tremblay (2011), as well as additional details relevant to potential effects from copper and zinc in the context of this offshore proposal.

Chemical therapeutants such as antibiotics, antibacterials and parasiticides have not historically been used in the New Zealand salmon aquaculture industry (Tucker 2014, http://www.environmentguide.org.nz/activities/aquaculture/environmental-effects/king-salmon-and-indigenous-fish/), and are not presently used by NZ King Salmon (Mark Gillard, NZ King Salmon, pers. comm.). However, their use in the future cannot be ruled out. Overseas, where such additives are used extensively, the main concern is the potential for these compounds to affect non-target organisms (phytoplankton and zooplankton, sediment bacteria) and the rise of resistant bacteria and/or parasites. The fate and environmental consequence of these potential contaminants from finfish farms is not well known. It is thought that most therapeutants are water soluble and disperse and degrade readily (MPI 2013), but some may be more persistent (Hamoutene et al. 2018). If the source is the same (i.e. feed/faecal material) managing the accumulation of more persistent compounds such as zinc may mean that effects from other, less persistent compounds would not be problematic.

Copper and zinc

Both copper and zinc are ubiquitous metals that occur naturally in the environment. They are both essential trace nutrients required at low concentrations by effectively all organisms. However, toxic effects can occur where these metals are concentrated in biologically available (bioavailable) forms above threshold concentrations (i.e. exceed metabolic requirements).

Both metals can be released from finfish farming operations in quantities that have the potential to result in their accumulation within sediments beneath and adjacent to farms over time. Copper is the principal active agent in antifouling paints which are often used in aquaculture operations, and have historically (up to 2015) been applied to anti-predation nets enclosing farms operated by NZ King Salmon. From this antifouling paint, copper can be released to the environment through leaching to the water and by physical abrasion during use or via *in situ* mechanical cleaning operations. Salmon feed contains zinc as an additive for fish health, leading to its discharge in faecal matter. Since deposition and accumulation of metals is mediated by settlement processes, it is expected to follow the pattern predicted for organic enrichment, if not its exact extent. Zinc in feed is typically highly bioavailable, and the same can be said for zinc in faecal matter. This is in contrast to copper, which is often bound in paint flake matrices or larger particulates.

Annual monitoring records for existing NZ King Salmon farm sites (particularly those categorised as high flow) may form a general basis for predictions of effects at the offshore Marlborough site. This is summarised from Sneddon and Tremblay (2011):

- Background sediment concentrations of copper and zinc in Tory Channel are in the order of 6 mg/kg and 37 mg/kg, respectively.
- There has been high variability for both copper and zinc beneath existing farms, with a consequent absence of clear temporal trends.
- Spatial sampling data for sediment copper and zinc showed elevated concentrations of sediment metals to be effectively limited to within 100–150 m of the farm edge.
- Accumulation of these metals at existing farms is managed through an adopted ANZECC (2000) framework that implements thresholds for varying levels of environmental protection, and has specific considerations for further action in the context of accumulation from salmon farming inputs (see MPI 2015).
- Infrequent and irregular exceedance of ANZECC (2000) sediment quality trigger values (ISQG-Low and -High[11]) has occurred at an established high-flow farm in Tory Channel (Te Pangu), but not at either of the newly installed salmon farms (i.e. farms installed since 2015).

The potential environmental issues identified and assessed for seabed effects from the offshore proposal are as follows:

- Accumulation of copper and zinc in the sediments to concentrations which may result in toxicity effects on seabed communities.
- Persistence of elevated sediment metals concentrations over time frames exceeding those for organic enrichment effects.
- Bioaccumulation of copper and zinc within marine organisms (through direct consumption and transfer through the food web). In particular, some suspension feeding bivalves are known to accumulate contaminants (Azizi et al. 2018; Brooks & Rumsby 1965), and this can result in sub-lethal stress (see De Luca-Abbott

[11] Respective ANZECC (2000) ISQG-Low and –High values for copper are 65 mg/kg and 270 mg/kg, and for zinc, 200 mg/kg and 410 mg/kg.

2001), though this has not been evaluated in the context of aquaculture waste, nor in horse mussels.

- Effects on epifaunal communities in the vicinity of farms either from direct (water column) or indirect (e.g. food web) mechanisms.

Metals are conservative contaminants and do not degrade to other forms; hence the principal measurable effect at salmon farm sites is expected to be increases in copper and zinc concentrations within sediments beneath and immediately adjacent to farms. A return to background concentrations during site recovery can occur only by processes (biological and physical) which either disperse metals or bury them in deeper sediments. While the dispersive nature of the offshore site will limit the rate of accumulation of metals in farm-associated sediments, there are insufficient data to conclude that sediment metals accumulation will not occur over time. Monitoring of concentrations is recommended, given that it is a new site with a potentially large discharge load.

If organic enrichment is high enough that anaerobic sediment conditions occur beneath pens at the proposed site, the reactive fractions of accumulated copper and zinc will be reduced through the formation of insoluble sulphide compounds, thus reducing their bioavailability. This transformation process, and the confounding effect of seabed organic enrichment, will largely preclude the attribution of effects from metal accumulation to seabed communities. After farm removal or fallowing, metal bioavailability may increase as the seabed recovers from enrichment and sediment conditions become aerobic. This has the potential to inhibit biological recovery of sites if high enough concentrations of copper or zinc occur.

Consumption of particulate farm waste by suspension feeders (bivalves, brachiopods) is likely to result in some level of accumulation of heavy metals due to their low capacity to metabolise these (Azizi et al. 2018), and the high bioavailability of zinc within the feed and faecal material. Consequences of accumulation of metals will depend on the tissue concentrations, and will result in adverse (sub-lethal) effects at high enough concentrations. The significance of metal accumulation in suspension feeders at the proposal site will depend (among other things) on the exposure to, and assimilation of farm waste (e.g. see Yigit et al. 2018).

The ANZECC (2000) sediment quality guidelines should take into account the sub-lethal effects to biota, including suspension feeding bivalves, thus these guidelines (and framework provided in MPI 2015) should be used for managing any potential toxic effects to biota.

3.4. Summary of effects and uncertainty

The predicted effects on the seabed from this proposal are generalised in Table 2. These are categorised by activity, with the most pronounced effects likely to result from the deposition of farm wastes (primarily feed and faeces) onto the seabed.

In particular, there are ecologically important and sensitive seabed habitats (horse mussels, brachiopod communities and reef habitat) within a large proportion of the proposal area. While these taxa are not at risk or endangered, there are measures that could be taken to reduce or mitigate the effect that the proposal has on these communities. These habitats appear to continue outside of the seabed area surveyed, but the spatial boundaries are unknown. There is some level of uncertainty around the tolerance of horse mussels and brachiopods to deposition, including at what enrichment level sub-lethal effects may manifest. Organic enrichment could also displace other more sparsely distributed epifauna that are widespread throughout the area (bryozoans, tube-dwelling anemones). Infaunal community responses to organic enrichment are well understood. Substantial alteration to infaunal communities is likely to result from the proposal, but a high production salmon farm could be operated at this site without them being affected to the magnitude at which they are allowed to be impacted beneath salmon farms within the Marlborough Sounds (i.e. ES 5).

Because of the highly dispersive nature of the site and high likelihood of far-field particle dispersal by resuspension processes, there also is potential for low-level enrichment effects outside of the modelled footprint. We note that far-field dispersal does not necessarily constitute an effect. Nonetheless, areas susceptible to accumulation of organic material such as the seafloor depressions to the east of the proposal area, and areas of high rugosity (e.g. biogenic habitat) are those more likely to manifest far-field enrichment effects. Such effects are also more likely to arise with cumulative deposition from multiple farms. Internationally, there is lack of understanding of the extent of far-field enrichment, but recent research suggests that in some areas (dispersive sites and/or intensive farming levels), this could be significant (Law 2019; Woodcock et al. 2018). The environmental consequences of low-level exposure are not well understood, but may comprise adverse sub-lethal effects (for example, reduced reproductive success from altered diet nutrition [White et al. 2016], or by contrast, increased growth from a nutritional subsidy [George & Parrish et al. 2015; Bergvik et al. 2019]). The effect is likely to be species- and exposure-specific.

Table 2. Summary of predicted effects by activity.

Activity	Environmental implications	Range of consequences, recovery *and uncertainty*
Mooring installation	1. Destruction and smothering of habitats/biota	The installation of each screw anchor is likely to result in the displacement of epifaunal and infaunal taxa in areas immediate to anchor sites (approx. 2 m^2). There will be small-scale resuspension and settlement of fine particulates, which will likely occur over a relatively short time frame (hours) with minimal impact due to the high currents that will rapidly disperse the sediment. Recovery of organisms will take place immediately after disturbance, but for sensitive or slow-growing taxa, recovery back to existing state could take up to several years in affected areas.
Presence of structures	2. Fouling organisms drop onto the seabed, potentially changing composition of biological communities	Colonisation of the anchor warps by hydroids and/bryozoans is expected to occur, based on observations of fouling on monitoring equipment deployed at the site. Some drop-off of these organisms (e.g. from natural sloughing and net cleaning) to the seabed is expected from the pen structures. This may result in the colonisation of the seabed by these taxa, while algae may also colonise near-surface structures, However, the difference in the light environment between the pen depths and the seabed depth is likely to limit the ability of algae to colonise the seabed. The effect will persist for the farm duration but recovery to community will occur in a moderate timeframe if the farm is removed.
	3. Shading by structures resulting in reduced food source	Shading can block sunlight from reaching the seabed, potentially causing a reduction in food availability for some organisms. Although this can lead to mortality of photosynthetic organisms at shallower sites, the depth of the seabed at the proposal site means the amount of light penetration to the seabed is extremely low in the first instance, thus there are few photosynthetic taxa living there.
Active farm operations (deposition)	4. Increased nutrients	Possible increase in algal abundance due to increased nitrogen and phosphorus availability. Very unlikely to be an issue at sites with limited light penetration to seabed already inhibiting algal growth, and breakdown processes in the water column.
	5. Increased predation on biological communities	Biodeposition of both fouling organisms and feed/faeces may encourage aggregation of scavenging and/or predatory organisms (e.g. sea cucumbers, sea stars, crabs, lice). This could cause potential displacement of prey species (e.g. horse mussels). Recovery on the scale of months to years for community composition (predators) to return to existing state depending on level of effect.
	6. Alteration to epifaunal communities and sensitive taxa	Depending on the level of deposition, communities may have an enhanced food supply effect, through to eventual displacement. Population level effects may also occur through sub-lethal effects such as reduced reproductive success or larval settlement and recruitment. Recovery will be on the order of several years (or more for habitat forming species such as horse mussels) following farm removal, but this is depending on the impact level. ***The tolerance of ecologically important and/or sensitive habitats (horse mussels and brachiopods) to farm-related enrichment is not well known. The dispersal of farm waste into the far field from highly dispersive sites is not well understood.***
	7. Near-bed O_2 depletion, stress to biota	At excessive enrichment levels, where organic matter accumulates on the seabed, respiration from the breakdown of organic matter can lower oxygen levels. This can cause stress to biological communities. This is highly unlikely based on the level of oxygenation at such a dispersive site, but may be possible at high enough farming intensity (many closely spaced pens with high feed throughput).
	8. Alteration to infaunal communities	Increased particulate organic matter from uneaten feed and faeces provides an additional food source and changes in sediment conditions for infaunal communities. Depending on the level of deposition, this can manifest as: a) a fertilisation effect with enhanced abundances and taxa richness, b) low infaunal species richness and extremely high abundances of a few opportunistic taxa responding to increased food supply and availability (at this level of effect total biomass and assimilative capacity of the community is enhanced), to azoic conditions (no life present), which are unlikely at this site. A gradient will be present, where the effect will decrease with increasing distance from the farm to the edge of the depositional footprint. Recovery of most taxa will be on the order of several months, but for more sensitive or slow-recruiting taxa, infaunal communities would be on the order of years following the removal of the farm. ***The dispersal of farm waste into the far field at highly dispersive sites is not well understood.***
	9. Accumulation of contaminants, and toxic effects on biota	Metals and other contaminants from feed/substances used on farm can deposit on the seafloor. These compounds can accumulate in the sediments to levels that can cause toxic, sublethal effects on biota (e.g. zinc from feed and copper from antifouling). Toxic concentrations (for example, of zinc) are unlikely at such a dispersive site, but elevated concentrations may persist in sediments for duration of the farm, and for several years after farm has been removed. ***The fate of therapeutants and toxic effects from contaminants are not well understood.***

4. EFFECTS MANAGEMENT, MITIGATION AND MONITORING

This assessment provides details around what predicted effects would look like under a range of scenarios, including an initial production level of 10,000 tonnes. The generalised approach of this assessment is appropriate for the implementation of effects-based management, whereby the potential effects of concern can be monitored, and farming practices adapted to minimise risk of unacceptable effects occurring as the scale of the development progresses. Effects-based management is defined here as the implementation of independent monitoring in conjunction with an adaptive management framework for the consent holder.

Although there could be adverse effects on ecologically important habitat associated with the proposed farming operation, there are options for reducing or avoiding these effects (Table 3). If these mitigation options are implemented, the ecological significance of the effects could be reduced to the extent that the site could support a salmon farm development of a substantial size.

The primary option for reducing adverse effects is avoidance of sensitive/ecologically important epifaunal communities during anchor installation and farm siting. Secondarily, effects-based management will help to keep effects within predicted or acceptable levels. Effects-based management is recommended for managing effects on both epifaunal and infaunal communities. The key aspects of this effects-based approach are:

1. clearly defined limits on level of acceptable/allowable effects
2. a well-designed monitoring programme that effectively measures the level of effect
3. a decision framework, outlining intervention points, whereby adaptive management must take place in the event that monitoring shows the effect is beyond what is deemed to be acceptable, as well as pathways for the monitoring results to feedback into the monitoring design.

In addition to avoidance and effects-based management options, there are also operational measures which can be routinely implemented to reduce the magnitude of some effects (see Table 4).

Table 3. Mitigation options for reducing the significance of effects at the proposal site.

Activity	Environmental implications	Narrative for options to avoid, remedy or mitigate (where applicable). **Guidance for monitoring is also provided in bold.**
Mooring installation	Destruction and smothering of habitats/biota during mooring installation	• Avoid sensitive and ecologically important habitat. • Use experienced personnel for anchor installation to minimise disturbance. *Given there could be a large number of moorings installed at the site, options to avoid, remedy or mitigate are recommended to be followed as much as practicable, particularly in areas where there are habitat-forming taxa present (i.e. horse mussels).*
Presence of structures	Alteration to biological communities from biofouling drop-off	• Periodic inspection (and maintenance, if required) of warps to manage the amount of fouling organisms attached. *An emphasis should be placed on inspections in the initial stages of operation, to gain a rapid understanding of the nature and extent of fouling at the site.*
Active farm operations (deposition)	Increased predation on biological communities from biodeposition and organic enrichment	• Avoid footprint overlap with sensitive and ecologically important habitat. • Effects-based management. ***Monitoring should be carried out during site development, and for a suitable period after the maximum level of production is achieved (this need not be annual), to look for signs of deteriorated condition and increased predation. This monitoring may be reliant on quantitative video techniques.***
	Alteration to epifaunal communities and sensitive taxa from organic enrichment	• Feed optimisation to limit feed waste. • Avoid footprint overlap with sensitive and ecologically important habitat. • Effects-based management. ***Where sensitive and ecologically important communities cannot be avoided, monitoring with adaptive management should be undertaken to minimise risk of undesirable effects. Monitoring should be informed by additional particle dispersal modelling (using the proposal scope) to identify potential 'hotspots' of enrichment, and areas subject to low-level deposition.***
	Near-bottom oxygen depletion Alteration to infaunal communities from organic enrichment	• Feed optimisation to limit feed waste. • Effects-based management. ***To keep effects are within the allowable limit. Monitoring should be informed by additional particle dispersal modelling (using the proposal scope) to identify potential hotspots of enrichment, and areas subject to low-level deposition.***
	Accumulation of contaminants and toxic effects on biota	• Avoid footprint overlap with sensitive and ecologically important habitat. • Minimise accumulation of contaminants by off-site washing of nets to minimise antifoulant leaching (if used). • Good husbandry to avoid the need for therapeutants. • Effects-based management. ***This includes occasional monitoring of physiochemical and biological properties of sediment until contaminant levels are well understood. The MPI 2015 framework should be appropriate, however this framework does not encompass effects on epibiota, primarily those known to be susceptible to accumulation such as suspension feeding bivalves. Sensitive epibiota should be specifically considered in monitoring.***

Table 4. Risk characterisation of potential effects associated with the initial proposal. Likelihood: N/A, unlikely, possible, probable, certain. Acceptable level of effects refers to that defined through the consenting process.

Activity	Environmental implications	Likelihood	Consequence: **Spatial extent** Localised (10s of m), medium (100s of m), large (> 1 km), regional (10s of km) **Magnitude** (slight, minor, major, severe), **Duration** (Short; days-weeks, moderate; weeks-months, persistent; years).	Options to reduce consequence or likelihood of effect	Residual effect comments
Mooring installation	1. Destruction and smothering of habitats/biota	**Certain**	**Spatial extent: Medium**. Limited to areas directly surround anchor sites. **Magnitude: Major**, displacement and loss of habitat**. Duration: Persistent**. Short term impact but recovery on scale of months to years for sensitive epifaunal species.	• Avoid disturbance to areas with sensitive and/or ecologically important epifauna. • Use experienced personnel for installation to minimise spatial scale of effect.	Localised disturbance of some areas of seabed that contain sensitive epibiota.
Presence of structures	2. Fouling organisms drop onto the seabed, potentially changing composition of biological communities and increasing predation	**Certain**	**Spatial extent: Medium**. Affected area limited largely to seabed beneath pen perimeters, mooring lines, and to a lesser extent underneath pens. **Magnitude: Slight**. **Duration: Persistent**. Effect for the duration of the farm. Recovery will be on the order of months to years.	• Monitoring and management of fouling levels.	Slight contribution to organic enrichment (see effect nos. 6 and 8).
	3. Shading by structures resulting in reduced food source for some organisms	**Unlikely** Due to site depth.	**Spatial extent: Medium**. Affected area limited largely to seabed beneath pen perimeters, mooring lines, and to a lesser extent underneath pens. **Magnitude: Slight**. **Duration: Persistent**. Effect for the duration of the farm. Recovery will be on the order of months to years.	Not applicable.	None.
Active farm operations (deposition)	4. Nutrients (mainly nitrogen and phosphorus) released from organic material resulting in increased algal growth	**Unlikely** Due to site depth**.**	**Spatial extent: Medium**. Limited mainly to within the primary footprint. **Magnitude: Slight**. Waste deposition and accumulation are low. **Duration: Persistent**. For duration of farm, but effects reversible within months following farm removal.	Not applicable.	None.
	5. Increased predation on biological communities from biodeposition and organic enrichment	**Possible**	**Spatial extent: Medium**, limited mainly to the primary footprint. **Magnitude: Major**. Possible displacement of sensitive epibiota. **Duration: Persistent**. For duration of farm. Recovery on the scale of months to years for community composition (predators) to return to existing state depending on level of effect.	• Avoid areas with sensitive and/or ecologically important epifauna to reduce risk of their predation. • Effects based management with emphasis on potential hotspots of enrichment.	Significant predation effects to ecologically important areas are avoided.
	6. Alteration to epifaunal communities and sensitive taxa, from organic enrichment leading to food supplementation to sub-lethal effects to displacement	**Possible**	**Spatial extent: Large**. Dependent on farm placement and pen configurations. **Magnitude: Uncertain, but could be major**. (Reductions in density within a proportion of the habitat). **Duration: Persistent**. For the duration of farm with recovery on the order of several years if habitat forming biota are displaced, but this is depending on the impact level.		Sublethal effects possible to ecologically important and/or sensitive habitats located outside of primary footprint. Possible displacement in areas susceptible to far-field waste accumulation, but there is uncertainty around the level at which displacement might occur.
	7. Near-bottom oxygen depletion, ultimately causing oxygen stress to epifaunal and infaunal species	**Unlikely**	**Spatial extent: Medium**. Would only occur in areas that reach excessive enrichment. **Magnitude: Major**. (displacement). **Duration: Persistent**. For duration of farm, but effects reversible within months following farm removal.	Not applicable.	None.
	8. Alteration to infaunal communities from organic enrichment, ultimately leading to displacement	**Certain**	**Spatial extent: Large**. Effect will occur throughout entire deposition zone, but intensity will be higher in the middle. **Magnitude: Major**. Displacement of sensitive infaunal species. **Duration: Persistent**. For the duration of farm with recovery of more sensitive or slow-recruiting taxa on the order of years following farm removal.	• Effects-based management with emphasis on potential hotspots of enrichment. • Feed optimisation to limit feed waste.	Some of the more sensitive infauna species will be lost in most enriched areas, but communities will still be reasonably diverse. Outside of this, a large area may show a 'fertilisation' effect, with enhanced abundances and taxa richness. This may extend outside of the primary footprint due to particle resuspension processes.
	9. Accumulation of contaminants in the sediment cause toxic effects on biota	**Possible**	**Spatial extent: Medium to large**. Restricted mainly to areas of accumulation, and/or high deposition. **Magnitude: Slight**, concentrations of contaminants in the sediment are unlikely to be at levels harmful to biota. **Duration: Persistent**. Duration of farm. Accumulations in the sediment may be apparent for several years after farm removal.	• As above, and; • Minimise accumulation of contaminants by off-site washing of nets to minimise antifoulant leaching (if used), good husbandry to avoid the need for therapeutants.	Elevated levels of contaminants in sediments may occur, but these will be within the threshold for possible biological effects.

4.1. Effects acceptability and management implications

We envisage that the acceptability of effects will be defined through the consenting process. Accordingly, the purpose of this assessment is not to determine what effects are acceptable and what are not, but rather, to provide context for what the ecological effects of the proposal might be. Nonetheless, this section does provide some context from seabed effects acceptability and management from existing salmon farms in the Marlborough area, and briefly discusses them in the context of applicability to this proposal.

Allowable effects may be constrained either spatially, or by intensity, depending on limits unique to the site. Within the Marlborough Sounds, seabed effects from existing salmon farming are managed by both a limit on the intensity of the deposition (ES 5; see MPI 2015, roughly equivalent to a flux of 13 kg solids/m^2/yr), and a limit on the spatial extent of the primary footprint/discernible enrichment (i.e. area > ES 3, or a flux of ~1 kg solids/m^2/yr). In the past, the allowable spatial extent has been defined in the resource consent for each site, while the thresholds and zoning concept are set out in the *Best Management Practice Guidelines for Salmon Farms in the Marlborough Sounds* (MPI 2015).

Based on the modelling described in this assessment, the proposal site appears to have the ability to support a substantial salmon farm development without reaching ES 5 anywhere within the primary footprint (contingent on farming layout). However, we need to consider the applicability of the thresholds of MPI (2015) to a potentially large-scale offshore development. These MPI (2015) thresholds were set in the context of the Marlborough Sounds using a zoning approach, whereby only the seabed directly beneath the pens may be impacted to this level (typically an area of ~1.5 ha per farm). The total area impacted by the primary footprint is also constrained. In the Marlborough Sounds, the shallower depths help to constrain the spatial extent of deposition. Therefore, the combination of the thresholds and the zoning approach defined in MPI (2015) may not be appropriate at this more dispersive site, though they do provide a good framework that could be adapted. In addition, the environmental thresholds in MPI (2015) consider effects only to seabed infauna, and were not set with consideration of epifaunal communities such as are present at this site.

Importantly, the ES approach defined in MPI (2015) should be validated for its applicability to the proposal site before it is used to define the allowable level of effects, and/or implemented into any sort of effects based management programme, to eliminate any uncertainty associated with differences between the Marlborough Sounds salmon farm areas and the proposal site.

International management context from other farming regions that are more similar in size and position in open ocean waters to the proposal site may provide additional guidance (e.g. Norway, Canada).

4.2. Adaptive management options

There are several ways in which seabed effects from deposition can be managed. As the modelling demonstrated, both the spatial extent and the intensity of the footprint are influenced by feed throughput, and farming configuration (pen spacings, block spacings, farm siting). Farming configuration can therefore be used as a method of avoiding and mitigating undesirable effects on the seabed (i.e. effects-based management), without a reduction in overall feed throughput. Minimising the intensity of the footprint in this way is a trade-off with increasing the total area impacted by deposition (e.g. fallowing, lighter feed loadings per pen with a higher number of pens).

With both the intensity and spatial extent of effects in mind, adaptive management actions to limit the effect of seabed deposition during active farming operations could include (but are not limited to):

- site fallowing/rotation to reduce intensity of impact and allow time for recovery between production cycles in a given area
- reconfiguration of pen layouts (removal of some pens, or re-alignment of pens within blocks to alter the spatial extent/intensity of the footprint)
- reduction in farming intensity (reduced feed/stocking density in some areas to reduce spatial extent or intensity of footprint)
- permanently re-siting pens to a new area.

4.3. Capturing the details of scientific monitoring

Given the emphasis on effects-based management as a mechanism for reducing and mitigating potential effects of the proposal, we recommend that a robust, adaptive monitoring and management framework is prepared. Additional depositional modelling using the final pen layouts and spacings is recommended to inform the monitoring design. This modelling should include resuspension of particles, and a higher number of released particles than was used in this assessment.

We emphasise the benefits of long-term monitoring and management plans (i.e. that do not need to be prepared annually). These have the benefit of being able to capture less frequent monitoring, and can be updated and resubmitted to the regulator as necessary to accommodate changes in activity, relevant new technology and scientific advancements.

Resource consents are static documents that capture only the knowledge at the time a decision is made on an application. As such, resource consent conditions that contain details specific to the design of scientific monitoring can become outdated. An alternative would be for resource consents to provide overarching ecological acceptability criteria, and monitoring objectives, and appropriately qualified scientists can design monitoring around these, without the risk of the monitoring approach becoming outdated. Combined with a consent requirement that the monitoring plan go through a review process with the regulator, this approach should ensure monitoring is robust, up to date, fit for purpose, and also acceptable to the regulator.

We note that the scope of this section is not to provide exact details of the recommended monitoring or management actions, rather, to provide an overview of how effects could be managed using these tools. A robust, and well thought out monitoring and management framework considering the themes discussed in this assessment would need to be prepared once details of the exact proposal is known. The framework should be prepared and commenced in advance of structure placement, particularly given that baseline monitoring may need to be performed if time series analyses and before/after comparisons are required.

5. SUMMARY OF FINDINGS

The main findings of our benthic assessment are as follows:

1. A range of sediment types were observed at the study area, grading from sandy mud through to coarse sand and gravels with high amounts of shell debris. Bathymetry and sediment type appeared to be largely influenced by the presence of McManaway Rock on the southeast edge of the survey area. The sediment was well oxygenated with low organic content. Rich infaunal (i.e. within sediment) communities were present across the area, with a total of 118 taxa recorded in the samples. The species were typical of those within communities in deep, high-flow areas within the Marlborough Sounds.
2. There were also distinct biological strata based on the seabed epifaunal characteristics. These were biogenic habitat (45% of the surveyed area), comprising two sub-strata; horse mussel/brachiopod beds, and horse mussel debris patch-reef. Other strata were soft bryozoan fields (~30% of the area), reef-edge assemblages (15% of the area), and muddier substrate areas with sparse epifauna (10% of the area). In addition, within the biogenic habitat stratum were large pockets (possibly up to 1–2 km across, primarily on the edges of the horse mussel patch-reef) of soft muddy sediments where epifauna were sparse. The reef edge communities flanked McManaway Rock, an area of which is classified as a significant marine site in the Marlborough coastal area.
3. The proposed site overlies water depths of 60 to 165 m. Water current velocities at the site are strong (mean and maximum near-seabed 31 and 86 cm/sec, respectively; mean and maximum mid-water, 35 and 110 cm/sec) and the predominant axis of flow is southeast/northwest. Due to site depth, it is unlikely that storm-driven currents are a factor of natural seabed disturbance. Nonetheless, the surveyed area is a highly dispersive environment where farm wastes will be rapidly assimilated.
4. Based on the depositional modelling (presented in Section 3 and Appendix 10), the site has capacity to support a large salmon farm development (i.e. larger than the present production in the whole of the Marlborough Sounds), without the primary footprint exceeding the 'bottom line' best management practice threshold (ES 5) that is used at sites within the Marlborough Sounds to manage effects on seabed infauna. The trade-off is a larger, more diffuse, footprint. Importantly, the zone of 'maximum' effect is less likely to be constrained to directly beneath the pens, as compared to farms managed in the Marlborough Sounds. To minimise footprint intensity, the farm layouts must consider the proximity of adjacent pens (or blocks), and the orientation of rows with respect to the primary flow axis. Nonetheless, there is potential for effects on seabed biological communities, including to the habitats of ecological importance, and the ecologically significant marine site at McManaway Rock.
5. At the initial proposed production level of 10,000 tonnes per year (20,000 tonnes of feed discharge) depositional modelling indicated that the maximum

depositional flux within the primary footprint would be on the order of 2.56 kg solids/m^2/yr (moderate enrichment), with a total footprint area of 535 ha. Scaling up the production to 40,000 tonnes of production, and using additional blocks of pens while maintaining efficient use of the space (i.e. overlapping depositional footprints), resulted in depositional flux of up to 9.0 kg solids/m^2/yr, with a total footprint of 658 ha (detailed in Appendix 10).

6. As context, the equivalent flux rates for ES 3 and ES 5 (relevant to the zoning approach used in the Marlborough Sounds) are ~1 and ~13 kg solids/m^2/yr, respectively. Fine farm waste material will also be dispersed, through water column transport and sediment resuspension processes, to the far field (i.e. outside of the total footprint). Through these processes, dispersal is estimated to be on the order of kilometres beyond the total footprint modelled in this assessment, although accumulation will be at low-levels that may not be easily discernible.
7. Based on the initial production level, in the most intensely affected area (moderate enrichment conditions), more tolerant and opportunistic taxa will begin to dominate infaunal communities, and sensitive taxa will be displaced. As a result, taxa richness will be reduced from background conditions, and total abundances may increase. There will be slight changes to sediment chemistry (sulphides and redox) due to increased microbial activity, and patches of bacteria may be visible. Some more sensitive (sessile suspension feeding) epifauna may show reductions in density, while more tolerant taxa may increase in density (e.g. mobile deposit feeders may aggregate in these areas). It is highly unlikely that levels of copper and zinc will reach an adverse biological threshold at this level. With increasing proximity to the edge of the footprint (~1.5–2 km downstream of the pen edges), these infaunal communities will grade to background conditions, with a large proportion of the footprint containing communities with enhanced taxa richness and abundances, akin to a 'fertilisation' effect.
8. Far-field waste dispersal, and effects from far-field deposition (outside of the footprint) are difficult to predict, but are an important consideration in any monitoring, due to the dispersive nature of the site and the potentially large farming area that it may be able to support.
9. It is not known how tolerant horse mussels and brachiopods are to farm-related deposition, but it is likely to be low. Thus, depending on the location of the structures within the proposal area, epifaunal communities may show sub-lethal effects, or be displaced, even at relatively low depositional levels (mild to moderate enrichment). The significant marine site and reef-edge assemblage areas also contain taxa likely to be sensitive to deposition.
10. Key to reducing the likelihood and consequence of ecological effects are: a) avoiding overlap of the footprint with sensitive horse mussel and brachiopod beds, and the McManaway Rock fringing strata, b) monitoring and effects based management whereby the potential effects of concern can be monitored,

and farming practices adapted to minimise the risk of unacceptable effects as the activity progresses. In addition, there are other operational management practices that can help to reduce some of the effects.

11. A robust, long-term management plan should be prepared prior to any structure installation. This should include clearly defined limits on 'effect acceptability', intervention framework and feedback pathways for adaptive management and monitoring, and details of a well-designed monitoring programme that measures the actual effects. Additional depositional modelling is recommended to inform the monitoring design, once the final farming configuration is known. This modelling should include a higher number of released particles, and particle resuspension.

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8. APPENDICES

Appendix 1. Full report of the MBES survey performed by Discovery Marine Limited (DML).

Reference: DML 18_48

13 November 2018

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REPORT OF SURVEY – PELORUS SOUND ENTRANCE MBES SURVEY

1. Survey Location

The location for this survey was at the entrance to Pelorus Sound - a rectangular region between Witts Rock, McManaway Rocks and Sentinel Rock, approximately 8.4km x 6.5km (refer Figure 1). The smaller rectangle (3.3km x 5.4km) contained within the greater survey area was given higher priority should weather or other unforeseen circumstances interfere with the survey.

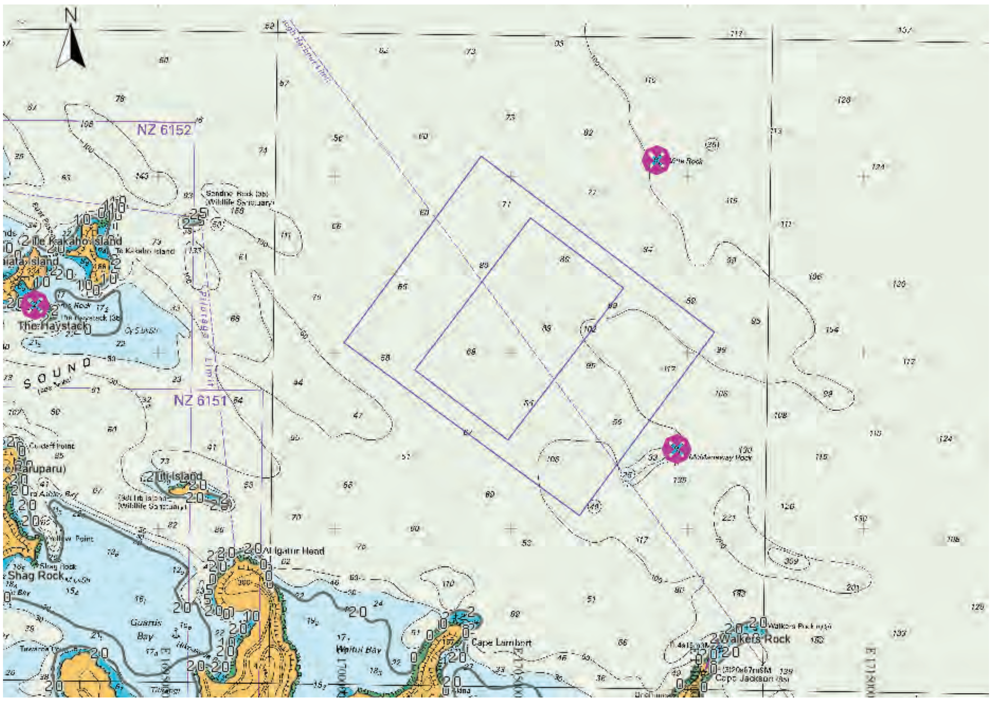

Figure 1: Pelorus Entrance Survey Area

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ABN 68 914 988 491

2. Survey Dates

This survey was conducted over three days, between 29-31 October 2018 NZDT. A summary of the survey has been tabulated below.

Table 1: Summary of Survey

Date (NZDT)	Summary of Tasks
27 & 28 Oct-18	• Survey vessel Ocean Eagle transits from Gisborne to Wellington for survey.
29-Oct-18	• DML survey crew join Ocean Eagle at Seaview Marina, Lower Hutt, Wellington. • Transit to survey area. • Begin sounding at 1510 NZDT.
30-Oct-18	• Continue sounding operations. • Cease sounding at 1548 NZDT due to deteriorating weather conditions affecting data quality. • Anchor at Waitui Bay, Cape Lambert - wait for weather to improve.
31-Oct-18	• Resume sounding 0708 NZDT. • Run crosslines, patch test lines and backscatter calibration lines. • End survey 1913 NZDT and transit to Seaview Marina.
1-Nov-18	• Arrive at Seaview Marina 0100 NZDT. Unable to leave berth due to weather.
2 & 3 Nov-18	• Survey vessel Ocean Eagle transits from Wellington to Gisborne after survey.

3. Survey Requirement:

The scope of works required a MBES backscatter survey of the survey area (refer to Figure 1 above). Seabed sampling to validate backscatter return and seabed type was agreed to be undertaken by Cawthron at a separate time.

4. Weather & Sea Conditions

The weather conditions throughout the survey period are summarized in Table 2 below.

Table 2: Weather Conditions During Survey

Date (NZDT)	Weather Conditions
29-Oct-18	• Southerly 5kts, minimal swell.
30-Oct-18	• Morning: South-easterly 10-15 kts, 1 metre south swell. • Afternoon: Winds rising to over 20 kts from SE, with 1-2 metre southerly swell - survey operations stopped due to marginal data quality.
31-Oct-18	• Morning: Southerly 5-10 kts. • Afternoon: approximately 1600 NZDT wind switched to NW 10-15 kts gusting 20 kts with 1 metre swell. Decision made to continue surveying until completion.

During the survey a low-pressure system passed close west of Cook Strait and influenced the wind and swell conditions in the area. Weather conditions on 30 October 2018 (NZDT) caused overnight survey operations to cease, continuing the following morning once the wind from the NW had died down. Weather conditions began to deteriorate during 31 October 2018 (NZDT), however, the decision was made to complete the entire survey area as data quality was only minimally impacted by the increasing vessel roll.

Barometric pressure readings obtained for Wellington and Nelson for the period of the survey have been extracted from the following website (https://www.timeanddate.com/weather/new-zealand/wellington/historic) and interpolated for the survey area (refer Appendix 1). These observations indicate the pressure in the survey area during sounding on 29 & 30 October was between 992-998mBar and for sounding on 31 October was between 1007-1011mBar. Since predicted tides were used for data reduction the changes in pressure have affected the final accuracy of the reduced depths. This is discussed further in Section 9 - Vertical Datum and Tides.

5. Survey Vessel

The survey was undertaken using Ocean Eagle (MNZ No 136678) which is 18.3 m in length and 5.5 m in width. It is fitted with a rigid over the side pole mount for the MBES on the port side. Figure 2 shows the MBES pole in the stowed position.

Figure 2: Ocean Eagle Fitted with MBES Pole

6. MBES Equipment

The following MBES equipment was used throughout the survey:

Table 3: MBES Equipment Used During Survey Operations

Key Components	Technical Specifications	Serial Numbers
MBES: Reson T50 R	Operating Frequency: 200khz, 300khz or 400khz Depth Range: 500+m Maximum Swathe Angle: 140° Beam Forming: 512 Beams (0.5° x 1.0° at 400khz) Mode: Equidistant Roll Stabilisation: Real time Max Ping Rate: Set to 20hz Depth Resolution: 6mm Operating Software: Seabat UI version 5.0.0.8	Transmit Array: 4817028 Receiver Array: 0818003
AML Micro X (Sonar Head)	Range: 1375 – 1625m/s Accuracy: 0.025 m/s Precision: 0.006m/s Resolution: 0.001m/s	011750
Minos X SVPT Serial No 30305	SV Sensor S No: 206244 Range: 1375 – 1625/s Accuracy: 0.011m/s	P Sensor S No: 305542 Range: 0.004 % F/S Accuracy: 0.005 dBar T Sensor S No: 404421 Range: 0.002^{oo} C Accuracy: -5^{o} to 45^{o} C

6.1 Motion and Heading Sensor

A combined positioning, heading and motion system was utilised for the survey. The sensor is an Applanix POSMV Wavemaster II and the inertial measurement sensor a Type 45 small form IP68 rated unit installed on a solid aluminium shelf on the centre line of Ocean Eagle in a locker near the vessel centre of rotation.

Table 4: Motion and Heading Sensor Equipment Used During Survey Operations

Key Components	Technical Specifications	Serial Numbers
Applanix POS MV Wavemaster II	Roll and Pitch Accuracy: 0.02° Heading Accuracy: 0.03° Real Time Heave Accuracy: 0.05m or 5% True Heave Accuracy: 0.02m or 2% Integrated Position Correction Service: Fugro Marinestar Position Uncertainty: G2 (<0.20m) Software: POSView – Real time monitoring	POSMV: 8045 / IMU Type 45 BD982: 5617C00093 POS Software: v9.21

7. Positioning System

Position fixing for the Pelorus Entrance Survey was by WADGNSS. The system utilises an OEM Trimble BD982 GNSS receiver card built into the POS MV Wavemaster II. The receiver card has the integrated satellite correction service (WADGNSS) Fugro MarineStar G2 service enabled. The position accuracy when online is consistently <0.2m at the POSMV IMU.

There were no problems with the position system throughout the duration of the survey.

7.1 Position Checks

A check was carried out on 2 November 2018 at Queens Wharf, Wellington to verify the positioning accuracy of the combined sonar and positioning system. LINZ mark DD8U was used for this check. Refer to Figure 3 showing the approximate location of DD8U (left), as well as a close-up of the mark (right). The position check was carried out by taping the distance between DD8U and the MBES pole (8.10m) whilst simultaneously taking a screenshot of the QINSy bullseye window (Figure 4) which shows the distance calculated by the positioning system as 8.07m between the MBES pole (set as active node) to DD8U. Several sets of measurements were taken for redundancy and all were found to be within +/- 0.20m.

Figure 3: DD8U Mark Used for Position Check

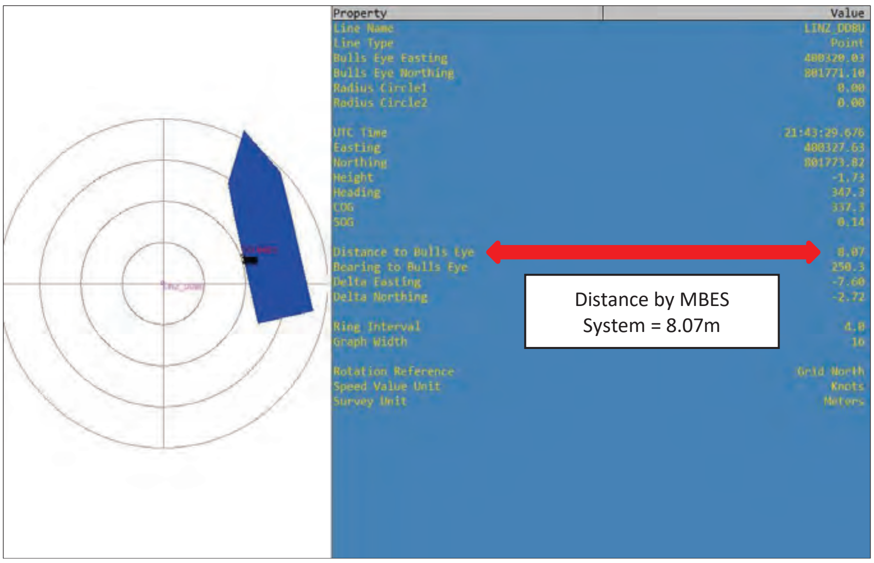

Figure 4: Positioning Check at Queens Wharf Mark DD8U

The position check was carried out on 2 November 2018 due to the lack of survey marks to use around the survey area as well as adverse weather conditions prohibiting the vessel from leaving the berth at Seaview Marina on 1 November 2018.

8. Horizontal Datum/Grid

The survey was conducted on the NZGD2000 Datum and New Zealand Transverse Mercator (NZTM) Projection.

9. Vertical Datum/Tides

Sounding data was reduced using LINZ supplied predicted tides for Anakakata Bay. Refer to Figure 5 indicating the location of Anakakata Bay (red arrow pointing at approximate location) in relation to the survey area.

The low-pressure system in the area over the survey period meant that barometric pressure in the survey area on 30 October was between 992-998mBar and on 31 October was between 1007-1011mBar. The predicted tides applied to the depth data are generated for a standard barometric pressure of 1013mBar and with the actual pressure nearly 17mBar lower, the predicted tides are likely to include an error of up to 0.17m. As a mean depth surface with depth accuracy of better than 0.5m was required no adjustment for impact of the reduced pressure has been made and the depth data has been reduced using the supplied predictions.

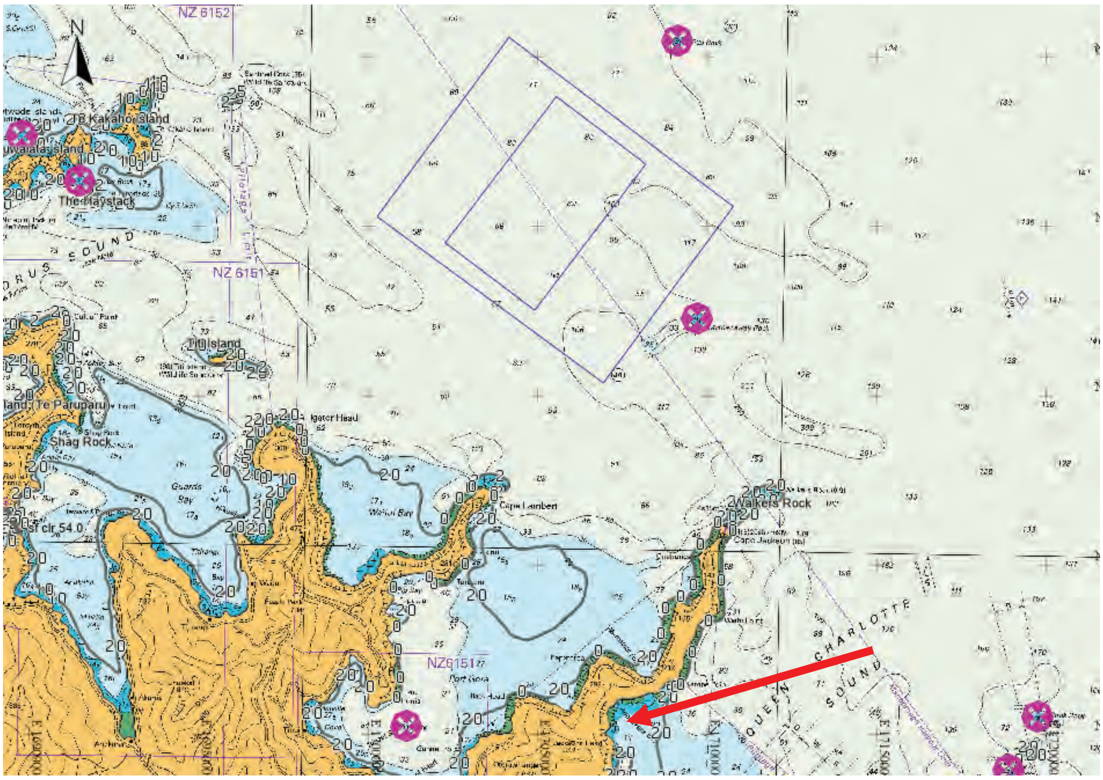

Figure 5: Location of Tide Station at Anakakata Bay

10. Software

The following software was used to reduce the data and produce deliverables:

Acquisition:	QINSy v 8.18.2
	Sonar UI 5.0.0.8 (Reson MBES Software)
Data Quality Control:	Qimera v 1.7.3
Data Rendering:	Terramodel v 10.6 for Sheet Production
	Fledermaus FMGT v 7.8.4 for backscatter mosaic
Other:	Microsoft Word
	Microsoft Excel

11. Conduct of Survey

The survey was run with MBES swaths overlapping and data logged to sequentially numbered files. To assist the helmsman with steering, three sets of lines were used depending on weather conditions at the time. One set running directly north-south, one running northeast-southwest, and the third running east-west. Bathymetry, backscatter, and water column data were all stored in the logged QINSy database files.

As opportunities arose during the survey relevant data was captured for system calibrations. A description of the calibrations carried out on the MBES system can be found in section 12 below.

12. Survey Coverage Achieved

Refer to the figure below showing the survey area and coverage achieved. The coloured depth scale shows the depth range 50 to 120m, deeper areas are shown in purple, shallower areas in red.

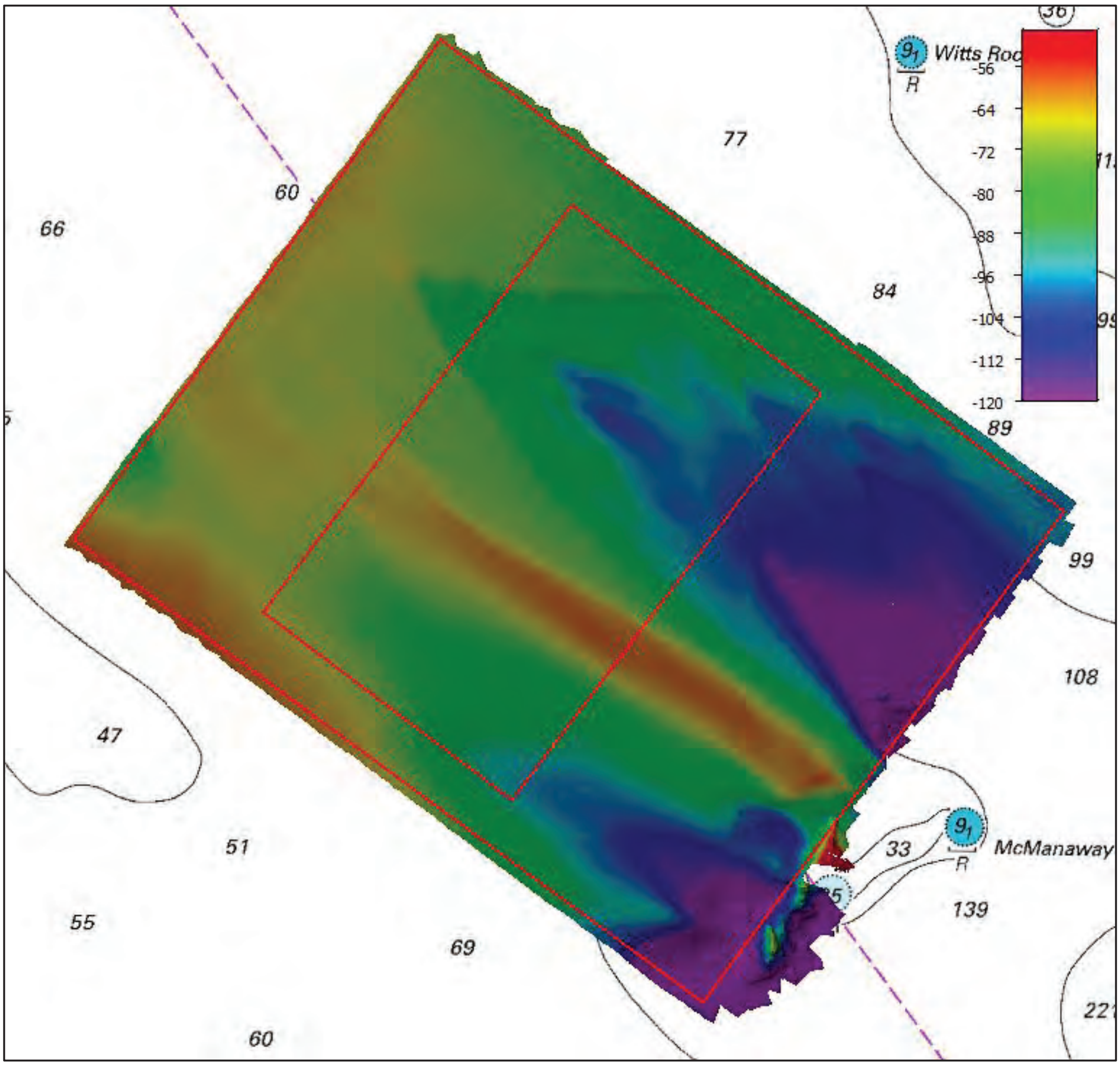

Figure 6: Survey Coverage Achieved

13. Calibrations and Quality Checks

13.1 MBES Patch Test

The installed MBES system was already calibrated prior to the survey so the already accepted offset values for roll, pitch and yaw as indicated in Table 5 were used. A set of check patch test lines were captured on 31 October 2018 to check that the validity of the offsets. These lines were processed using Qimera v 1.7.3 and the results where all close to zero, confirming the confirm the MBES was operated with the correct patch test values.

Table 5: Patch Test Values Used for Survey

Patch Test Component	Values accepted for the survey
Roll	-0.940°
Pitch	-1.350°
Yaw	0.250°

13.2 Crossline Checks

Two crosslines were run perpendicular to the mainlines to provide an independent check on the data and accuracy of the tidal reduction. A further check on data accuracy was undertaken by comparing overlapping data collected over separate days. In general, there was an observed difference between the crosslines and overlapping data of 0.15-0.30m. The discrepancies can be explained by the tidal reduction method used for this project.

As mentioned previously, the tides were predicted rather than observed and the actual pressure was up to 17mBar lower to that used for computing predictions. Additionally, there is a considerable distance between the survey area and Anakakata Bay (refer to Figure 5). The mismatch in overlaps is an acceptable result given the 70-100 m average depth range in the area.

13.3 Checks with Existing Data from Previous Survey

An additional check on the data was carried out by comparison with survey data collected during the LINZ Order 1 Survey of Queen Charlotte Sounds 2016-2017 (referred to as HS51). The overlapping area included depths ranging from 30-100 metres.

The figure below shows a profile comparison between the data captured for this project (in blue dashed line) and the data from HS51 (in green). They match each other very closely, however, there are some areas where there are differences of approximately 0.2-0.3 metres. This can be attributed to the tidal reduction method used for this project.

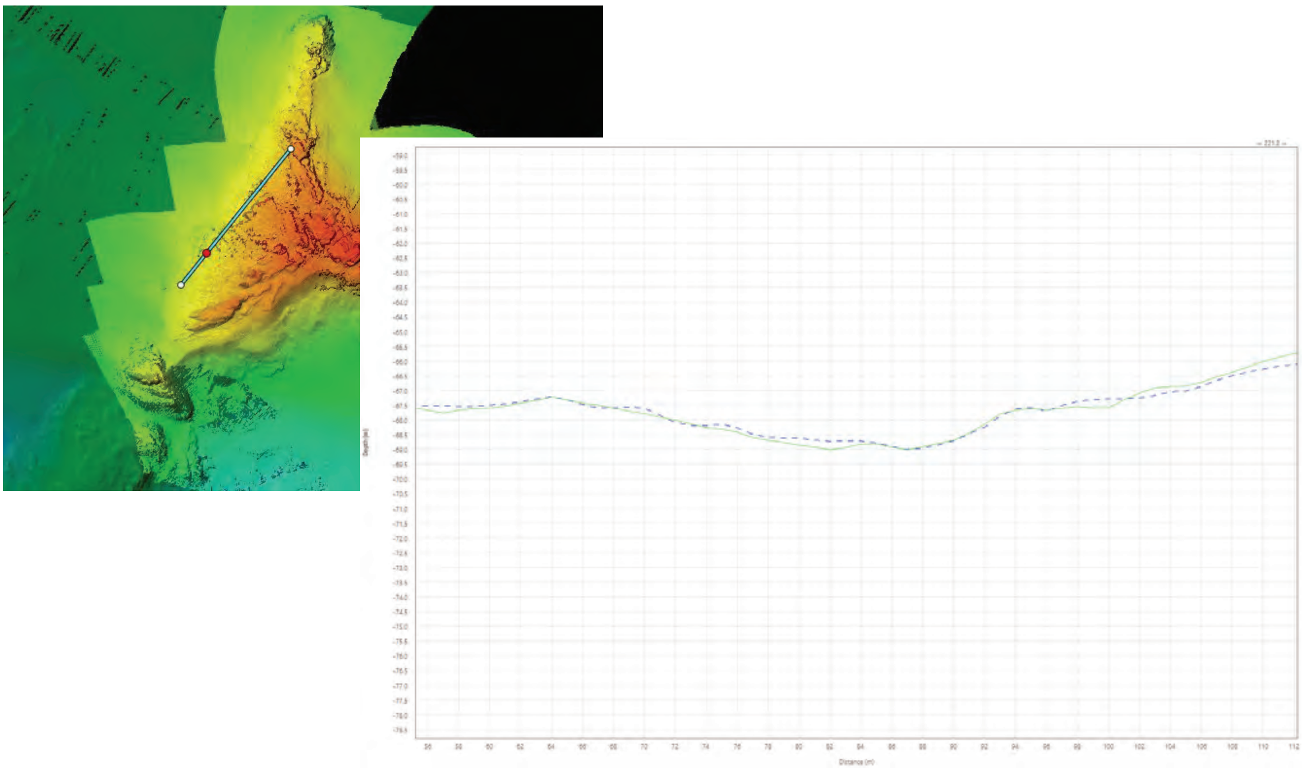

Figure 7: Profile Comparison with Data from HS51

14. Backscatter Calibration Lines

Backscatter was logged throughout the survey and backscatter calibration lines were run on 31 October 2018. All efforts were taken to keep the sonar settings constant throughout the survey, however, adjustments had to be made based on depth as well as signal return strength. A total of 5 different combinations or "sets" of sonar settings were used throughout the survey. Each "set" required two backscatter calibration lines run over the same area but in opposite directions.

The tables at Appendix B show the five different sonar settings used and all line files for the entire survey with the settings used for each. The corresponding database file number for each calibration line is included in the table in the far-right column.

The backscatter mosaic produced from the survey will be provided once complete processing has been undertaken.

15. Retention of Data

DML will retain copies of the project deliverables, including source data files, on its servers for a period of 12 months from completion of the project. The data will then be archived to a digital medium and retained for 7 years. After the initial 12 month period client requests to access and supply project data will incur a fee.

DML wishes to thank Cawthron for the opportunity to undertake this project and looks forward to working with Cawthron again in the future.

For Discovery Marine Ltd

Dan Graham
Surveyor

Survey Supervised and Results Approved By

Bruce Wallen
MNZIS, FIG/IHO Cat A Surveyor

List of Appendices

A. Barometric Pressure During the Survey
B. Backscatter Settings

Enclosures:

1. Survey Plan (shoal depths plotted)
2. Backscatter Mosaic (still to be provided)
3. ASCII File of Soundings, 4m grid
4. XTF Files

Appendix A: Barometric Pressure During the Survey

Pressure readings for Wellington and Nelson were extracted from the website https://www.timeanddate.com/weather/new-zealand, then tabulated and pressure readings interpolated for the survey area.

Barometric Pressure Readings

Date	Time	Wellington mBar	Nelson mBar	Survey Area (Interpolated)
29 Oct 18	10:00	995	995	995
29 Oct 18	16:00	992	992	992
29 Oct 18	22:00	992	992	992
30 Oct 18	04:00	991	991	991
30 Oct 18	10:00	996	995	995
30 Oct 18	16:00	999	998	997
30 Oct 18	22:00	1006	1006	1006
31 Oct 18	04:00	1009	1009	1009
31 Oct 18	10:00	1011	1011	1011
31 Oct 18	16:00	1007	1007	1007
31 Oct 18	22:00	1005	1006	1005

Appendix B: Backscatter Settings Used During the Survey

Different Settings Used Throughout Survey Requiring Backscatter Calibrations

Set	Frequency (kHz)	Power (db)	Gain (db)	Absorption	Spreading	Pulse Width	Calibration Lines
1	400	220	2	80	30	90	0092 & 0093
2	400	220	2	80	30	60	0090 & 0091
3	300	220	2	80	30	120	0084 & 0085
4	400	220	2	110	30	90	0088 & 0089
5	300	220	2	80	30	300	0086 & 0087

MBES Settings Used for Each Line Throughout Survey

Project	File No. (Line)	Set 1	Set 2	Set 3	Set 4	Set 5
100	0001					
100	0002					
100	0003					
100	0004					
100	0005					
100	0006					
100	0007					
100	0008					
100	0009					
100	0010					
100	0011					
100	0012					
100	0013					
100	0014					
100	0015					
100	0016					
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100	0018					
101	0019					
101	0020					
101	0021					
101	0022					
101	0023					
101	0024					
101	0025					
101	0026					
101	0027					
101	0028					
101	0029					

101	0030					
101	0031					
101	0032					
101	0033					
101	0034					
101	0035					
102	0036					
102	0037					
102	0038					
102	0039					
102	0040					
102	0041					
102	0042					
102	0043					
102	0044					
102	0045					
102	0046					
102	0047					
102	0048					
102	0049					
102	0050					
102	0051					
102	0052					
103	0053					
103	0054					
103	0055					
103	0056					
103	0057					
103	0058					
103	0059					
103	0060					
103	0061					
103	0062					
103	0063					
103	0064					
103	0065					
103	0066					
103	0067					
103	0068					
104	0069					
104	0070					
104	0071					
104	0072					
104	0073					
104	0074					

104	0075					
104	0076					
104	0077					
104	0078					
104	0079					
104	0080					
104	0081					
104	0082					
104	0083					
104	0084	**Backscatter Cal Lines Start**				
104	0085					
104	0086					
104	0087					
104	0088					
104	0089					
104	0090					
104	0091					
104	0092					
104	0093			**Backscatter Cal Lines End**		
104	0094					
104	0095					
104	0096					
104	0097					
104	0098					
104	0099					
104	0100					
104	0101					
104	0102					
104	0103					
104	0104					
104	0105					
104	0106					
104	0107					
104	0108					
104	0109					
104	0110					

Appendix 2. Sampling location coordinates and sampling dates for grab samples, drop cameras, and video sled tows. Paired coordinates are the start (first) and end (second) of video sled tows.

Station ID	Type	Date	NZTM_E	NZTM_N	NZTM_E	NZTM_N
A	Grab sample	25.01.2019	1704212	5474410		
B	Grab sample	25.01.2019	1701909	5471322		
C	Grab sample	25.01.2019	1701149	5470283		
D	Grab sample	25.01.2019	1705368	5473590		
E	Grab sample	25.01.2019	1704608	5472563		
F	Grab sample	25.01.2019	1703822	5471512		
G	Grab sample	25.01.2019	1703062	5470511		
H	Grab sample	25.01.2019	1702302	5469484		
I	Grab sample	25.01.2019	1703379	5468711		
J	Grab sample	25.01.2019	1704963	5470739		
K	Grab sample	25.01.2019	1705723	5471790		
L	Grab sample	25.01.2019	1707624	5471981		
M	Grab sample	25.01.2019	1705280	5468914		
N	Grab sample	25.01.2019	1707421	5467356		
O	Grab sample	25.01.2019	1709005	5469472		
P	Grab sample	25.01.2019	1707497	5470637		
Q	Grab sample	25.01.2019	1705786	5467178		
R	Grab sample	25.01.2019	1703062	5472791		
S	Grab sample	25.01.2019	1706420	5469839		
T	Grab sample	25.01.2019	1706585	5468863		
U	Grab sample	25.01.2019	1709119	5471220		
C07	Video sled	8/9.01.2019	1704760	5470486	1704653	5470321
C23	Video sled	8/9.01.2019	1703560	5470878	1703637	5470756
C14_1	Video sled	8/9.01.2019	1703400	5469988	1703043	5470116
C12	Video sled	8/9.01.2019	1702189	5472052	1702299	5471940
C06	Video sled	8/9.01.2019	1703875	5472114	1703734	5472146
C05	Video sled	8/9.01.2019	1706071	5471605	1705887	5471667
C22	Video sled	8/9.01.2019	1705381	5472395	1705471	5472216
C03_1	Video sled	8/9.01.2019	1706202	5472759	1706304	5472702
C02	Video sled	8/9.01.2019	1705653	5473265	1705556	5473086
C20	Video sled	8/9.01.2019	1704844	5473965	1704934	5473791
C21	Video sled	8/9.01.2019	1704384	5474641	1704453	5474522
C16	Video sled	8/9.01.2019	1705098	5469907	1705008	5469688
C19	Video sled	8/9.01.2019	1704720	5468555	1704845	5468393
C10	Video sled	8/9.01.2019	1706736	5467171	1706912	5467012
C11	Video sled	8/9.01.2019	1707520	5468024	1707659	5467833
C18	Video sled	8/9.01.2019	1706461	5468973	1706565	5468795
C17	Video sled	8/9.01.2019	1706148	5471013	1705821	5471046
C15	Video sled	8/9.01.2019	1707331	5470758	1707473	5470594
C03_2	Video sled	8/9.01.2019	1706711	5471950	1706800	5471976
C04_1	Video sled	8/9.01.2019	1707651	5471809	1707877	5471631
C04_2	Video sled	8/9.01.2019	1707678	5471641	1707787	5471494
C14_2	Video sled	8/9.01.2019	1702331	5470334	1701135	5470531
C24	Video sled	8/9.01.2019	1703437	5469005	1703582	5468945
C27	Drop camera	25.01.2019	1708317	5470194		
C8	Drop camera	25.01.2019	1709575	5471330		
C26	Drop camera	25.01.2019	1706679	5470181		
C1	Drop camera	25.01.2019	1704599	5472515		

Appendix 3. Methodologies for sediment sampling and data analysis.

Sample collection

Single sediment grab samples were collected at each sampling station using a van Veen grab. Each grab sample was examined for sediment colour, odour and texture. The top 30 mm of one sediment core (63 mm diameter) was analysed for organic content as percent ash-free dry weight (%AFDW), sediment grain size, and redox potential (Eh_{NHE}, mV). Laboratory analytical methods for sediment samples can be found in the table below.

A separate core (130 mm diameter, approximately 100 mm deep) was collected from each grab for macrofauna identification and enumeration, and sieved through 0.5 mm mesh. Taxonomic experts (at the Cawthron Institute Taxonomy Lab) identified all organisms to the lowest practicable resolution.

Data analysis

Infaunal data were analysed to ascertain levels of abundance (number of individuals per core) and taxa richness (number of taxa per core). Abundance data were fourth-root transformed to de-emphasise the influence of the dominant species (by abundance). The infaunal assemblages were visualised using dendrograms from hierarchical cluster analysis using the group average mode based on Bray-Curtis similarities (Clarke & Warwick 1994). The SIMPROF test was used to detect any station grouping pattern at significance level of 5%. The major taxa contributing to the similarities of each group (areas) were identified using analysis of similarities (SIMPER; Clarke & Warwick 1994; Clarke & Gorley 2001). All multivariate analyses were performed with PRIMER v6 software.

Analyte	**Method**	**Default detection limit**
Sediment samples		
Organic matter (as ash-free dry weight) [a]	Ignition in muffle furnace 550 °C, 6hr, gravimetric. APHA 2540 G 22nd ed. 2012. Calculation: 100 – Ash (dry wt).	0.04 g/100 g
Sediment grain size [a]	Drying for 16 hours at 103 °C, gravimetry (Free water removed before analysis). Wet sieving with dispersant, sieve to seven size fractions 2.00 mm – 63 µm, gravimetry (and for all but 2 mm, calculation by difference).	0.1 g/100g dry wt

[a] Hill Laboratories

Appendix 4. Enrichment Stage calculations for the proposal site, using polynomial relationships derived from dispersive sites in Tory Channel, Marlborough Sounds (as described in MPI 2015).

Seabed condition can be placed along an enrichment gradient which has been quantitatively defined according to Enrichment Stage (ES). The ES assessment references a selection of informative chemical and biological indicator variables.

For each indicator variable (raw data), an equivalent ES score was calculated using previously described relationships (MPI 2015). Average ES scores were then calculated for:

- sediment chemistry variables (redox)
- organic content (% AFDW)
- macrofauna composition variables: abundance (N), total number of taxa (S), Shannon-Weiner diversity index (H'), Pielou's evenness index (J'), Margalef richness index (d) and biotic indices (AMBI, mAMBI and BQI).

The overall ES score for a given sample was then calculated by determining the weighted average of those three groups of variables (see next page for full results).

	Raw data values for each variable/sample										Equivalent ES for raw variables										Indicator group ES			
Station	TOM	Redox	N	S	J'	d	SWDI	AMBI	M-AMBI	BQI	TOM_ES	Redox_ES	N_ES	S_ES	J'_ES	d_ES	SWDI_ES	AMBI_ES	M-AMBI_ES	BQI_ES	Organic Loading	Sediment chemistry	Macrofauna	**Overall ES**
F	3	273	87	27	0.88	6	2.92	2.16	0.73	9.55	1	1.67	1.25	n/c	1.17	2.51	1.8	1.48	2.3	1.61	1	1.67	1.73	1.65
E	4.4	84	74	31	0.9	7	3.09	1.73	0.8	12.93	3	3.37	1.13	n/c	1.07	1.97	1.77	1.04	2	1.5*	3	3.37	1.5	2.02
J	3.1	268	155	40	0.81	8	2.97	1.94	0.81	9.96	1	1.72	1.7	n/c	1.5	1.72	1.79	1.26	1.95	1.59	1	1.72	1.64	1.59
C	3.2	128	236	37	0.74	7	2.66	2.89	0.7	7.72	1	2.98	2.02	n/c	1.84	2.13	1.9	2.23	2.48	1.93	1	2.98	2.07	2.15
I	2.4	333	171	41	0.84	8	3.1	2.56	0.79	8.66	1*	1.13	1.77	n/c	1.36	1.71	1.76	1.89	2.04	1.72	1	1.13	1.75	1.55
R	2.9	325	50	14	0.8	3	2.1	1.38	0.63	7.53	1*	1.2	0.83	4.24	1.55	4.03	2.29	0.69	2.84	1.98	1	1.2	2.31	1.96
A	4.1	174	122	43	0.87	9	3.26	2.12	0.85	12.86	3	2.56	1.51	n/c	1.22	1.57	1.76	1.44	1.85	1.5*	3	2.56	1.55	1.9
P	3.2	127	171	43	0.89	8	3.35	2.17	0.85	10.34	1	2.99	1.77	n/c	1.12	1.63	1.76	1.49	1.84	1.59	1	2.99	1.6	1.82
K	3.9	171	158	37	0.87	7	3.14	2.3	0.79	9.34	2	2.59	1.71	n/c	1.22	1.91	1.76	1.63	2.03	1.63	2	2.59	1.7	1.91
O	2.8	329	193	31	0.83	6	2.86	2.09	0.75	10.09	1*	1.17	1.87	n/c	1.41	2.57	1.82	1.41	2.21	1.59	1	1.17	1.84	1.62
N	3.4	112	159	38	0.84	7	3.05	1.4	0.85	9.55	1	3.12	1.72	n/c	1.36	1.85	1.77	0.71	1.84	1.61	1	3.12	1.55	1.81
G	4.1	162	56	23	0.89	5	2.79	1.75	0.73	12.31	3	2.67	0.92	n/c	1.12	2.7	1.84	1.06	2.32	1.5*	3	2.67	1.64	1.98
Q	2.7	231	293	59	0.85	10	3.47	1.81	0.97	11.11	1*	2.05	2.18	n/c	1.31	1.5*	1.78	1.13	1.75	1.63	1	2.05	1.61	1.64
H	2.5	286	61	19	0.93	4	2.75	1.77	0.7	8.66	1*	1.55	0.98	3.9	0.93	3.36	1.86	1.08	2.45	1.72	1	1.55	2.03	1.84
T	3.5	265	82	27	0.91	6	2.99	1.92	0.76	10.14	2	1.74	1.21	n/c	1.02	2.46	1.78	1.24	2.18	1.59	2	1.74	1.64	1.7
S	3.6	297	174	41	0.85	8	3.16	2.41	0.81	8.66	2	1.46	1.79	n/c	1.31	1.72	1.76	1.73	1.98	1.72	2	1.46	1.71	1.69
D	4.5	117	170	39	0.81	7	2.98	2.09	0.8	12.26	3	3.08	1.77	n/c	1.5	1.81	1.78	1.41	2	1.5*	3	3.08	1.68	2.09
L	2.8	126	78	33	0.89	7	3.1	2.08	0.78	9.55	1*	3	1.17	n/c	1.12	1.83	1.76	1.4	2.06	1.61	1	3	1.57	1.79
U	3.1	328	129	39	0.86	8	3.17	1.77	0.84	10.79	1	1.18	1.56	n/c	1.26	1.7	1.76	1.08	1.86	1.61	1	1.18	1.55	1.42
B	4.3	154	44	17	0.87	4	2.46	1.79	0.66	9.51	3	2.74	0.73	4.04	1.22	3.45	2.01	1.1	2.69	1.62	3	2.74	2.11	2.32
M	4	322	60	24	0.91	6	2.89	1.37	0.77	9.72	3	1.23	0.97	n/c	1.02	2.62	1.81	0.68	2.12	1.6	3	1.23	1.54	1.63
																				Variable group weightings to calculate overall ES:	**0.1**	**0.2**	**0.7**	

No sulphide samples were taken (i.e. sediment chemisty was derived only from redox)

Appendix 5. Infauna count data by sample, from the least to the most dominant taxa.

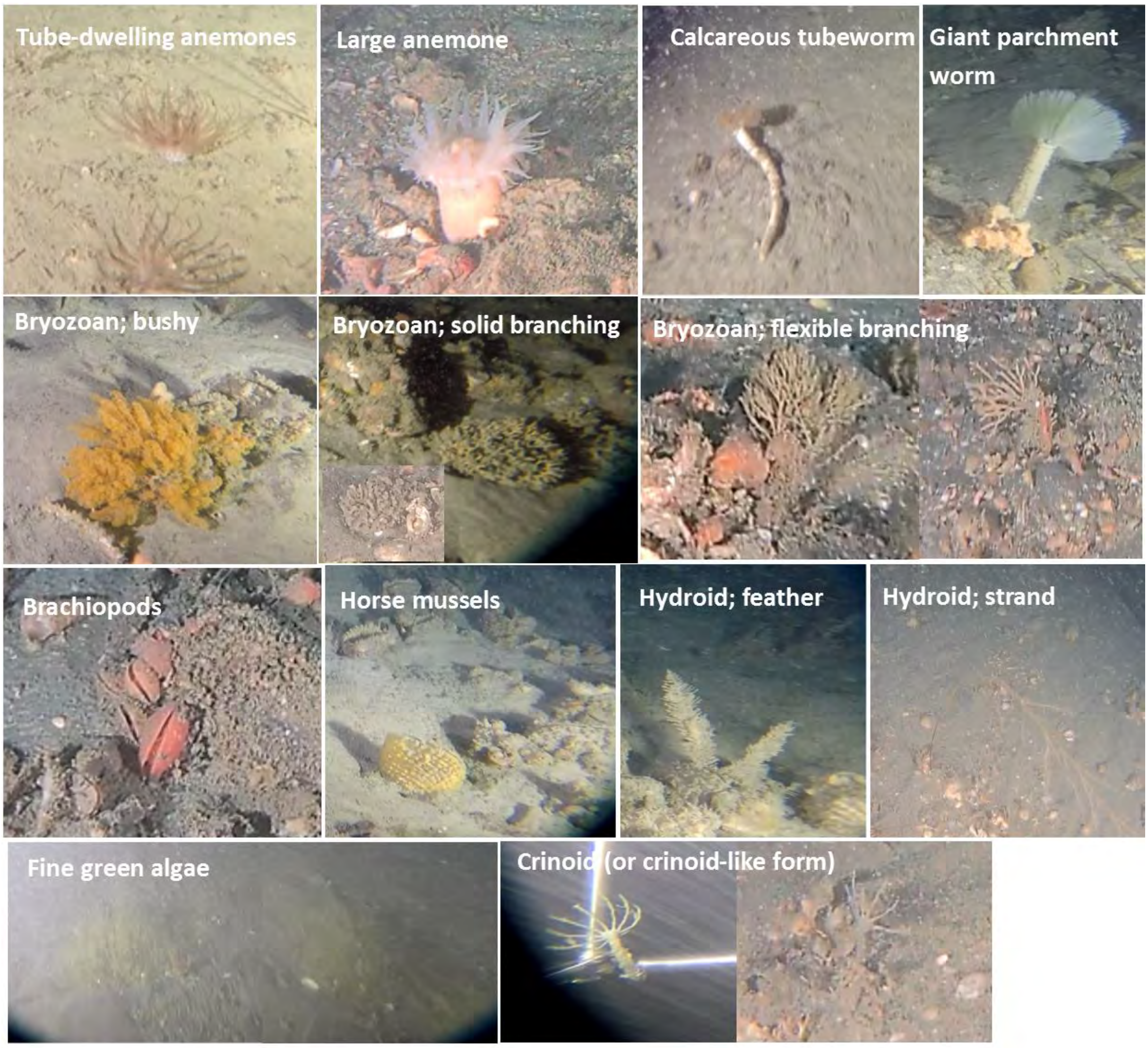
Taxa	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	avg. abund.	rel. abund. (%)
Total abundance	122	44	236	170	74	87	56	61	171	155	158	78	60	159	193	171	293	50	174	82	129		
Taxa richness	43	17	37	39	31	27	23	19	41	40	37	33	24	38	31	43	59	14	41	27	39		
Paraonidae	9	1	29	13	6	11	4	3	16	30	17	13	7	24	2	16	10	19	11	8	23	13.0	10%
Nematoda	2	1	79	2	1	3		2	32	4	15	6	2	3	4	21	21		23	7	6	12.3	9%
Amphipoda		2	15	2	3	9	3	4	3	28	12	3	2	21	11	3	4	7	28	6	14	9.0	7%
Ophiuroidea	3	2	11	1		2	1	5	9	8	9		4	7	33	12	47	5	6	5	5	9.2	6%
Cirratulidae	9	8	9	6	5	9	3	6	15	11	8	8	7	8	9	5	8	3	4	7	5	7.3	6%
Ampharetidae	3	1	6	9	1	11		10	4	10	13	7		9		7	1	1	14	6	12	6.9	5%
Prionospio sp.	1		11	2	1	4		4	7	6	5			5	16	5	11	4	7	4	4	5.7	4%
Maldanidae			4	30	2			1	2	1	1	4	3	7	2	9	24		1	2	3	6.0	4%
Cumacea	6	10	5	12	1	6	9			6	5		3	1		4		2	7	8	4	5.6	3%
Spiophanes kroyeri	22	5		18	12	5	10	2			1	1								5	6	7.9	3%
Lumbrineridae	6	1	6	3	3	1	1		5	1	7	2		1	19	6	10	2	8		2	4.7	3%
Oligochaeta	1		8			3			13	4	12	3		2		3	6		4	1	2	4.8	2%
Syllidae	4		4	4		1			10	2	5		1	6	6	5	11		2			4.7	2%
Pholoidae								3		2		2		1	18	11	4		4		4	5.4	2%
Aricidea sp.			1		1			2	4	2	1			8	15	3	3		3	2	3	3.7	2%
Dorvilleidae			1	23					2	1				1		3	11		2			5.5	2%
Exogoninae	1		11			1			5	2	9	1		1		4	3		3	1	1	3.3	2%
Nemertea	6	2	3	2		2			1	3	2			5		2	6		2		1	2.8	1%
Sabellidae						2			1	3		2		17		3	1	1	5	1	1	3.4	1%
Ostracoda	1		1		4		1	3	1	1	1	1	1		2	5	6		1		2	2.1	1%
Tanaidacea			3	1	1	1		6	2		4		1	2	4				2	1	2	2.3	1%
Sipuncula				3			1		2	1	3	2	8		1	2		1	1	2	3	2.3	1%
Terebellidae	1		2	1	2	1		2	5	1	1			3		2	4		2		2	2.1	1%
Pratulum pulchellum	2		1						2	4	1	1	3	1		2			2	2	2	1.9	1%
Aglaophamus sp.			2	4	2		1	2	2	1	1		2					1		4		2.0	1%
Goniadidae			2	1		2	1		1		1	3	4			3	1	2			1	1.8	1%
Phoxocephalidae	1		1						4	2	1		1			5	4		1		1	2.1	1%
Anthuridae									1	2	2			6	2		7				1	3.0	1%
Aoridae	7	3															9					6.3	1%
Capitella sp.															18							18.0	1%
Paraprionospio sp.					1			2		4	3	2				1			5			2.6	1%
Macrochaeta sp.			2									2		1	8		3					3.2	1%
Nuculidae					2	1	2				1	1	1						5	2	1	1.8	1%
Corbula zelandica				1										1	2	4	6		1			2.5	1%
Flabelligeridae	2			1	1	2								3	1	5						2.1	1%
Cossura consimilis	1		2	2	7							1									1	2.3	1%
Bivalvia				1								1	1	1	2	1	1		3			1.4	0%

Taxa	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	avg. abund.	rel. abund. (%)
Total abundance	122	44	236	170	74	87	56	61	171	155	158	78	60	159	193	171	293	50	174	82	129		
Taxa richness	43	17	37	39	31	27	23	19	41	40	37	33	24	38	31	43	59	14	41	27	39		
Caprellidae	1			1		1											6		2			2.2	0%
Glyceridae										1	2			1	2	1	2			1	1	1.4	0%
Leptochiton inquinatus															2	4	3				2	2.8	0%
Cadulus teliger				4			2			1		1	1							1		1.7	0%
Poroleda lanceolata	2			2	4							1	1									2.0	0%
Scutopus ventrolineatus				1					1	1		1		2			1		3			1.4	0%
Pycnogonida			1									1			2		5					2.3	0%
Bryozoa	1	1							1		1			1	1		1		1			1.0	0%
Chrysopetalidae																	8					8.0	0%
Hesionidae											2			1		1	3		1			1.6	0%
Tawera spissa																	8					8.0	0%
Spio sp.	1		2						1	1		1									1	1.2	0%
Copepoda			5										1						1			2.3	0%
Euphilomedes sp.		1							1						2		3					1.8	0%
Sigalionidae					1		4										1	1				1.8	0%
Cossuridae							3											1	1	1		1.5	0%
Isopoda	2															1	1				2	1.5	0%
Myriochele sp.				3					1							2						2.0	0%
Notomastus sp.	1			4	1																	2.0	0%
Paraprionospio coora	2					3			1													2.0	0%
Phyllodocidae					2			1				1					1		1			1.2	0%
Pleuromeris paucicostata										1			3								2	2.0	0%
Polynoidae											6											6.0	0%
Sigapatella tenuis	5											1										3.0	0%
Terebellides narribri											1			2					2	1		1.5	0%
Travisia sp.									5							1						3.0	0%
Asellota			1							1					3							1.7	0%
Ampelisca sp.								2		1	1										1	1.3	0%
Nucinella maoriana				1	2					1			1									1.3	0%
Nebaliacea	2		1	1																		1.3	0%
Spionidae			1	1							1			1								1.0	0%
Axiopsis sp.	1				1	1	1															1.0	0%
Gastropoda (micro snails)		1			2															1		1.3	0%
Hydrozoa											1						1		1	1		1.0	0%
Maoricolpus roseus roseus				4																		4.0	0%
Munnidae							2							1			1					1.3	0%
Purpurocardia purpurata									1					1			1			1		1.0	0%
Saccella maxwelli					1		1				1										1	1.0	0%
Salpidae																	4					4.0	0%
Sternaspis scutata	1	1					2															1.3	0%
Sycon sp.					1												3					2.0	0%
Neolepton sp.			1			1															1	1.0	0%
Pectinidae	1		1														1					1.0	0%
Arthritica bifurca					1							1							1			1.0	0%
Brachiopoda	1																1		1			1.0	0%
Capitellidae	1			1								1										1.0	0%
Cypridinodes sp.										1											2	1.5	0%

Taxa	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	avg. abund.	rel. abund. (%)
Total abundance	122	44	236	170	74	87	56	61	171	155	158	78	60	159	193	171	293	50	174	82	129		
Taxa richness	43	17	37	39	31	27	23	19	41	40	37	33	24	38	31	43	59	14	41	27	39		
Diasterope grisea	1						1			1												1.0	0%
Melliteryx parva		3																				3.0	0%
Onuphis aucklandensis	3																					3.0	0%
Opheliidae				1		2																1.5	0%
Pilargidae				1					1					1								1.0	0%
Priapulida	2			1																		1.5	0%
Valvifera																1				1	1	1.0	0%
Nucula nitidula			1														1					1.0	0%
Polyplacophora			1											1								1.0	0%
Acrocirridae															2							2.0	0%
Ascidian (solitary)															1	1						1.0	0%
Halicarcinus sp.									2													2.0	0%
Halicarcinus tongi												1				1						1.0	0%
Lysidice sp.																	2					2.0	0%
Mussel Spat							1														1	1.0	0%
Owenia petersenae																					2	2.0	0%
Oweniidae						1					1											1.0	0%
Pleuromeris zelandica										2												2.0	0%
Sabellariidae																	2					2.0	0%
Scalibregma inflatum																	2					2.0	0%
Spiophanes modestus									2													2.0	0%
Taeniogyrus dendyi		1				1																1.0	0%
Chaetopteridae			1																			1.0	0%
Polychaeta Unid.			1																			1.0	0%
Aphroditidae					1																	1.0	0%
Appendicularia									1													1.0	0%
Armandia maculata	1																					1.0	0%
Asteroidea																1						1.0	0%
Barantolla lepte								1														1.0	0%
Cliona celata																	1					1.0	0%
Cuspidariidae	1																					1.0	0%
Cypridinodes reticulata																	1					1.0	0%
Dosinia sp.																	1					1.0	0%
Ebalia laevis																			1			1.0	0%
Echiura																1						1.0	0%
Ennucula strangei				1																		1.0	0%
Euchone sp.									1													1.0	0%
Euphrosinidae																1						1.0	0%
Gnathiidae												1										1.0	0%
Halicarcinus cookii										1												1.0	0%
Haustoriidae													1									1.0	0%
Hiatella arctica	1																					1.0	0%

Taxa	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	avg. abund.	rel. abund. (%)
Total abundance	122	44	236	170	74	87	56	61	171	155	158	78	60	159	193	171	293	50	174	82	129		
Taxa richness	43	17	37	39	31	27	23	19	41	40	37	33	24	38	31	43	59	14	41	27	39		
Leitoscoloplos sp.									1													1.0	0%
Leuroleberis zealandica																1						1.0	0%
Limaria orientalis																	1					1.0	0%
Maxacteon sp.					1																	1.0	0%
Mysidacea																1						1.0	0%
Natatolana sp.																			1			1.0	0%
Naticidae							1															1.0	0%
Nereididae (juvenile)																1						1.0	0%
Notoacmea sp.															1							1.0	0%
Notomithrax minor				1																		1.0	0%
Nuculanidae										1												1.0	0%
Opisthobranchia Unid.	1																					1.0	0%
Orbiniidae									1													1.0	0%
Phyllochaetopterus sp.																	1					1.0	0%
Pista sp.																	1					1.0	0%
Prionospio aucklandica														1								1.0	0%
Prionospio multicristata																	1					1.0	0%
Serpulidae															1							1.0	0%
Serratina charlottae																	1					1.0	0%
Sigapatella sp.																	1					1.0	0%
Spirorbidae	1																					1.0	0%
Talochlamys sp.									1													1.0	0%
Tanea sp.							1															1.0	0%
Terebratella sanguinea	1																					1.0	0%
Theora lubrica										1												1.0	0%
Thyasiridae												1										1.0	0%
Trachyleberis lytteltonensis													1									1.0	0%
Trochochaeta sp.														1								1.0	0%
Upogebia danai															1							1.0	0%

Appendix 6. Representative images of taxa referenced in the epifaunal community descriptions, as described from video footage.



Appendix 7. Methods for calculating near seabed wave velocities.

Solving the Laplace equation subject to the kinematic boundary conditions yields the following expression for the horizontal velocity component of a surface gravity wave at depth z:

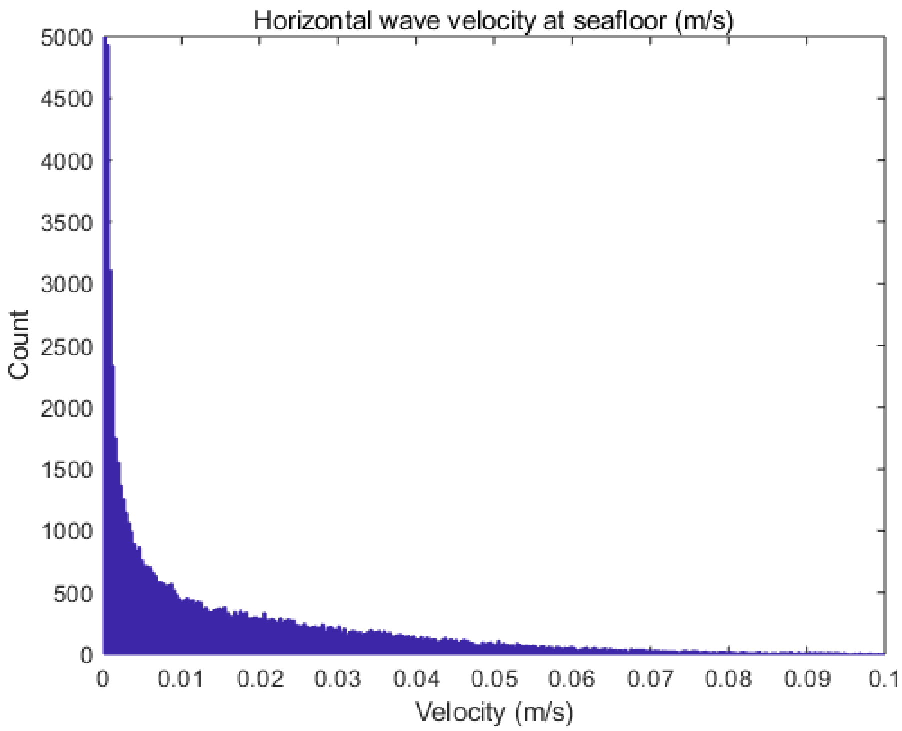
$$u = a\omega \frac{\cosh[k(z+H)]}{\sinh kH} \cos(kx - \omega t) \qquad \text{(Eq. A1)}$$

Where a is the amplitude which we take to be half the significant wave height, ω is the waves angular frequency, $k = 2\pi/\lambda$ is the wave number (λ is the wavelength), and H is the total water depth.

Taking only the amplitude of Eq. A1, at the seafloor (e.g. $z = -H$) yields:

$$u_{\text{max, (z=-H)}} = \frac{a\omega}{\sinh kH} \qquad \text{(Eq A2)}$$

The distribution of maximum seabed velocities calculated from the hindcast data is shown below. Full model description and locations of the wave model data points and field sampling station are provided in Newcombe et al. (2019).



Appendix 8. ADCP deployment and results summaries. Full details can be found in Newcombe et al. 2019.

Table A8.1. Summary of the ADCP data deployments (locations also shown in Figure 2).

ADCP	Upwards ADCP (Sentinel)	Downwards ADCP (Buoy)
Latitude	40.90 ° S	40.92 ° S
Longitude	174.26 ° E	174.24 ° E
Deployment start	5 October 2018	14 October 2018
Deployment end	9 January 2019	26 February 2019
Depth at deployment	92 m	67 m
Bin size	3 m	2 m
Burst frequency	1 Hz	4 Hz
Averaging interval	3 minutes	3 minutes
Sampling frequency	30 minutes	30 minutes
Sampling depths (m below MSL)		
Near surface depth	15	4
Mid depth	42	30
Near seabed depth	87	58
Total depth at site	92	67

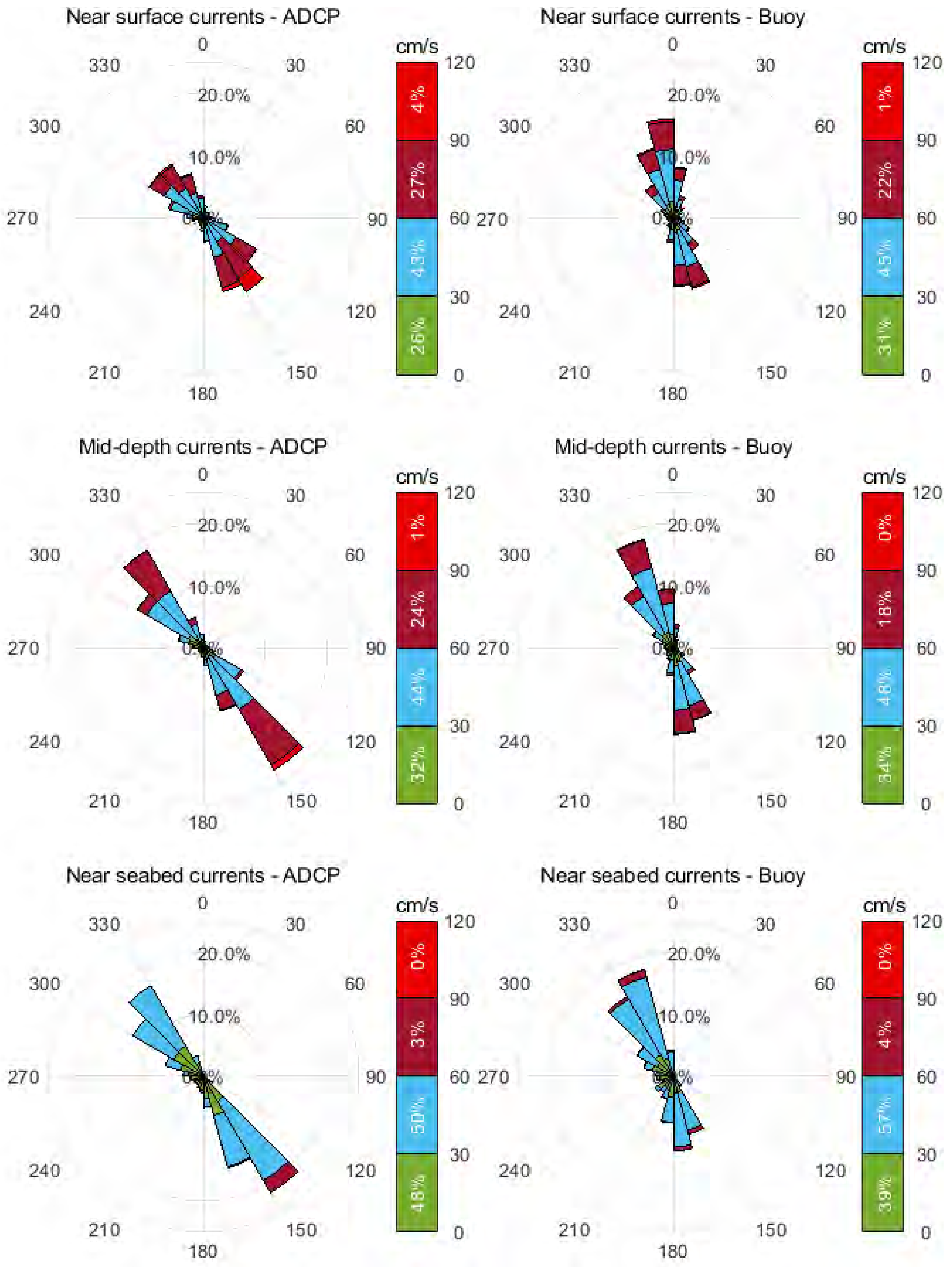


Figure A8.1. Measured current data from the upwards facing ADCP (left) and downward facing ADCP (right) at near-surface, mid-depth and near-seafloor elevations. The directions are in the 'going to' sense; that is, currents at 90 degrees in the rose plot would be travelling from west to east. The white numbers within the colour bars give the percentage of time that current velocities are within that range. For example, mid-depth current speeds exceed 90 cm/s 1% of the time.

Appendix 9. Method used for modelling deposition using SMTOMOD (solid material transport (offshore) model), and for approximating the equivalent ES for different solids flux levels. Full model description and validation against DEPOMOD can be found in Smeaton & Vennell (2019-draft).

A double spring/neap cycle was taken from data measured using an upwards facing ADCP (see Newcombe et al. 2019, Appendix 8, and Figure 2) and replicated once to create a depth-varying velocity time series of four spring/neap cycles. This time series was then used to represent currents throughout the model domain. The upper 10 m of current data showed a high degree of noise and was removed. Velocity values recorded at 10 m depth were used to fill in this removed data. Similarly, the deepest velocity recorded (6.5 m above the seabed) was used to represent velocities below this point. That is, velocities were assumed to be constant in the upper 10 m and lowest 6.5 m of the water column. Vertical and horizontal dispersion coefficients were assumed to be constant throughout the velocity field with values of $D_v = 0.001$ and $D_H = 0.1$, respectively.

Model particles were released from depths of -35 m to the sea surface at 2 m intervals e.g. z_0 = [-35:2:-1]. At each release depth, particles were released at random locations within the circular pens' perimeter of radius R:

$$\mathbf{x}_0 = \mathbf{x}_C + (\text{rand}\, R \cos[\text{rand}\, 2\pi]\,, \text{rand}\, R\ \sin[\text{rand}\, 2\pi], z_0), \quad \text{rand} \in [0,1].$$

Here, $\mathbf{x}_0$ is the particle release point and $\mathbf{x}_C$ is the pen's centre. Two particles were released every 15 minutes from each pen—one particle representing wasted food, and one particle representing faeces[12]. Sinking velocities of 0.032 m/s and 0.095 m/s were used for faeces and food pellets respectively (Cromey et al. 2002). Once released, particles drifted according to the velocity field and their paths were modelled using a fourth order Runge-Kutta solver in MATLAB with a time step of Δt = 30 seconds. At each time step, a random walk adjustment was applied to account for turbulent effects such that the final particle position ($\mathbf{x}_f$) differed from the initially calculated position ($\mathbf{x}_i$) by:

$$\mathbf{x}_f = \mathbf{x}_i + \left(\text{randn}\sqrt{6\,\Delta t\, D_H}\,, \text{randn}\sqrt{6\,\Delta t\, D_H}\,, \text{randn}\sqrt{6\,\Delta t\, D_v}\,\right)$$

Where randn is a random number drawn from a normal Gaussian distribution between values of -1 and 1. Once the random walk adjustment was made, particle depths were checked against local bathymetry data, if the particle depth was equal to or deeper than the total depth at the particle's *x-y* location, the particle was removed from the simulation.

[12] The number of particles released was reduced for these model runs to decrease the model runtime. Additional modelling should use higher numbers of released particles.

Upon completion of the particle tracking simulation, particles were assigned a total mass and carbon mass value according to whether they were representative of food or faeces, using values given in Table A9.1. Particles were then binned into a 10 m by 10 m grid and the daily flux of each bin was calculated. Mean flux was calculated by averaging over the final three spring/neap cycles of the simulation.

Table A9.1. Input values used for depositional modelling.

Parameter	Value
[1]Food wasted as % of food fed, f_w	3%
[1]Water content of feed, f_{H2O}	9%
[1]Digestibility, f_d	85%
[1]Carbon % of food pellets (dry weight)	49%
[1]Carbon % of faeces (dry weight)	30%
200 m Circumference pens	
Feed Input, $\dot{M}_{in}$	5480 kg/pen/ day (2,000 tonnes per year)
Food flux to seabed (solids/**carbon**) $\dot{m}_{food} = \dot{M}_{in}(1 - f_{H2O})f_w$	149.6 kg/pen/ day **73.3 kgC/pen/day**
Faecal flux to seabed (solids/**carbon**) $\dot{m}_{faeces} = \dot{M}_{in}(1 - f_{H2O})(1 - f_w)(1 - f_d)$	725.6 kg/pen/day **217.7 kgC/pen/day**
150 m Circumference pens	
Feed Input, $\dot{M}_{in}$	1370 kg/pen/day (500 tonnes per year)
Food flux to seabed (solids/**carbon**) $\dot{m}_{food} = \dot{M}_{in}(1 - f_{H2O})f_w$	37.4 kg/pen/day **18.3 kgC/pen/day**
Faecal flux to seabed (solids/**carbon**) $\dot{m}_{faeces} = \dot{M}_{in}(1 - f_{H2O})(1 - f_w)(1 - f_d)$	181.4 kg/pen/day **54.4 kgC/pen/day**

[1] values taken from Cromey et al. (2002)

Approximate Enrichment State calculation

Enrichment stage scores were approximated for different solids flux levels (Table A9.2) according to Keeley et al. (2013b), based on the average flux rate from the four time series scenarios (feed loadings) modelled for a dispersive site. Because the relationship between predicted depositional flux and enrichment effects will vary depending on site characteristics and feed load distribution over time, the values should be used as a guide, rather than hard and fast thresholds.

Table A9.2. Solids flux levels and corresponding Enrichment Stage score approximated from Keeley et al. (2013b) for dispersive sites.

Solids flux (kg m^2 yr)	1	2	3	4	5	6	7	8	9
Approximated Enrichment Stage	3.0	3.3	3.6	3.8	3.9	4.1	4.2	4.3	4.4

Appendix 10. Depositional footprint – spatial extent and intensity.

The predicted intensity of deposition in the primary footprint has been determined for a range of farming scenarios (low intensity to high intensity), and pen configurations (small to large pen sizes and small to large spacings) across different parts of the proposal area (Table A10.1). The feed loadings per pen were based on the upper limits of operational feasibility with the exception of scenario 2b, as advised by NZ King Salmon. See Section 3.2.2 for further background and detail regarding the modelling approach.

The scenarios set out to answer the following questions:

1. Does the depositional footprint change much over the proposal area? *This is answered in Scenario 1—which looks at the same pen layouts at multiple locations across the area (Figure A10.2).*
2. How does footprint intensity change with increasing pen size, changing block configurations and increasing feed throughput? *This is answered in Scenario 2—which looks at different block layouts, and different pen size and feed throughputs (Figure A10.3).*
3. How does depositional intensity change with differences in footprint overlap? *This is answered in Scenario 3—which looks at the same block layouts, but decreasing spacing between blocks and increasing number of blocks along the main flow axis (Appendix 4).*

Scenario 4 is discussed in full in Section 3.2.2.

Table A10.1. Farming scenarios and summary of results for depositional modelling. The 'primary footprint' is defined as enrichment that is likely to be discernible using indicators used for routine monitoring (e.g. in MPI 2015). Circ. = circumference, ES = Enrichment Stage.

SCENARIO DESCRIPTION						RESULTS (PRIMARY FOOTPRINT)					TOTAL FOOTPRINT
Scenario name	# pens per block	# blocks	Block config.	Pen size (circ., m)	Distance b/w blocks (m)	Feed (mt/pen/yr)	Width* (m)	Length** (m)	Max flux (kg solids/ m^2/yr)	Max ES^π	Total area (ha)	Total area (ha)
Influence of bathymetry												
1a	10	1	2x5	200	n/a	2,000	854	2735	4.68	3.9	135	388
1b	10	1	2x5	200	n/a	2,000	875	3354	3.24	3.6	140	427
1c	10	1	2x5	200	n/a	2,000	891	2555	4.58	3.9	120	368
1d	10	1	2x5	200	n/a	2,000	907	3584	3.00	3.6	139	447
Influence of farming intensity and pen arrangements												
2a	12	1	3x4	200	n/a	2,000	844	3547	3.99	3.8	160	402
2b	12	1	3x4	150	n/a	500	0	0	0.97	3.0	0	402
2c	10	1	2x5	200	n/a	2,000	862	3273	2.87	3.6	145	428
Footprint overlaps												
3a	10	2	2x5	200	1000	2,000	977	4396	4.95	3.9	251	545
3b	10	2	2x5	200	500	2,000	952	4005	5.58	4.1	234	505
3c	10	3	2x5	200	500	2,000	1029	4646	7.41	4.2	295	574
3d	10	4	2x5	200	500	2,000	1140	5250	9.00	4.4	348	658
Initial proposed production level (discussed in full in Section 3.3)												
4	8	2	2x4	150	500	1,250	663	3271	2.56	3.4	139	535

* perpendicular to current flow ^π^See Appendix 7 for how this was calculated.
** parallel to current flow

Results and discussion

Some of the pen technology currently being considered can grow up to 1,000 tonnes of salmon per year. A 10,000-tonne production scenario could be achieved by using 10 pens, which is the highest number of pens that one barge could realistically service (Mark Gillard, NZ King Salmon; pers. comm.). Accordingly, as an indication of an upper-limit for a single farm block, a 10-pen, 10,000-tonne production scenario is one of the primary farming scenarios modelled in this assessment.

Footprints are depicted as 'additional' solids flux to the seabed, with the **'primary footprint'** defined as enrichment that is likely to be discernible using indicators[13] used for routine monitoring (e.g. in MPI 2015). The primary footprint is shown in each plot as a dashed line overlaid on the total footprint (using no resuspension). We do note that at such a dispersive site, enrichment may become discernible at a lower level, thus the **'total footprint'** area should also be considered.

[13] Organic matter, sediment sulphides, redox potential, and macrofaunal community measures.

To aid in interpretation, the seabed solids flux has also been converted to an approximate 'Enrichment Stage'[14] (the applicability of ES to this site is discussed later in the report). The Enrichment Stage concept represents a succession of changes in sediment chemistry and infaunal biology along a seven-stage enrichment gradient from pristine (ES 1) to highly enriched (ES 5), to azoic (no life present; ES 7). Each enrichment stage can be related to a seabed solids flux level, using relationships published in Keeley et al. (2013b), as we have done in this assessment.

Intensity of deposition

Across all single block scenarios (10–12 pens; scenarios 1a-d and 2a-2c), the maximum footprint intensity ranged from 0.97–4.68 kg solids/m^2/yr (Table A10.1, Figure A10.3 and Figure A10.4), which are equivalent to ~ES 3 and ~ES 3.9, respectively. At the same production level (Scenarios 1a-1d) the maximum footprint intensity changes by only 1.68 kg solids/m^2/yr across the entire area (Table A10.1), with a maximum flux of 4.68 kg solids/m^2/yr. The deposition is most intense in farm blocks located in shallower areas. The maximum intensity of the deposition increases with increasing rows of pens (Scenario 2a; Figure A10.4); a block configuration comprising three rows of four pens reaches 3.8 kg solids/m^2/yr. Smaller pens (150 m circumference), and lower feed throughput (25% of the of the previous scenarios) result in substantially lower maximum flux; 0.97 kg solids/m^2/yr (just under ~ES 3.0; Scenario 2b; Table A10.1).

Maximum footprint intensity increased as more blocks of pens were added along the main flow axis (Scenarios 3a-3d) due to overlapping footprints from different blocks (Figure A10.5). With block spacings of 500 m, two blocks of 10 pens had a combined footprint with a maximum intensity of 4.95 kg solids/m^2/yr (ES 3.9). Three blocks of pens had a maximum of 7.41 kg solids/m^2/yr (ES 4.2) in the combined footprint, and four blocks of pens had a maximum of 9.0 kg solids/m^2/yr (ES 4.4).

Other than reducing feed throughput (which has economic implications), the key considerations for minimising the footprint intensity at this site are avoiding overlapping footprints from multiple pens, or blocks of pens. This can be done by:

- arranging pens in a 'row' perpendicular[15] to the main current axis (which is more or less NE/SW across the site)
- minimising the number of rows in a block of pens
- arranging rows of pens within blocks so that pens are alternately placed from those in the adjacent row
- increasing spacings between pens or blocks, particularly in the NW/SE direction.

[14] Approximated from the equations provided in Keeley et al. (2013b), as an average across all four equations for the dispersive site.

[15] We note there may be engineering constraints associated with this layout.

Spatial extent of deposition

The modelled depositional footprints follow a SE and NW direction, in line with the primary flow axis (Newcombe et al. 2019). Across all single block scenarios (10–12 pens, but not including 2a), the primary footprint size ranged from 2.6–3.6 km (along the primary flow axis), and 844–907 m perpendicular to the primary flow axis.

At the same production level (Scenarios 1a-1d) the footprint length changes by ~500 m across the entire area (Figure A10.2), with a maximum of ~3.6 km. By contrast, the footprint width changes little, generally extending less than 100 m from the pen edge in all scenarios. Feed throughput has a more substantial influence on footprint length (see Scenario 2b) than the extension of the pens in the primary flow directions (see Scenario 2a; Figure A10.3 and Table A10.1). Reducing the feed throughput to 500 mt/pen/yr (25% of the former scenarios) eliminates the primary footprint entirely (Figure A10.3). For this scenario (2a), we note a substantial area of seabed that would be affected instead by low-level (solids flux 0–1 kg/m^2/yr) deposition (also see Figure A10.3).

Footprint length also increased with increasing number of blocks as footprints overlapped. For example, one block of 10 pens (Scenario 2c; Table A10.1) had a footprint totalling 3.3 km, and with the addition of more blocks of pens at 500 m along the primary flow axis, the footprint extends by about 550 m each time (Scenarios 3b-3d; Figure A10.4; Table A10.1).

Outside of the primary footprint in all scenarios, there is a large area subject to low level (0–1 kg solids/m^2/yr) deposition of organic waste from the farms. Resuspension of the material from within the total footprint will result in additional dispersal of waste (see Box 3 in Section #), estimated to be on the order of several km's, beyond the primary footprint.

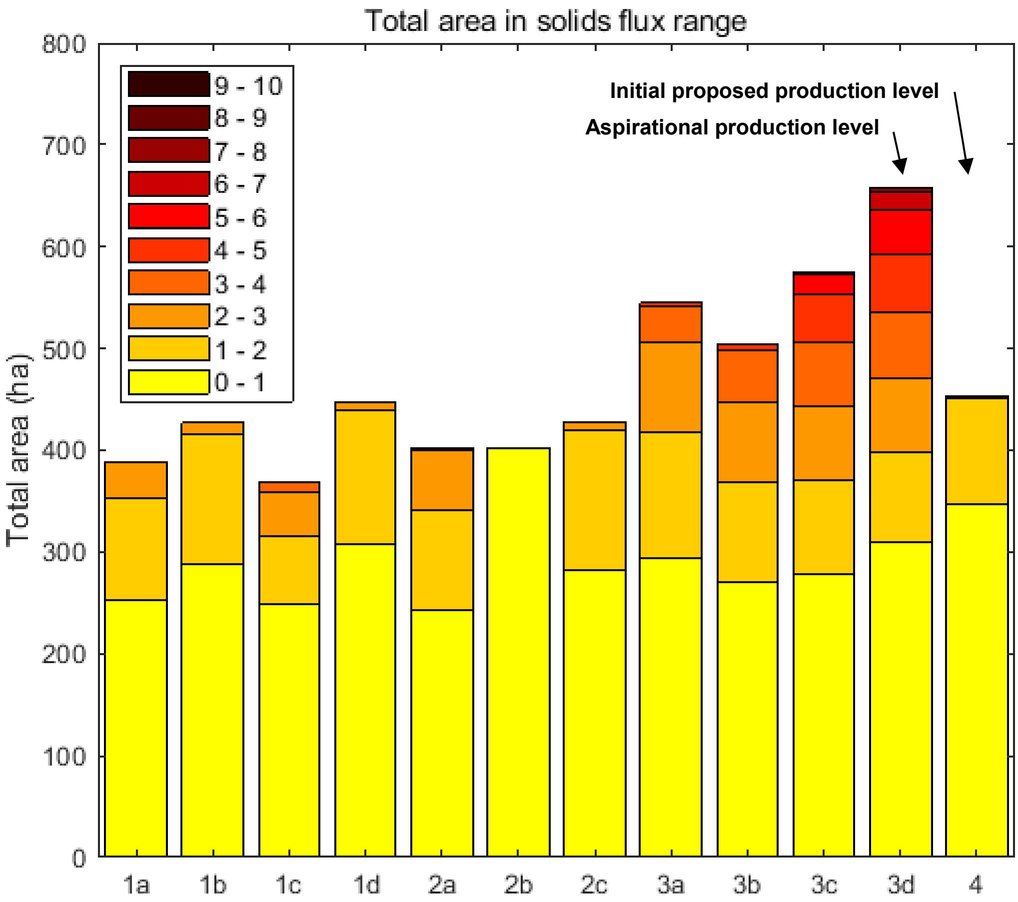


Figure A10.1. Summary of the total area affected by differing amounts of depositional flux (scale shows kg solids/m²/yr) for each of the scenarios modelled in Table A10.1.

Effects on the seabed from organic deposition

Organic enrichment directly beneath finfish farms is usually evaluated via a suite of different 'indicators'. Changes to sediment properties are typically the first effect to show, followed by changes to seabed communities. Environmental impacts on epibiota and infaunal communities will vary considerably depending on the sensitivity of the species to organic deposition, and the extent to which the site is developed (see Section 3.2.2 for further detail).

It follows that, based on Scenario 3d (four farm blocks), major changes to sediment chemistry in the most impacted areas would be expected to the extent that the seabed would be approaching hypoxia (oxygen deficiency). Excessive accumulation of organic waste on the seabed can also result in anoxic conditions in the overlaying water, which can cause oxygen stress to biological communities (particularly epifauna). However, despite the chance of hypoxic sediment conditions with scenario 3d, anoxic conditions in overlying water are unlikely given the well-flushed nature of the site, and the correspondingly low accumulation of organic waste at the modelled feed levels.

The scenarios in this assessment show it is unlikely that the infaunal communities will be impacted to or beyond the 'peak of opportunist' stage (ES 5; Figure 13, Table 1), even directly below the pens. However, if the pens are arranged closely enough together with a high enough feed throughput, this outcome is theoretically possible. It is likely that this will be precluded by operational or practical limitations (e.g. pen spacings, fish health requirements).

Based on the aspirational scenario (3d), which had 40 pens, infaunal communities in the middle of the footprint may experience high enrichment (ES ~ 4.4), and a major change in community composition is expected. Compositional changes will include dominance of opportunistic infauna and displacement of sensitive taxa, but other taxa may still persist. Overall taxa richness will be reduced but there will likely be higher total abundances. This is also likely to result in the displacement of many epifaunal taxa. Outside of the most impacted area, the level of enrichment will improve gradually with increasing distance from the edge of farming area. A substantial part of the footprint will experience moderate enrichment (ES between 3 and 4), where opportunistic taxa are less prevalent (but still may be a dominant component of the infauna), but taxa richness is still reduced. There will also be a substantial area at the footprint margins where infaunal communities experience a 'fertilisation' effect, typically characterised by minor enrichment, flux just under 1 kg solids/m^2/yr, and often discernible as increased overall diversity and total abundances, and altered community composition.

Far-field biological effects (outside of the primary footprint) are more difficult to predict due to the processes of resuspension, diffusion and dilution. In areas such as the large seafloor depressions (north-eastern corner), and high substrate rugosity where particles are less likely to be resuspended (e.g. horse mussel beds, biogenic habitat), there is a higher likelihood of effects from accumulation of organic material. With respect to infaunal communities, mild to moderate enrichment effects may manifest in these areas. Far-field enrichment effects on communities are difficult to discern from natural variation, and even when discernible are also difficult to untangle from other possible sources of enrichment. To date, monitoring has shown no cases of equivocal farm related far-field enrichment in areas adjacent to the Marlborough Sounds salmon farms.

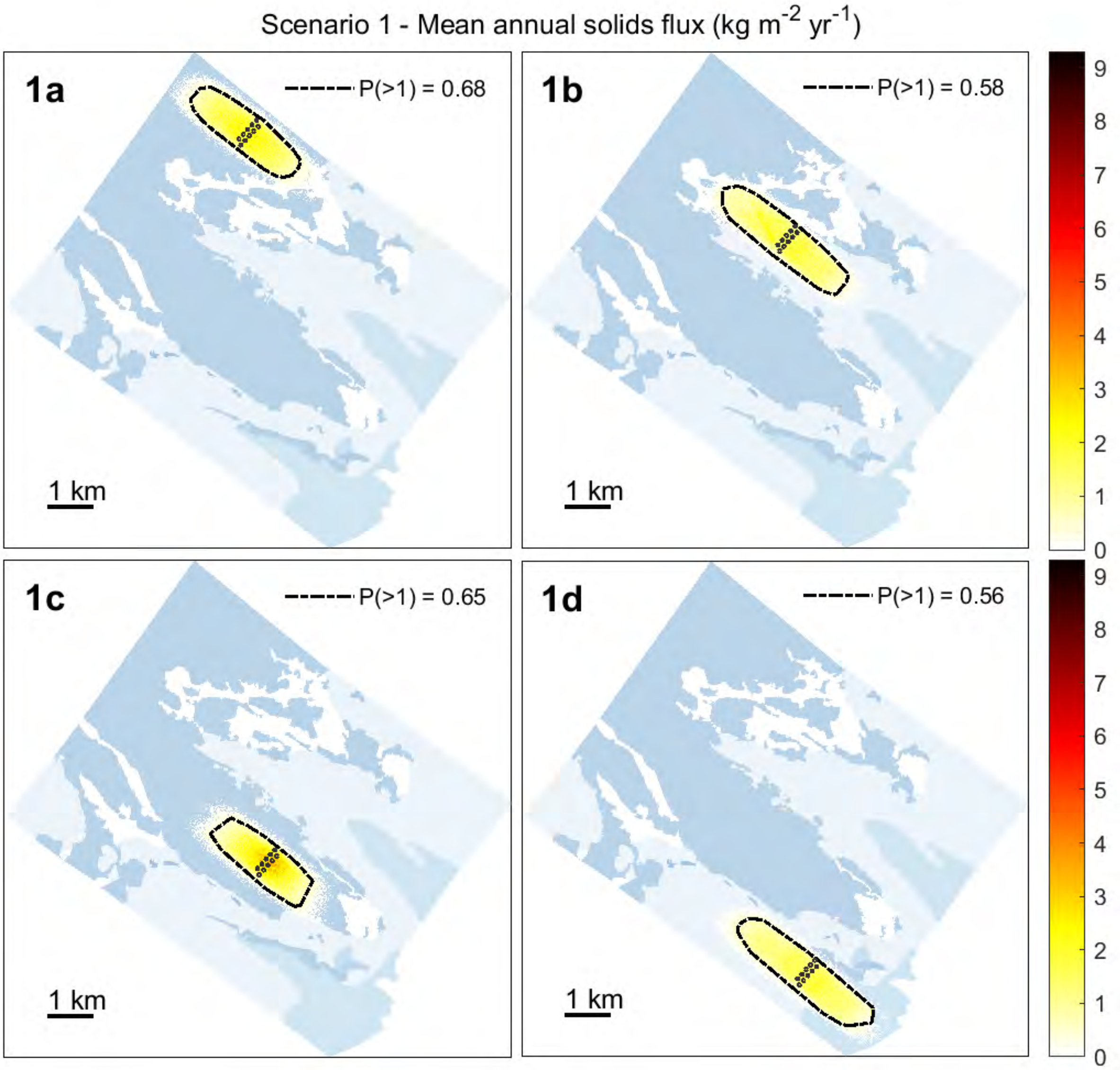


Figure A10.2. Scenario 1 depositional model outputs; multiple locations across the area. The dashed line indicates the boundary of the area where solids flux is > 1 kg/m²/yr. P = the probability of encountering solids flux of > 1 kg/m²/yr within that area. The background delineates the epifaunal strata described in Section 2.5.2. Dark areas contain biogenic habitat.

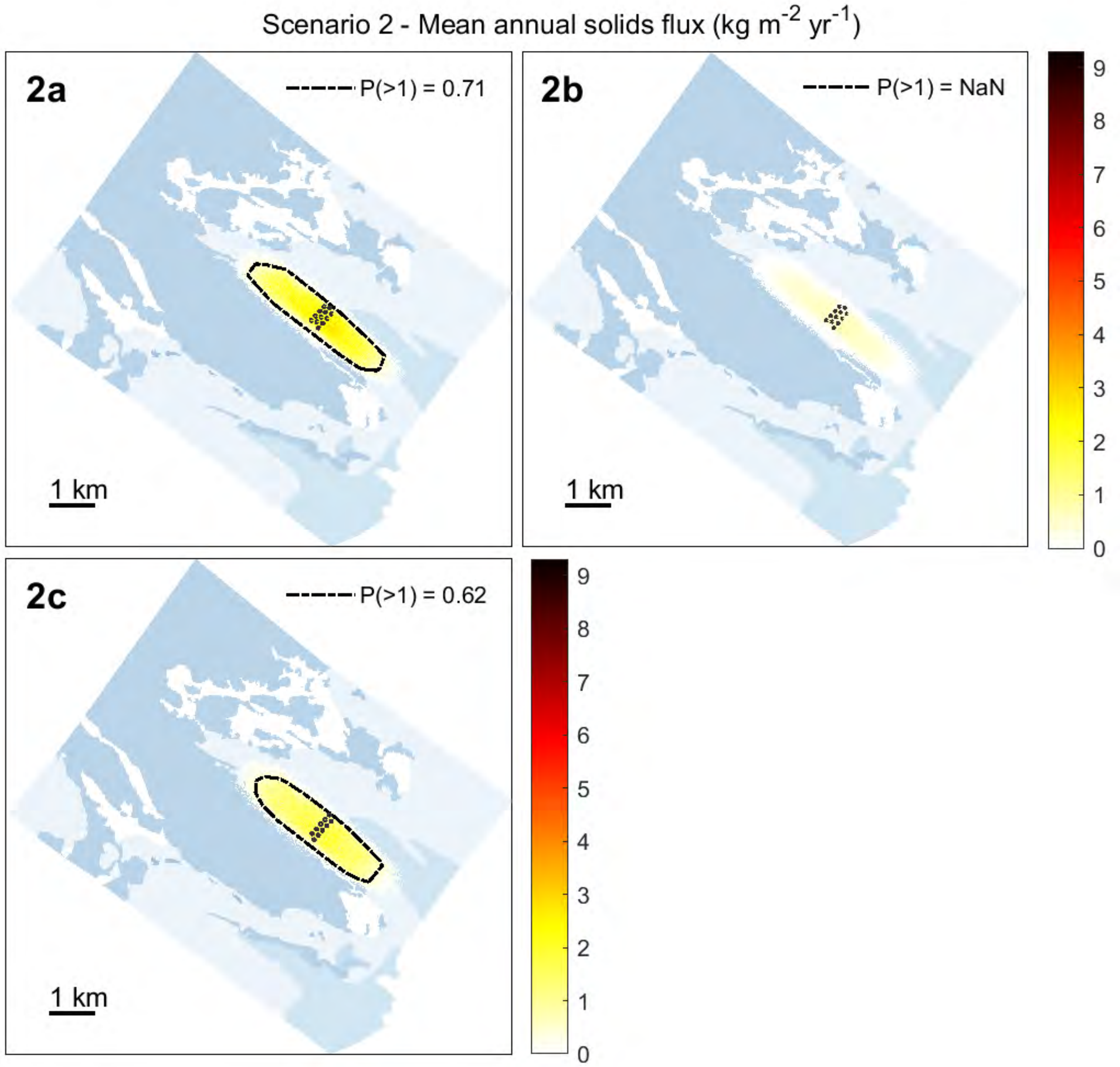


Figure A10.3. Scenario 2 depositional model outputs: different block layouts and different pen size and feed throughputs. The dashed line indicates the boundary of the area where solids flux is > 1 $kg/m^2/yr$. P = the probability of encountering solids flux of > 1 $kg/m^2/yr$ within that area. The background delineates the epifaunal strata described in Section 2.5.2. Dark areas contain biogenic habitat.

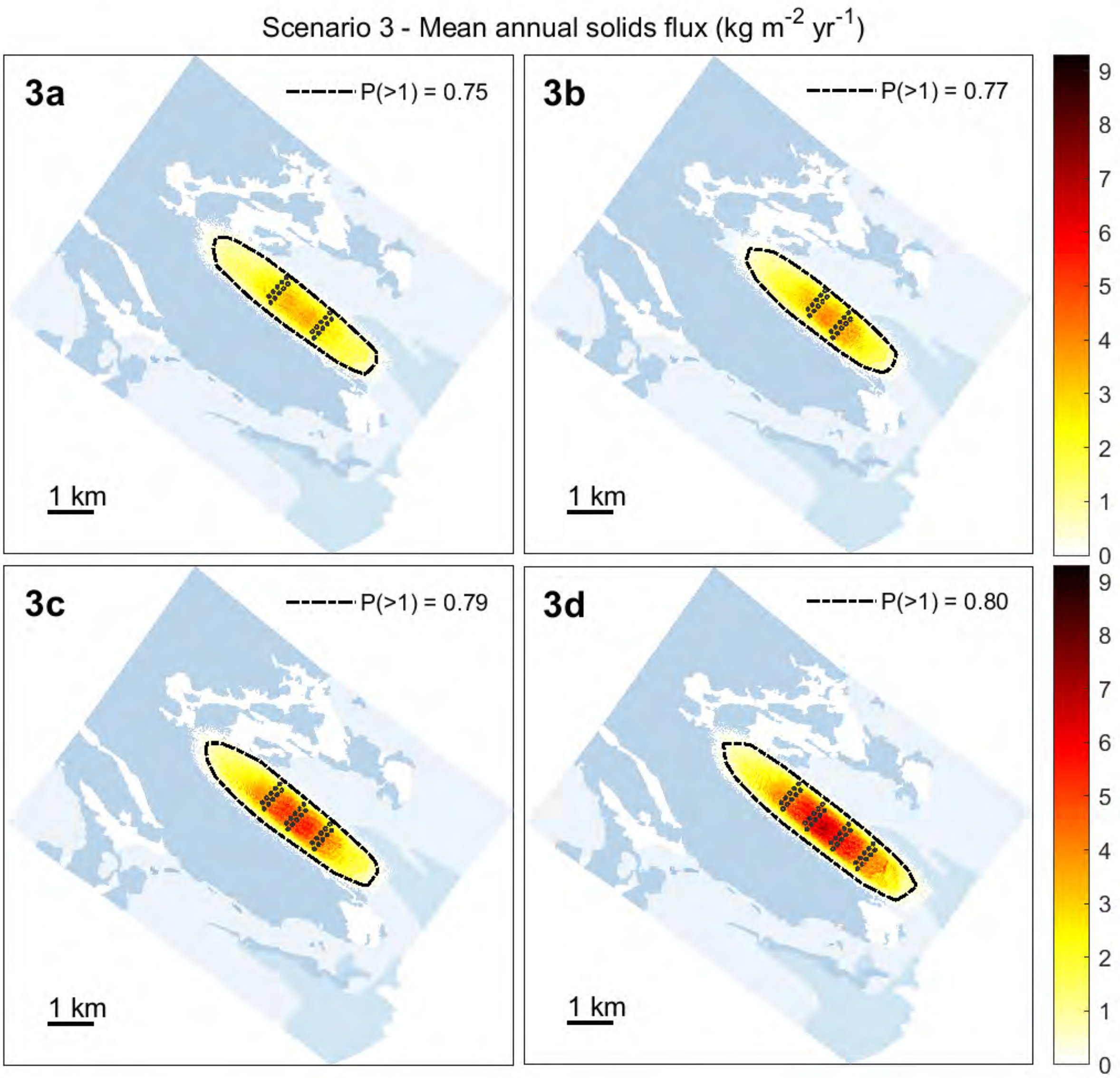


Figure A10.4. Scenario 3 depositional model outputs; same block layouts but increasing footprint overlap. The dashed line indicates the boundary of the area where solids flux is > 1 kg/m²/yr. P = the probability of encountering solids flux of > 1 kg/m²/yr within that area. The background delineates the epifaunal strata described in Section 2.5.2. Dark areas contain biogenic habitat.

APPENDIX E: Water Column Report

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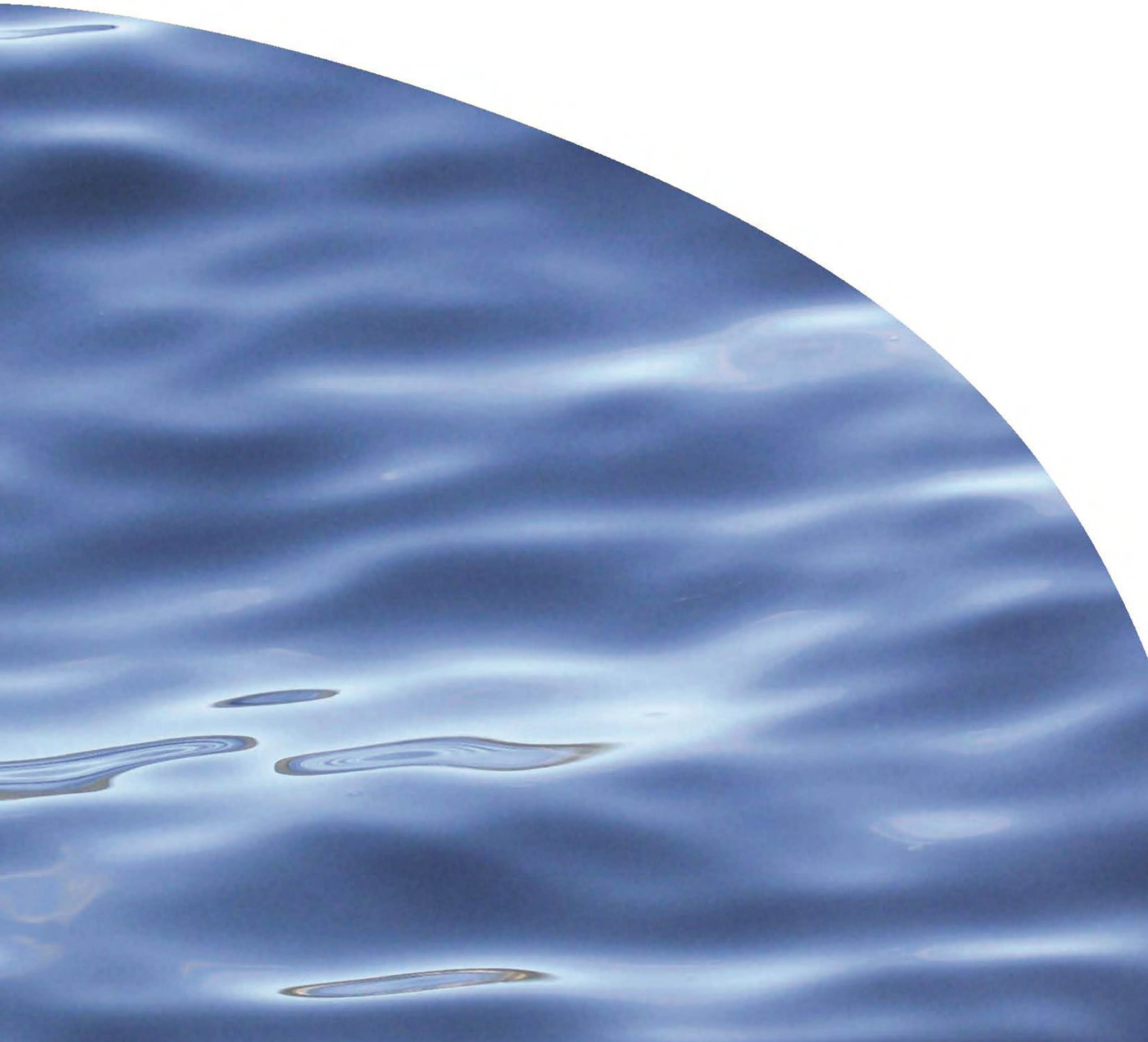
REPORT NO. 3313

WATER COLUMN ASSESSMENT FOR A PROPOSED SALMON FARM OFFSHORE OF THE MARLBOROUGH SOUNDS



WATER COLUMN ASSESSMENT FOR A PROPOSED SALMON FARM OFFSHORE OF THE MARLBOROUGH SOUNDS

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EXECUTIVE SUMMARY

Background

The New Zealand King Salmon Co. Limited (NZ King Salmon) want to develop a salmon farm offshore of the Marlborough Sounds, north of Cape Lambert. The Cawthron Institute was asked to provide a report that characterises the environment within and around the proposed farm area, considers the suitability of the site for salmon farming and assesses the potential effects on the water column arising from the proposal. Specifically, the effects considered in this assessment are:

- depletion of dissolved oxygen (DO) from fish respiration
- nutrient loading associated with the addition of feed and production of fish wastes, and related effects on phytoplankton species abundance and composition
- submerged artificial lighting, particularly effects associated with plankton responses.

Our assessment is largely based on reviews of published literature and draws on knowledge from long-term monitoring of existing salmon farms in the Marlborough Sounds. To improve our understanding of the local water column environment, we carried out field surveys comprising deployment of Acoustic Doppler Current Profilers (ADCPs), measurements of salinity, temperature, turbidity, nutrients, oxygen and chlorophyll-*a*, and phytoplankton counts in water samples collected in the proposed farm area.

General mitigation and monitoring recommendations are provided where appropriate. We understand that NZ King Salmon intends to undertake an effects-based approach to farm development, which can be based on water quality management objectives. This would be supported by additional monitoring determined by the regulator to provide the best information on the effects of the activity on the wider environment. For this assessment, we have assumed that the water quality management objectives would be similar to those set by the 2013 Board of Inquiry report and adopted for other existing farms in the Marlborough Sounds.

Magnitude and significance of assessed effects

- The proposed farm area is in deep water (60–110 m) in a region of fast currents (mean mid-depth current speeds = 40 cm/s). Data collected indicated little variation of current speeds with depth, with slightly higher values near the surface and at offshore stations. Sampled mean currents in the top 35 m of the water column tend towards the northwest and, according to results of drift modelling, waste particulates are likely to be transported in this direction towards the open sea during the ebb tide.

- Results of field surveys confirmed that the water column in the proposed farm area is relatively uniform with respect to variations of temperature, salinity and turbidity with depth. Nutrient concentrations were also unremarkable and within the range of concentrations measured at an existing farm in Port Gore. Water samples contained mostly diatoms characteristic of a moderately-nutrient enriched and well-mixed water column. A few phytoplankton species known to be potentially toxic to farmed finfish

were identified. However, these were at low numbers, are all common species in the region and would not be harmful to fish unless occurring as intense blooms.

- We found a decreasing trend in DO concentrations in the waters from October 2018 to January 2019, which is a normal pattern associated with the warming of the waters in the summer period. Dissolved oxygen concentrations ranged from 7.0 to 8.9 mg/L and percent saturation generally exceeded 90% evidencing a well-oxygenated environment. Results of a unidirectional flow model indicated near-field DO reductions of about 10% downstream of the net pens for the measured mean current speed of 40 cm/s. Long-term DO monitoring of existing farms in the Marlborough Sounds has shown that mean oxygen concentrations are usually high (> 90% saturation) during the year and throughout the water column and although near-field oxygen concentrations can be slightly lower, we consider that these changes in DO levels are unlikely to cause issues for the wider environment at the 20,000 tonnes of feed per annum proposed for Stage 1. Beyond this feed level, we recommend improved modelling validated from data at close to Stage 1 production levels of fish.

- We also modelled the concentrations of total nitrogen (TN) released by the total biomass of salmon and concentration changes downstream of the net pens anticipated for Stage 1. The results indicated a 30% increase in ambient TN concentrations for the mean current speed was possible. This estimate represents peak 'worst-case' conditions as it does not consider dispersion, dilution and transformation of TN in the water column. Hydrodynamic and biophysical modelling work is underway to improve these estimates. Nevertheless, due to the highly dispersive and open water nature of the site, dissolved forms of N (ammonium and urea) are likely to be short lived and will be quickly assimilated by pelagic phytoplankton and bacteria; therefore, the peak 30% increase is unlikely to be associated with any toxicity.

- Modelling of nutrient dispersion suggests that up to 1% and 2% of the released nitrogen from the farm could enter Pelorus and Queen Charlotte sounds, respectively. While these are equivalent to relatively small inputs to these regions at the proposed Stage 1 feeding levels (equivalent to a 200 tpa feed in Pelorus and 400 tpa feed in Queen Charlotte), these would be cumulative to existing and potential new farms in these regions. Prior modelling suggests that cumulative biochemical water changes associated with the new small inputs would also be small, which suggests that the cumulative impacts from the proposal would be limited, at the Stage 1 level – however additional work may be required to assess higher feeding inputs.

- Based on the physical and biological characteristics of the site, the small scale of the farm compared to the Cook Strait, and the small footprint of the artificial lights, we concluded that the effects of the proposed submerged artificial lighting on the water column environment are likely to be small. While these effects may be measurable at some level within the pen structures themselves, the effects in terms of the wider Cook Strait region will be very small and unlikely to be measurable.

A summary of the issues considered in this report and their magnitude of effects associated with the proposed salmon farm is given below:

Issue	Potential effect	Magnitude of assessed effect
Depletion of dissolved oxygen	Reduced concentrations to levels that affect biological processes	The farm will be in deep and highly flushed waters and therefore oxygen reductions would be very localised. We estimate up to 20% reduction in DO levels immediately downstream of the pens at Stage 1 of farm development.
Nutrient loading	Increased concentrations of dissolved nutrients	The effect of fish wastes on nutrient concentrations will be greatest near the farm and decrease with distance as a function of mixing and dilution. Preliminary estimates indicate a peak 30% increase in ambient TN concentrations immediately downstream from the pens for mean currents of 40 cm/s at Stage 1.
	Phytoplankton growth	Increased nutrient levels can enhance phytoplankton growth. The extent to which the added nutrients from the farm lead to phytoplankton changes over and beyond existing levels will be limited in space and time. The hydrodynamic characteristics of Cook Strait do not favour the development of phyto-flagellate blooms.
Artificial lighting	Attraction of phototaxic organisms	Although likely to occur, the effect will be minimised by the small spatial footprint of the lights and the inability of small organisms to maintain their position within high currents.
	Vertical migration and benthic settlement of planktonic organisms	Potentially influenced near the lights. These effects will be highly localised and positioning of the farms in high currents will most likely mitigate these effects.

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1. INTRODUCTION

Cawthron Institute (Cawthron) was contracted by The New Zealand King Salmon Co. Limited (NZ King Salmon) to provide a report characterising and assessing the effects on the water column as part of a proposal to develop a salmon farm offshore of the Marlborough Sounds, due north of Cape Lambert, and east of the Chetwode Islands (Figure 1).

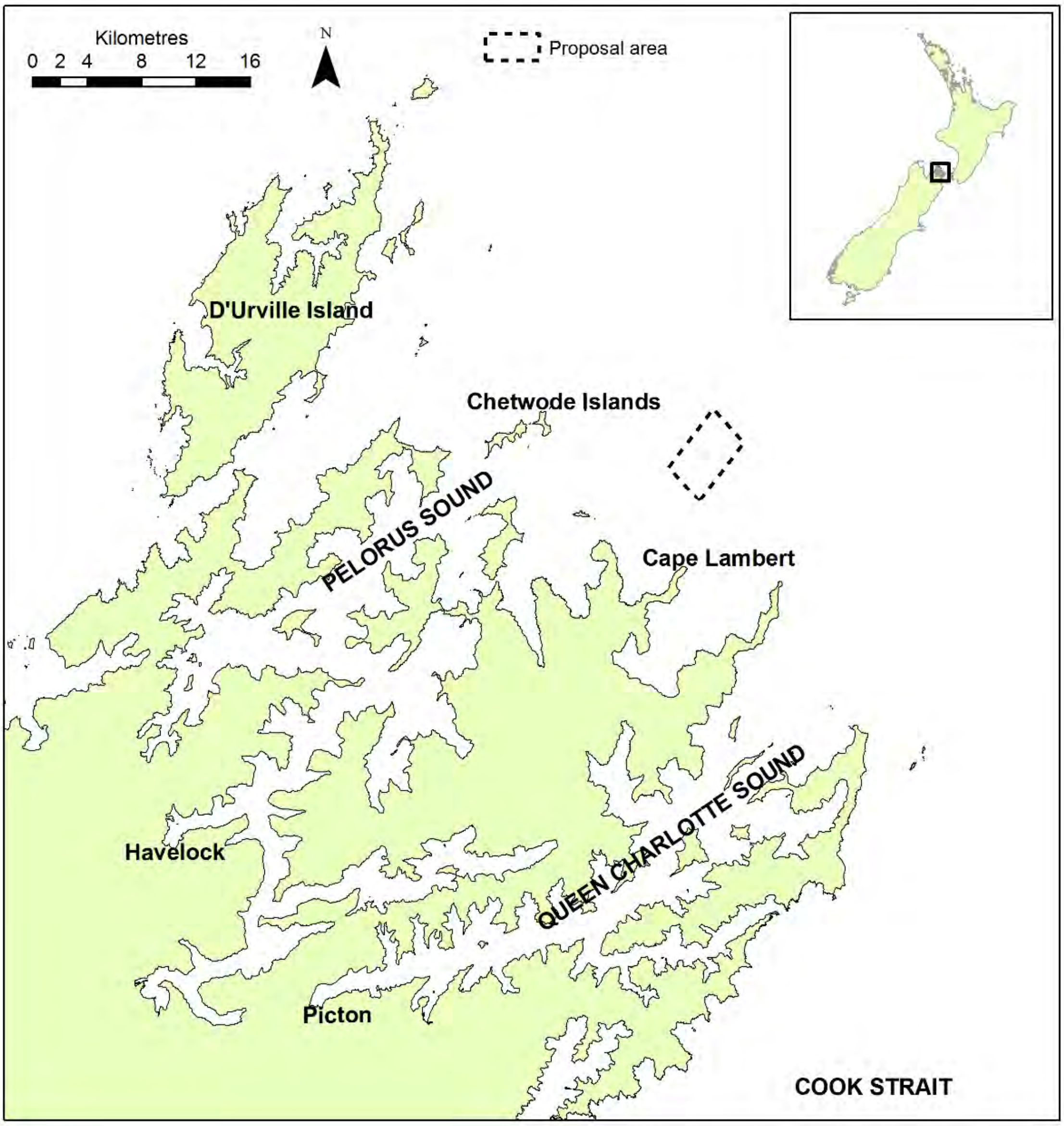


Figure 1. Location of the proposed farm in relation to the Marlborough Sounds. The proposed farm area is shown as black dashed polygon.

This assessment has been informed by information collected as part of literature reviews and new data obtained from field surveys targeting the proposal area undertaken in August and October 2018 and January 2019 (Figure 1).

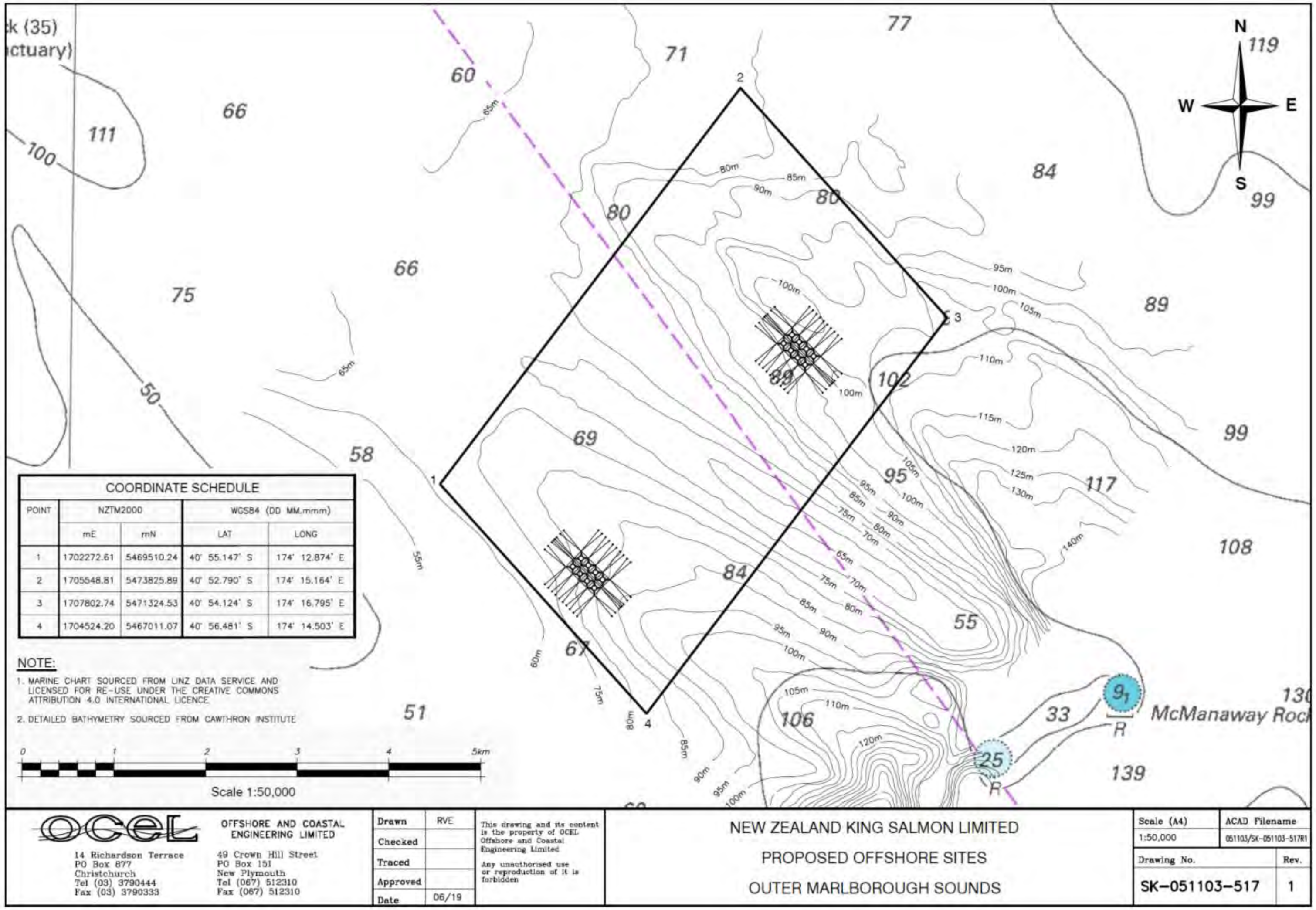
1.1. Proposed salmon farm

NZ King Salmon's proposal is to develop an area of 1,792 ha to farm King salmon (*Oncorhynchus tshawytscha*). Two blocks of black-coloured net pens will be installed within this area in a staged development:

- Stage 1 = up to approximately 10,000 tonnes of production (20,000 tonnes of feed per annum; tpa) over two separate sets of pens (16 in total); the proposed farm layout at this stage is shown in Figure 2.
- Stage 2 = up to 40,000 tpa feed over 40 pens.
- Further staged increases to reach a production level of 40,000+ tonnes production (80,000 tpa of feed) (aspirational at this stage).

Each set of pens will comprise up to eight plastic circles with a circumference of up to 200 m each; supported by mooring lines leading to a grid system at depth and one barge.

The exact locations and details of Stage 1 are yet to be confirmed, but NZ King Salmon estimate that there will be a maximum discharge of c. 1,000 tpa into each pen and that each pen will produce c. 500 tonnes of fish. Our analysis has used this scenario. There is a possibility that a trial of other types of structures might be attempted within the permit area. This pilot farm or farms would use a maximum of 4,000 tpa feed (included in the initial 20,000 tpa feed) and be located using the same site suitability criteria. Pen technologies for such exposed environments are relatively new, and the details of the pen structures and mooring design used in the proposal are yet to be confirmed.



COORDINATE SCHEDULE

POINT	NZTM2000		WGS84 (DD MM.mmm)	
	mE	mN	LAT	LONG
1	1702272.61	5469510.24	40° 55.147' S	174° 12.874' E
2	1705548.81	5473825.89	40° 52.790' S	174° 15.164' E
3	1707802.74	5471324.53	40° 54.124' S	174° 16.795' E
4	1704524.20	5467011.07	40° 56.481' S	174° 14.503' E

Figure 2. Layout of the proposed farm at Stage 1 showing the two blocks of net pens in the outer Marlborough Sounds.

1.2. Scope of the report

This assessment forms one component of a wider assessment of environmental effects that has been conducted to inform the NZ King Salmon resource consent application. There is a range of potential effects of salmon farming on the water column environment and these have been thoroughly reviewed by Forrest et al. (2007) and Gillespie et al. (2011). In this assessment, we consider the following effects:

- **Dissolved oxygen (DO)**, primarily associated with fish respiration
- **Nutrient enrichment**, associated with the addition of feed and production of fish wastes, and associated changes in **phytoplankton** species composition and abundance
- **Submerged artificial lighting**, on the physical environment and plankton communities.

In addition to supporting the marine farm consent application, the site characterisation parts of this report will be used by NZ King Salmon to confirm site suitability from a salmon farming operational perspective.

2. POTENTIAL EFFECTS OF FINFISH FARMING ON THE WATER COLUMN

Reduction of dissolved oxygen (DO) in the water column and nutrient enrichment are key potential water column effects of finfish aquaculture (MPI 2013). Depletion of DO can occur as a result of fish respiration and bacterial processing of waste products—causing a mid-water reduction in oxygen concentration. If the seabed beneath a salmon farm becomes enriched by particulate wastes, biological activity of bacteria can cause a reduction in near-seabed DO. In New Zealand, monitoring data from existing salmon aquaculture operations reveal that water column DO concentrations do not get significantly depleted (Forrest et al. 2007). Seabed oxygen issues are not addressed in this report, but by an accompanying benthic report (Elvines et al. 2019).

Nutrients can be added directly to the water column in a particular farm as feed or can enter the water column in the form of particulate and dissolved waste products from the fish. In marine systems, a concern with nutrient enrichment of the waters is the potential for an increased occurrence of phytoplankton blooms, some of which may be toxin-producing. Some of these biotoxins can be directly toxic to fish, and others can accumulate in shellfish and affect consumers. In a review of empirical studies of salmon farming on the water column, Knight and MacKenzie (2017) found that ‘Based on in-depth international reviews of many such studies, there appears to be limited evidence of demonstrable effects of nutrient enrichment on phytoplankton production in temperate mesotrophic systems such as the Marlborough Sounds.’ Nonetheless, few opportunities have become available to test for effects of large-scale offshore finfish farms (Welch et al. 2019), so some uncertainty remains about the nature of effects. Moreover, responses to aquaculture can differ between ecosystems, making it difficult to generalise about the nature of effects.

Primary production can be limited when there is insufficient light for photosynthesis, but when sufficient light is available (e.g. during summer months), nutrients may become limiting. In marine systems, primary production is generally limited by nitrogen over other nutrients (Howarth & Marino 2006). For this reason, nitrogen is the focus of studies assessing of environmental effects of finfish farming on the water column in the marine environment (Gillespie et al. 2011).

2.1. Offshore finfish farming

Offshore sites such as that considered in this assessment provide multiple advantages in terms of environmental effects on the water column over near-shore sites. They provide good conditions for turbulent mixing and strong currents, thereby increasing the rate of dilution and dispersal of farm-derived wastes (Welch et al. 2019). Because they are in deeper open waters, they are likely to have cooler water temperatures than more protected near-shore waters.

Enrichment and reductions in DO are less likely to occur in offshore environments with substantial flushing, as water moves quickly through the farm. Offshore waters carrying aquaculture-derived nutrient loads are less likely to interact with sources of potential stress, such as terrestrial run-off or other coastal nutrient sources (e.g. coastal upwelling, existing inshore finfish farms or outfalls). Because of limited nutrients, harmful phytoplankton species are also less likely to occur as intense blooms in offshore environments than in more enclosed water.

Aquaculture structures, such as net pens, can modify water currents in the immediate area in which they are installed. This is of concern in low-flow sites and enclosed water bodies when further slowing of currents can have negative environmental consequences. However, this is less of a problem in offshore sites where currents are relatively strong and structures occupy a small proportion of the total surrounding volume of water.

3. SUMMARY OF EXISTING KNOWLEDGE OF WATER COLUMN ENVIRONMENTS IN THE COOK STRAIT

In this section, we provide an overview of the water column environment in the proposed farm area and the wider Cook Strait. This includes information on tides and currents, water column characteristics and a historical perspective of blooms of toxin-producing phytoplankton in the Strait.

3.1. Tides and currents

Water circulation in Cook Strait is determined by a complex balance between the D'Urville Current which flows from the west and mixes with the southward extension of the 'Wairarapa Eddy' (Stevens et al. 2019). The semidiurnal tide together with the constricted geomorphology of the Strait contribute to strong currents which can be as high as 3.4 m/s (Vennell 1994, 1998). The consensus from the early oceanographic studies is that the fastest flows are tidal and that the net flow is to the south (Heath 1986). However, more recent studies have identified wind-driven northward residual flows on the western side of the Strait (Stevens 2014). Occasionally, the Southland Current penetrates sufficiently far north and also contributes to the waters in the Strait (Shaw & Vennell 2000).

Volumes of water moving through the Strait are large (estimated total volume = 4.1 million m^3/s; Vennell 2011). Net water movement is towards the south (i.e. from the Tasman Sea to the Pacific Ocean), with net southern flow estimated at 250,000 m^3/s (Stevens 2014).

Offshore of the Marlborough Sounds, wind fields are very complex because of the surrounding mountainous terrain. Consequently, wind-driven currents can play more or less important roles locally (Walters et al. 2010; Stevens 2018) and are certainly a feature in the proposed farm area. As a result, complex eddy fields can form around coastal embayments (Stevens et al. 2019).

During most of the time, the water column in the Strait is well-mixed. Stratification does occur and is strongest in summer causing temperature to vary by as much as 3 °C with depth (Stevens et al. 2019).

Plumes of cool and nutrient-rich upwelled waters from the west coast of the South Island are carried by the D'Urville Current into the greater Cook Strait and drive primary production in the area. This flow of nutrient-rich waters occurs throughout the year, but it is only visible at the surface during the summer (Stevens et al. 2019).

3.2. Water column characteristics

A site located near the mouth of Port Gore has been included in Marlborough District Council's (MDC) state of the environment (SOE) water quality monitoring programme. This site is located approximately 4 km to the south of the southern corner of the proposed farm and provides useful background dataset for the area. Results of monthly sampling carried out in the period July 2013–July 2015 were reported in Broekhuizen (2015), and additional data were available for review for this report (MDC/Cawthron/NZKS unpublished data). According to Broekhuizen, the sampling location at the mouth of Port Gore 'probably [has] water-quality properties that are very similar to those of Cook Strait'. The available data show the following characteristics over the monitoring period (values are approximate):

- a generally well-mixed water column, with little variation of temperature and salinity with depth
- temperature range: 12.5–17 °C
- salinity range: 33–37.5 psu
- oxygen saturation range: 85–100%
- chlorophyll-*a*: generally < 1 mg/m^3, with occasional peaks (the highest concentration was 5 mg/m3)
- turbidity range: 0–5 NTU
- nutrient ranges: dissolved reactive phosphorus (DRP): 3–20 mg/m^3; ammonium (NH_4): 2–40 mg/m^3; dissolved reactive silica (DRSi) 40–250 mg/m^3; and total nitrogen (TN): 120–450 mg/m^3 (usually < 350 mg/m^3)
- DRSi/DIN ratio: 0.3–2.5.

Turbidity was greater in deep waters (in van Dorn water samples collected from just above the seabed) than in shallow waters (0–15 m integrated samples). However, a limited number of deep water results was presented, so it is unknown how persistent this difference was. Chlorophyll-*a* and NH_4 tended to be slightly higher in surface waters. No other parameter showed evidence of consistent variability between shallow and deep samples, which is consistent with the observation of a well-mixed water column.

Other sites are also included in the NZ King Salmon monitoring and the MDC SOE water quality monitoring programme[1]. However, we note that the datasets are quite distinct; the offshore data presented in this report are high-frequency data collected over a few months while the Marlborough Sounds data are a long-term lower-frequency data set (> 5 years of monthly sampling).

[1] https://cawthron.shinyapps.io/WQ-Marlborough/

On a larger scale, water temperature and dynamics of upwelling in greater Cook Strait[2] were investigated by Chiswell et al. (2017). This study reports upwelling of cool water in the Kahurangi Shoals, on the upper west coast of the South Island. This cool water then moves through the greater Cook Strait to Cook Strait itself. Surface temperature in the greater Cook Strait, estimated from satellite imagery and from a Regional Ocean Modelling System, also showed an effect of cool waters from the eastern side of Cook Strait moving into the area to the north and east of the Marlborough Sounds, i.e. incorporating the area considered in the present report. Monthly averages of six years of data showed that this relatively cool body of water sitting to the north and east of the Marlborough Sounds was most apparent from late spring to autumn. In the colder months, water temperatures were more homogenous across the greater Cook Strait (Chiswell et al. 2017). The mean monthly temperature occurred in February, when surface waters north of the Marlborough Sounds averaged approximately 17 °C (Chiswell et al. 2017).

Long-term (13 years) sea surface temperature data available for a single site in outer Port Gore (taken from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery) show that temperatures > 18 °C were uncommon and rarely exceeded 19 °C (Figure 3, reproduced from Taylor et al. 2015). The lowest temperatures varied between 11 °C and 12 °C every year.

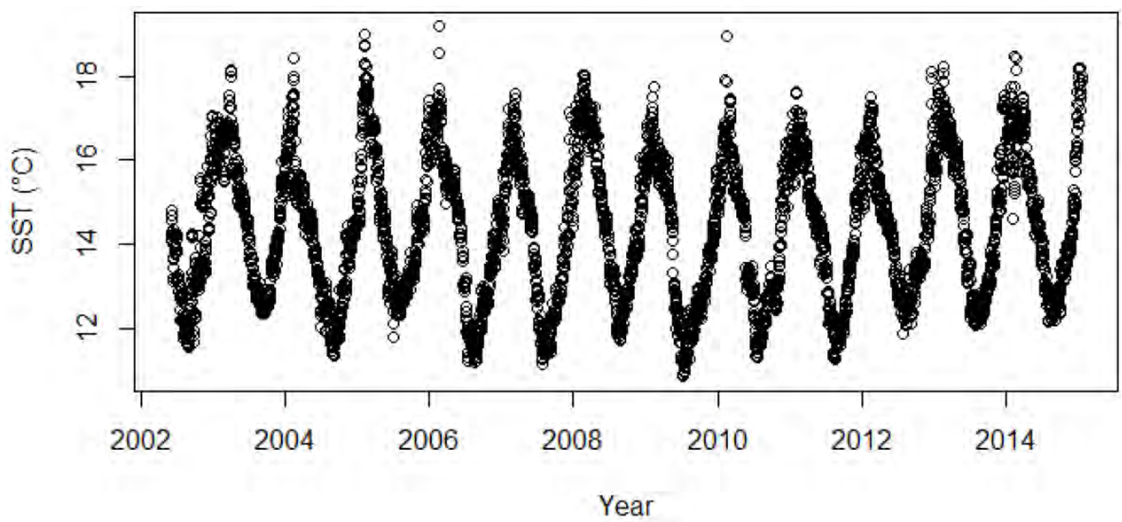


Figure 3. Sea surface temperature (SST) for outer Port Gore derived from MODIS satellite data (Lat: -40.98306°, Long: 174.2602°). Adapted from Taylor et al. (2015).

Remotely-sensed chlorophyll-*a* concentrations were also calculated monthly for the greater Cook Strait by Chiswell et al. (2017). As for temperature, six years of satellite data were used for this calculation. Data within 10 km of the coast were excluded

[2] The area extending from offshore Cape Egmont (Taranaki) to offshore Kahurangi, and south east through to Cook Strait proper

(near-shore measurements are inaccurate due to the effects of suspended sediments in the water column). However, the general pattern of chlorophyll was still informative with respect to the area considered in the present report. In autumn, winter, and spring, the area to the north of the Marlborough Sounds generally had lower concentrations of chlorophyll-*a* than other areas of the greater Cook Strait (concentrations were approximately between 0.5 and 0.75 mg/m^3). However, in summer, a small area of high mean surface chlorophyll relative to much of the greater Cook Strait (approx. 0.75–1 mg/m^3) persisted to the north of the Marlborough Sounds.

3.3. Historical perspective of harmful algal blooms

Harmful algal blooms (HABs) in the Marlborough Sounds can be localised events occupying only a small bay or inlet, or extensive phenomena where cells are transported, and resident populations established, around much of the region. Blooms originating in the North Island have been observed to cross Cook Strait and intrude into the Marlborough Sounds. There are a few locations where resident populations result in the formation of HABs every year and other locations which are rarely, if ever, affected. Some species may become a major component of the phytoplankton for a period of several years, only to eventually decline in abundance and disappear. The ability to form long-lived resting cysts that reside in the sediments is an important feature of the life cycle of some HAB species that enables their establishment and long-term residence. Over the last 20 years, there have been numerous HAB blooms that have required some response from the aquaculture industry or food safety regulators, and a number of large events which have had significant economic and social consequences.

In January 1989, in Big Glory Bay (Stewart Island), a *Heterosigma* bloom occurred that resulted in a loss of more than 600 tonnes of farmed salmon. This was a costly blow to the developing industry (Chang et al. 1990; MacKenzie 1991). *Heterosigma akashiwo* is well known internationally as a cause of sea-cage salmon mortalities. *H. akashiwo* is commonly observed in low numbers in water samples from the Marlborough Sounds but the only known major bloom was observed in Pelorus Sound in late summer 2018. It is believed that this caused some mortalities on the Pelorus Sound farms but no details are available.

In March 1998, a bloom of *Karenia brevisulcata* in Wellington Harbour caused mass mortalities of marine fauna and flora and adversely affected the Mahanga Bay shellfish hatchery (Chang 1999). The bloom was preceded by reports of dead fish (tuna, billfish) abalone, seals and penguins along the Wairarapa coast. A bloom of *K. brevisulcata* would undoubtedly have devastating effects if it occurred in the vicinity of salmon farms. It probably exists within the Marlborough Sounds region but no further blooms of this species have been observed since the 1998 event.

During the spring of 2002, *Karenia* spp. blooms *(K. mikimotoi, K. brevisulcata, K. concordia*) caused mass mortalities of fish (flounder, mullet, etc.) in the Hauraki Gulf and the total loss of cultured abalone on a farm in Kennedy Bay, Coromandel Peninsula (Chang et al. 2001). Varieties of *Karenia* species are common in the Marlborough Sounds and a bloom of *K. mikimotoi* was observed in inner Nydia Bay, Pelorus Sound, as recently as March–April 2019. It is not inconceivable that an intense and extensive *Karenia mikimotoi* bloom could occur that would impact Pelorus Sound salmon farms.

In June 2010, a bloom of the chrysophyte alga, *Pseudochattonella verruculosa* in inner Queen Charlotte Sound caused substantial mortalities (> 200 tonnes) of salmon at the Ruakaka Bay salmon farm. Commercially, this was the most serious fish kill event since the 1989 Big Glory Bay bloom (MacKenzie et al. 2011a). In 2016, *P. verruculosa* caused catastrophic losses on salmon farms in Chile in 2016 and it has been determined (Montes et al. 2018) that very low cell numbers (< 1 cell/mL) can cause anomalous salmon behaviour. This species probably poses the highest HAB risk to salmon farming in the Sounds, but little is known about its ecology.

In February–April 2011, the first recorded bloom of *Alexandrium pacificum* (PSP-toxin producer) occurred in Tory Channel which eventually spread to other regions of Queen Charlotte Sound and resulted in shellfish harvest closures of up to three months (MacKenzie et al. 2011b). Blooms of *A. pacificum* have re-occurred in this area every year since, although their intensity and duration appear to be in decline. In May 2018, *A. pacificum* was first observed in Nydia Bay, Pelorus Sound and a major bloom developed that closed mussel harvesting in much of the sound for several months. The bloom re-occurred in 2019, again resulting in a prolonged and extensive mussel harvesting closure. Blooms of a closely related species (*Alexandrium catenella*) has been associated with mass mortalities of salmon in Chile (Montes et al. 2018) but the threshold for inducing anomalous behaviour in salmon is relatively high (> 400 cells/mL).

Blooms of several of species in a phytoplankton group known as the Haptophytes have been the cause major mortality events impacting the Scandinavian sea-cage salmon industry (Aune et al. 1992). Several *Chrysochromulina* and *Prymnesium* species have been identified as the culprits in these events, most recently a bloom of *Chrysochromulina leadbeateri* that caused the death of an estimated eight million fish in northern Norway in May 2019. *Chrysochromulina* spp. are common in the Marlborough Sounds; however, to our knowledge no harmful effects of these micro-algae have been observed on any New Zealand salmon farms.

There are a few diatom species (*Chaetoceros convolutus*, *C. concavicornis*) that possess barbed spines that can lodge in fish gills, cause irritation, limit dissolved oxygen uptake and can lead to mortalities of penned fish (Albright et al. 1993). These species are common, but rarely if ever abundant, in the Marlborough Sounds and we are not aware of any evidence that suggests that are a significant cause of salmon morbidity.

Apart from the diatoms, all the potentially hazardous algae discussed above are flagellates that flourish in sheltered areas where water flow is restricted and where strong thermal and/or salinity gradients result in a well stratified water column. The deep, high current flows and well mixed water column characteristics of the Port Gore site are not conducive to the generation of blooms of these species. The rapid transit of cells through the site from blooms established elsewhere (e.g. in sheltered locations in Queen Charlotte or Pelorus Sound) is likely to be inconsequential.

4. CHARACTERISTICS OF THE WATER COLUMN IN THE PROPOSED FARM AREA

In this section, we summarise results of field surveys undertaken to obtain data to support estimates of dissolved oxygen (DO) and nutrient loading changes and better understand the characteristics of the water column in the proposed farm area. The methods used (further detail given in Appendix 1) and additional data to those shown below are shown in this section.

4.1. Physical characteristics

4.1.1. Currents and bathymetry

Currents and bathymetry are important factors determining the dispersion and dilution of farm wastes through the water column.

The bathymetric profile within the wider proposed farm area increases from 60 m on the SW corner to approximately 110 m on the NE corner (Figure 2). The proposed areas of the net pens are in waters deeper than 80 m. For a more detailed description of the bathymetry and benthos of the proposed farm area we refer the reader to Elvines et al. (2019).

Two Acoustic Doppler Current Profilers (ADCPs) were deployed to measure current velocities within the proposed survey area (Figure 4). One ADCP was moored on a buoy at station 2, downward-facing, and measured currents during the period 14 October 2018–26 February 2019. A second ADCP was deployed on the seabed at station 3 (92 m depth), upward-facing, and measured currents during the period 5 October 2018–9 January 2019. The deployment locations are shown in Figure 4. The deployment durations, location coordinates and approximate depths of the water column at these locations are summarised in Appendix 2.

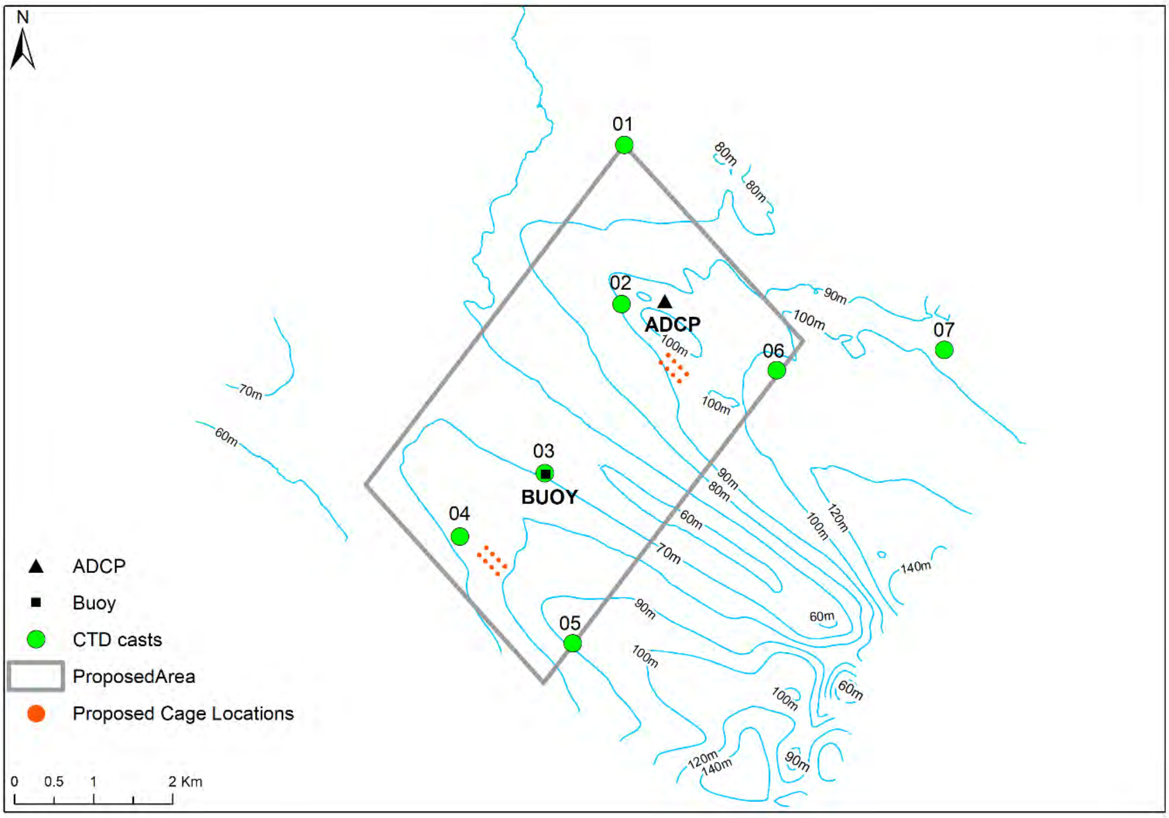


Figure 4. Locations of ADCP deployments and sites sampled for physical-chemical water quality parameters within the proposed survey area shown in yellow. Stations 2 and 3 are located near the moored upward facing (ADCP) and downward facing (BOUY) ADCPs.

Mean mid-depth current speeds recorded by both ADCPs are of the order of 40 cm/s with the further offshore ADCP at station 2 recording slightly higher values (Figure 5). These are higher than depth-averaged speeds recorded at other 'high-flow' salmon farm sites in the Pelorus Sound (13–20 cm/s) and in Queen Charlotte Sound (10–29 cm/s) (Gillespie et al. 2011). Near the surface, mean current speeds in the proposed survey area were slightly higher, which is attributed to the influence of wind and wave motion. Across the 20–50 m water column profile, mean current speeds did not vary substantially. The highest speeds recorded by the upward-facing and downward-facing ADCPs were 124 cm/s and 98 cm/s, respectively.

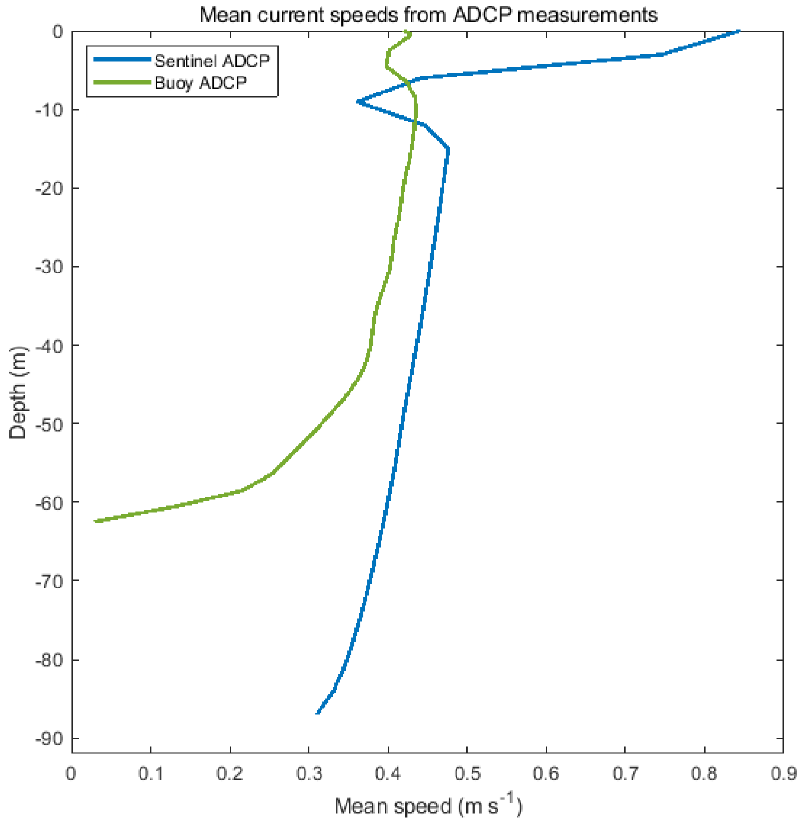


Figure 5. Mean current speeds measured by the upward-facing (Sentinel) and downward-facing (Buoy) ADCPs.

Velocity roses for near surface, mid-depth and near seabed current measurements taken by the two ADCPs are presented in Figure 6. These roses summarise the distribution of current velocities for four speed ranges. White numbers within the colour bars give the percentage of time during the deployment that current speeds were recorded within specific ranges.

Tidal currents are funnelled through Cook Strait, driven by the near 180-degree phase difference in tidal elevation between the west and east coasts of New Zealand. This NW/SE directionality is demonstrated by the current roses. During a substantial proportion of the time (74% as measured by the Sentinel ADCP; 68% as measured by the Buoy ADCP), surface currents were > 30 cm/s. Currents remained strong near the sea bed, with speeds exceeding 30 cm/s 68% of the time and 66% of the time at the Sentinel ADCP and buoy ADCP, respectively.

Current speeds measured by both ADCPs demonstrate the significant capacity of the environment to dilute and disperse suspended material from the farm and from other sources.

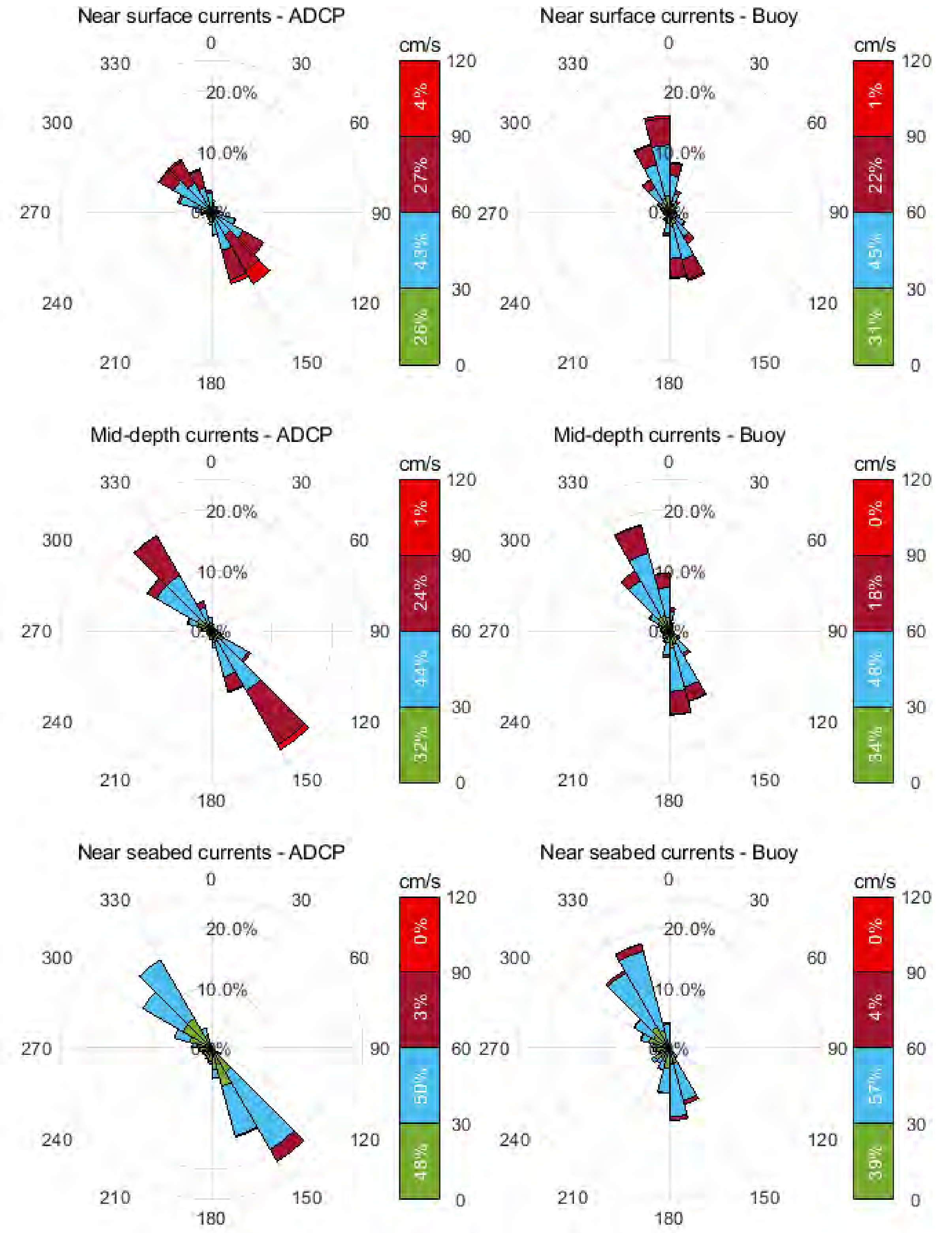


Figure 6. Current speed roses for near-surface, mid-depth and near-seabed based on data collected by the upward-facing (left) and downward-facing (right) ADCPs. The directions are in the 'going to' sense; that is, currents at 90 degrees in the rose plot would be travelling from west to east.

A 3D currents hindcast model (SCHISM) for the Marlborough Sounds and Tasman Bay area was made available from an MBIE-funded (Ministry of Business, Innovation and Employment) aquatic animal health programme. This model provides spatially varying hindcast data during the month of December 2017 and has been validated throughout both Pelorus Sound and Queen Charlotte Sound, but not specifically for the proposed farm area. Velocities taken from this model show good directional agreement with our ADCP-measured data but have higher absolute speeds which could be due to differing meteorological conditions between the modelled time period and the ADCP deployment period.

Depth-averaged velocity fields for the area of interest at peak ebb and flood tide are shown in Figure 7 (a) and (b), respectively. Figure 7 indicates that while bathymetry is variable in the proposed farm area, peak currents are reasonably unidirectional along the NW-SE axis. Slightly higher current speeds are observed in the ebb-direction (Figure 7 (a)) due to a jet developing from flow being forced between the lower North Island and Arapawa Island. Velocity fields presented in Figure 7 (a) and (b) suggest that dissolved wastes from the finfish development in the proposed area could, in theory, be transported into both Pelorus and Queen Charlotte sounds. Further modelling work is being undertaken to determine the potential for particles/nutrients to disperse to these areas and provide more accurate predictions of farm impacts at the regional scale.

Temporal averaging of depth-averaged velocities over a complete number of spring/neap cycles reveals the net movement of water in the area (Figure 8). Comparing the small net current speeds over the proposed farm area (c. 0.1 m/s) to peak currents shown in Figure 7 illustrates the dominance of tidal flow in the region. While Figure 8 shows a small gyre immediately south-east of the proposed farm area, this will likely have negligible effect on waste and nutrient transport in the water column. Mean depth-averaged tidal excursions[3] of 9.3 km and 8 km were calculated from the ADCP data at station 2 for an ebb and flood tide respectively.

[3] The horizontal distance travelled by a particle during an ebb or flood tide.

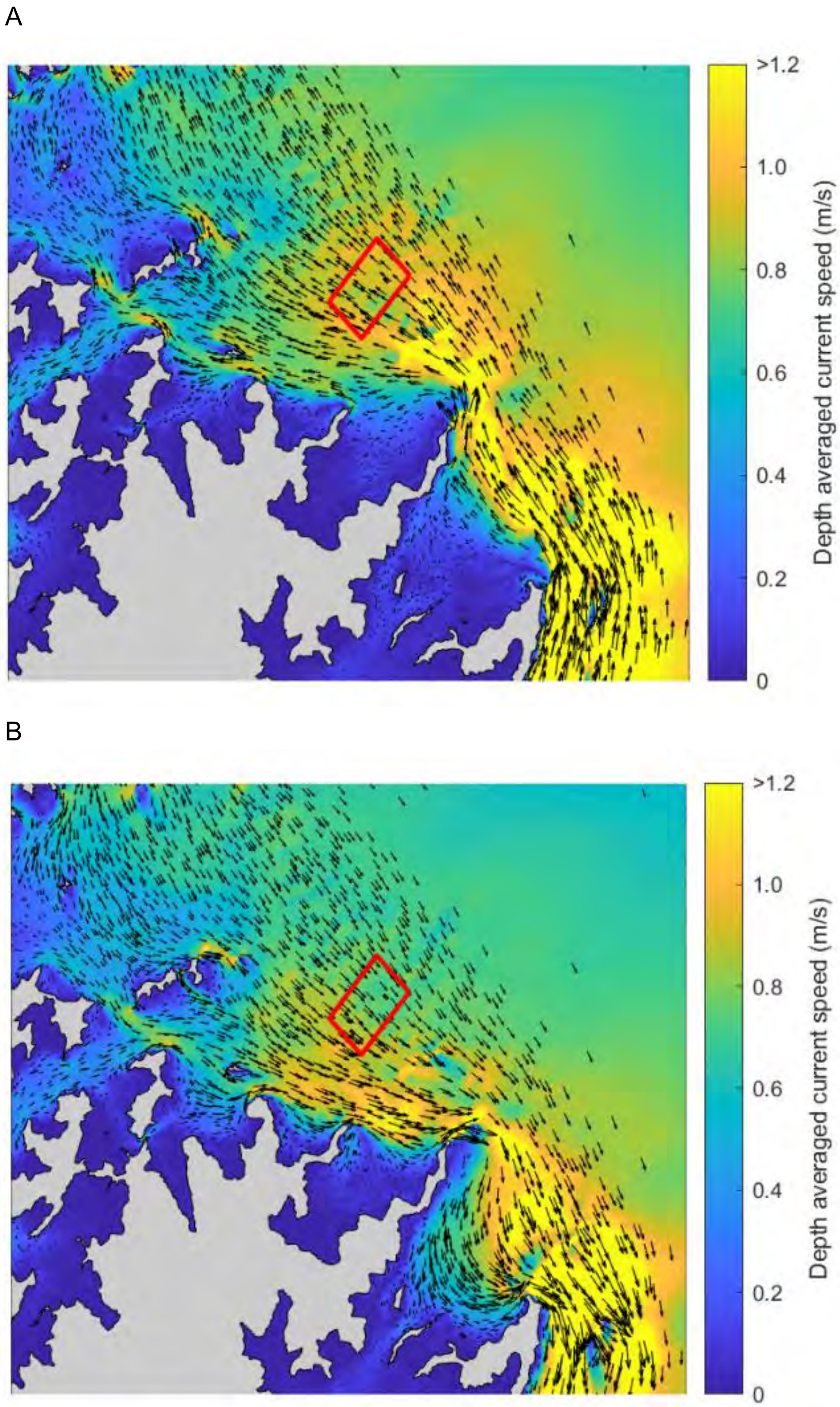
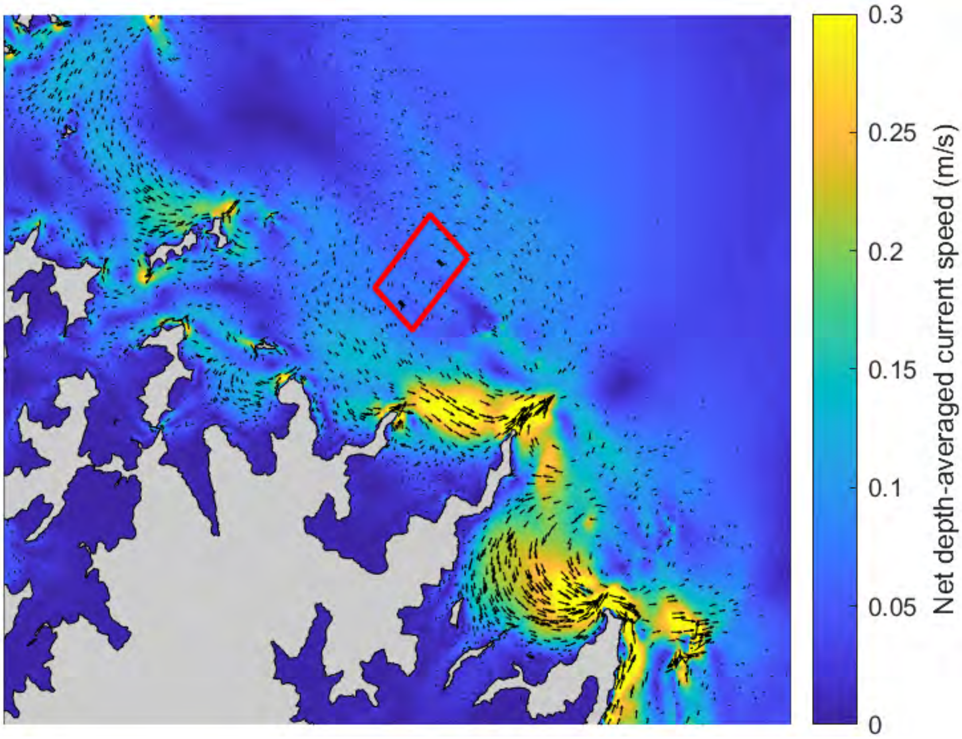


Figure 7. Peak ebb (A) and flood (B) tidal currents offshore of the Marlborough Sounds. Background colours refer to depth-averaged speeds (m/s) while arrows show the directional movement of water. The red polygon shows the proposed farm area.

A



B

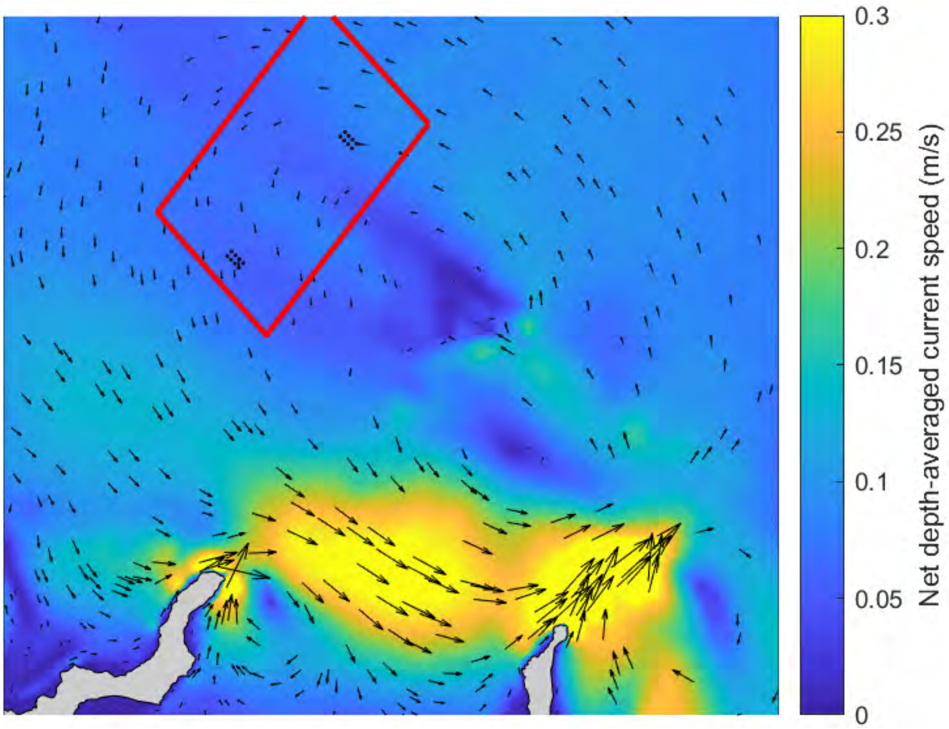


Figure 8. Net depth averaged currents offshore of the Marlborough Sounds over a 29-day period in December 2017. Background colours refer to time and depth-averaged speeds (m/s) and provide an indication of net drift. (A) shows the net currents for the greater Marlborough Sounds region while (B) is a zoomed in image showing the area near the proposed farm development. The red polygon shows the proposed farm area.

Summary

Both measured and modelled currents data indicate strong currents in the area would be associated with large flushing of food, wastes and nutrients into and out of the localised environment. This will largely mitigate accumulation and localised enrichment and the development of anoxic conditions around the farm site.

4.1.2. Waves

In this section, we assess the potential effects of farm structures on wave attenuation to provide an indication of the engineering requirements. We also discuss probabilities that significant wave heights exceed given values, wave return periods, and how long exceedances will likely last to provide relevant operational information.

Wave energy may be attenuated by salmon farm net pen structures. Given the small scale of this proposed farm relative to the surrounding environment, any attenuation effects are expected to be noticeable only in the immediate vicinity of the farm (Gillespie et al. 2011). Consequently, the effects of the farm on the wave environment are deemed inconsequential and are not discussed any further.

To inform this assessment, a 10-year high resolution (1 km spatial resolution, 3 h time resolution) SWAN (Simulating Waves Nearshore) wave hindcast model was commissioned from MetOcean Solutions Ltd. This model is based on wave data for five locations (P1–P5) shown in Figure 9. The geographical grid references of these points are given in Appendix 3.

Data points P1–P4 are the four corners of the proposed salmon farm; P5 is the location of a wave measuring instrument (accelerometer) attached to a buoy. This instrument recorded significant wave height, mean wave direction, average wave period and dominant wave period but did not record spectral information. Data were collected over 20-minute periods every 30 minutes from 14 September 2018 to 28 February 2019, except during the period 8 November 2018–9 December 2018 when a prolonged outage occurred following a storm event. Therefore, the data shown in this report do not represent the larger wave events associated with the storm. Consequently, measured data underestimate wave heights during the deployment period. The data are, however, suitable for validating the modelled hindcast model.

Figure 9. Locations of modelled wave data sampling (yellow circles), measured wave data (P5), and the downwards and upwards facing ADCP deployments. Image from Google Earth.

All wave heights presented in this report are significant wave heights (Hs; the mean trough-to-crest height of the highest third of waves). Maximum wave heights will be larger than the significant wave heights given by the hindcast.

Wave period in this report refers to the dominant wave period (also called peak period). Dominant wave period is the period associated with the most energetic frequency band of waves in the spectrum of waves recorded during the 20-minute sample.

Wave roses

Figure 10 compares the distributions of measured and modelled significant wave heights (Hs) for 'sea' and 'swell' components at site P5. Waves classed under sea component, by definition, have periods less than 8 s and tend to be generated by local weather systems or are remnants of large events that have been attenuated by shallow water. The swell component (periods > 8 s) includes waves generated from large weather systems further afield that propagate through the ocean until they are attenuated by shallow water. White numbers within the colour bars next to the roses give the percentage of time that waves were within respective significant wave height ranges. Measurements taken from the buoy did not contain spectral data and thus it is not possible to decompose measured waves into their sea and swell components.

Waves propagate predominantly from the NW and SE directions through Cook Strait and the majority have significant wave height < 1.5 m. Model data for site P5 predicts significant wave heights are below 1 m during 64% of the time with a strong NNW-SSE bias while measured data show a more multi-directional and calmer wave environment (Hs under 1 m during 88 % of the time).

It should be noted that the buoy went offline during a storm and did not record waves associated with this event. Additionally, the period of deployment was over summer when the wave climate is typically at its calmest. For these reasons, the buoy data are probably underestimating the frequency of larger waves.

The area of the proposed salmon farm is largely sheltered from southerly swells, which is evident when comparing the swell and sea components of the individual roses. Modelled wave data for sampling points P1–P4 are shown in Appendix 4. Points P1 and P2 have a higher frequency of larger wave events (> 1 m) due to being further offshore and hence less sheltered. At the more inshore sites (P3, P4, P5), larger wave events come predominantly from the NW. This is likely due to sheltering from both the NE of the South Island and SW of the North Island.

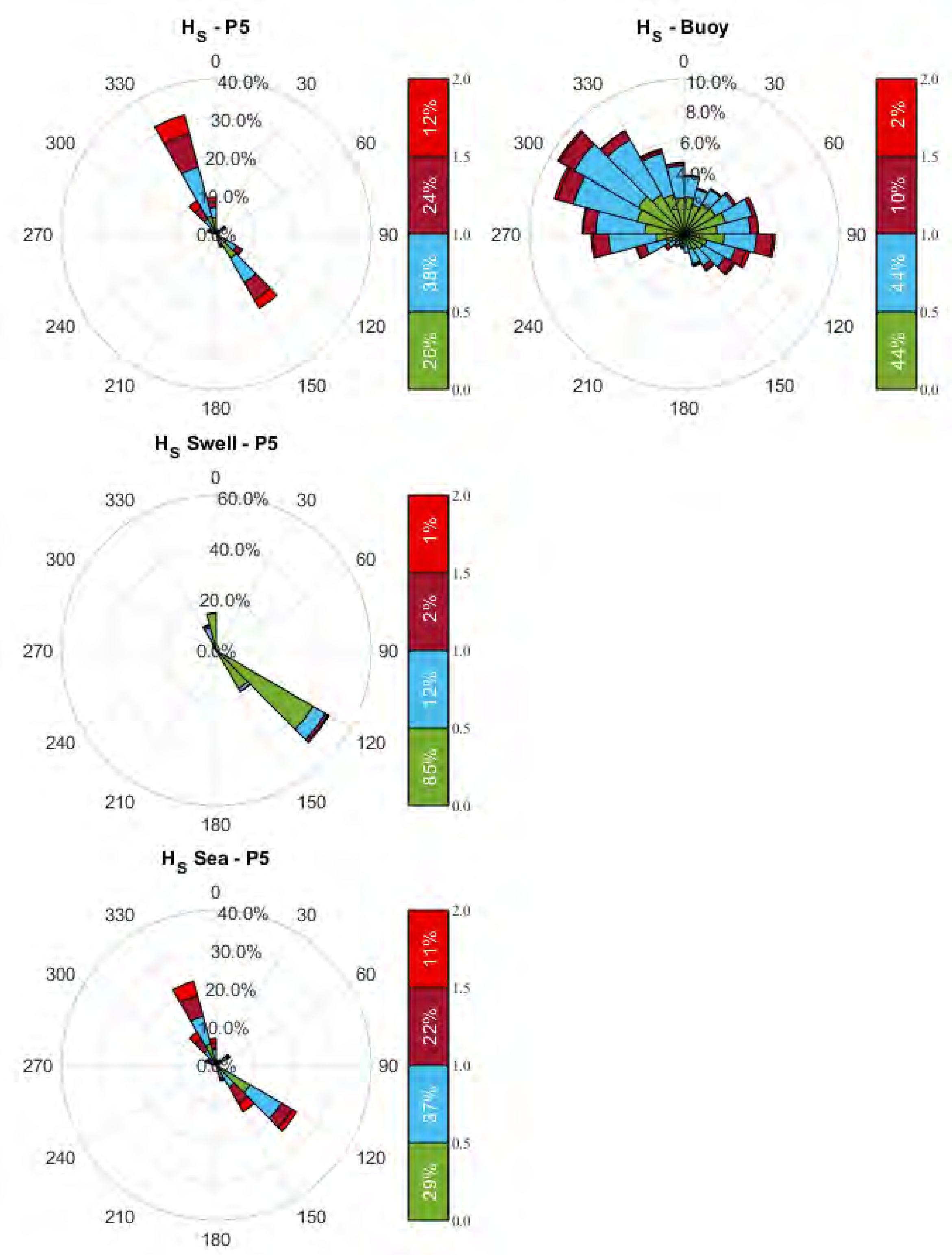


Figure 10. Comparison of measured and modelled wave heights for ‘sea’ and ‘swell’ components at site P5. The directions are in the ‘coming from’ sense; that is, waves at 90 degrees in the rose plot would be travelling from east to west.

Wave probabilities

The probabilities that significant wave heights exceed given values are presented in Figure 11. The lower graph shows the same probabilities expressed as a return period. A return period of 10 years indicates that there is a 10% chance of significant wave height exceeding this value in one year or, alternatively, one can expect significant wave height to exceed this value once every 10 years.

The results are relatively uniform across all sites with slightly higher probabilities of larger waves at the sites furthest offshore (P1, P2). Model data suggest that the probability of any wave exceeding an H_s value of 2 m is 6–13% depending on distance from shore, and the probability of any wave exceeding an H_s value of 3 m is < 2%.

Measured data from the buoy accelerometer underestimate the likelihood of large wave events relative to the model data. This is due to the instrument's short deployment time relative to the length of the hindcast data and the fact it went offline during a storm where large wave events would have almost certainly occurred.

The 6-month return period wave heights range from 4.57 m nearshore (at site P3) to 5.26 m further offshore (at site P2) (Figure 11). One-year return period wave heights range from 4.75 m nearshore (at point P3) to 5.42 m further offshore (at point P2).

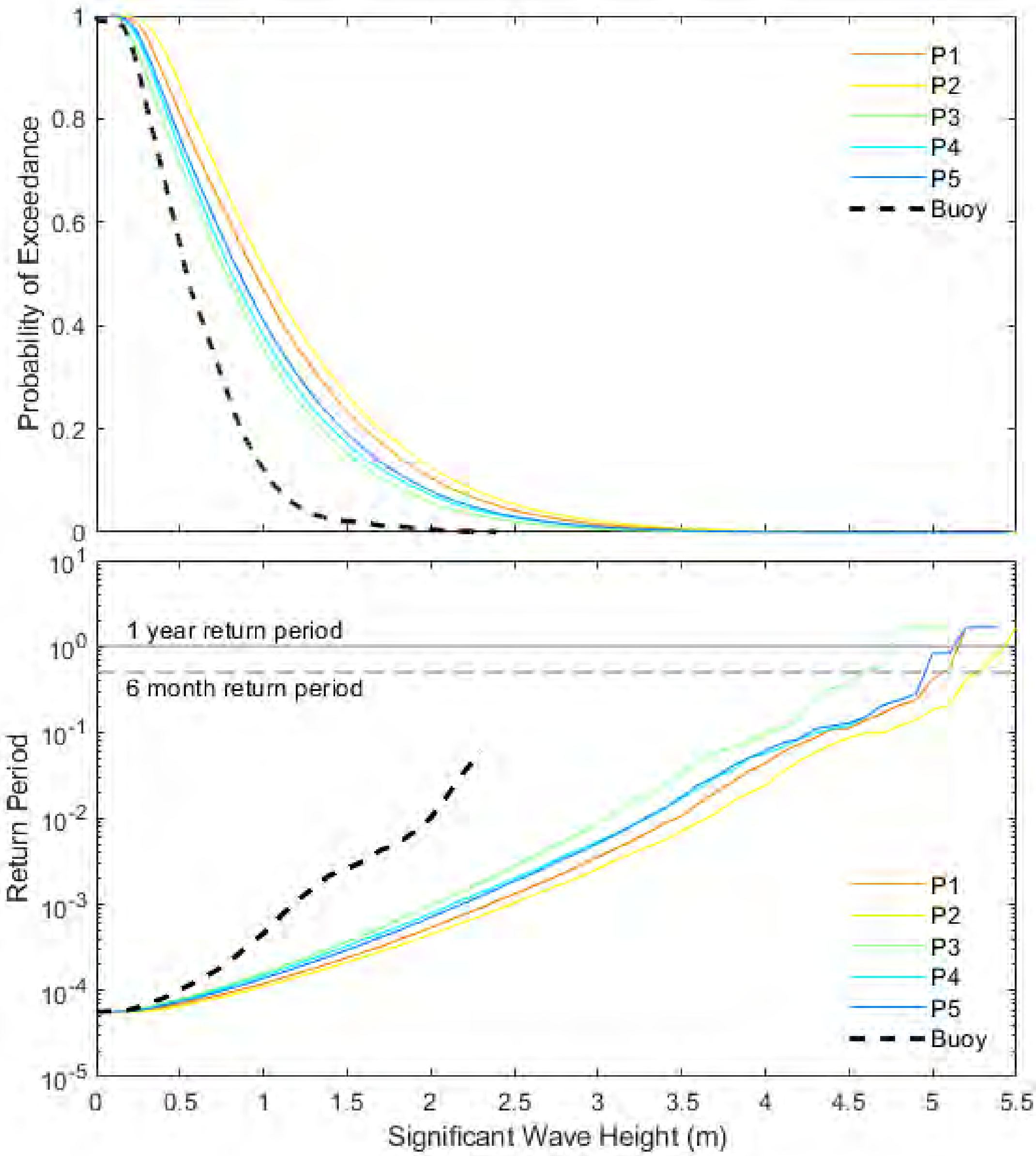


Figure 11. Probability distribution for significant wave height (H_s) exceedences (upper graph) and the same probabilities expressed as return periods (lower graph). The buoy-measured data are shown by the thick dashed black line.

Exceedance times

Time between exceedance gives an indication of timeframes available for maintenance to be completed on the farm, or for the farm to be harvested. Duration of exceedance is defined by how long waves will remain above a given significant wave height, and how long a farm may be inaccessible. Median values taken from model hindcast data for both parameters are presented in Figure 12. Measured data from the buoy accelerometer is not shown as its short deployment time meant it did not provide meaningful information.

Significant wave height can remain under 1 m for 5 days at a time and exceedances of 1 m tend to last less than 8 days. Exceedances of 2 m occur roughly 21 to 35 days apart and tend to last no more than 5 days. Time between exceedance increases rapidly with wave height beyond an Hs value of 2.9 m, although duration of exceedance remains mostly constant at roughly two days. This suggests wave events beyond intense are reasonably infrequent (at most bi-annually) and short-lived.

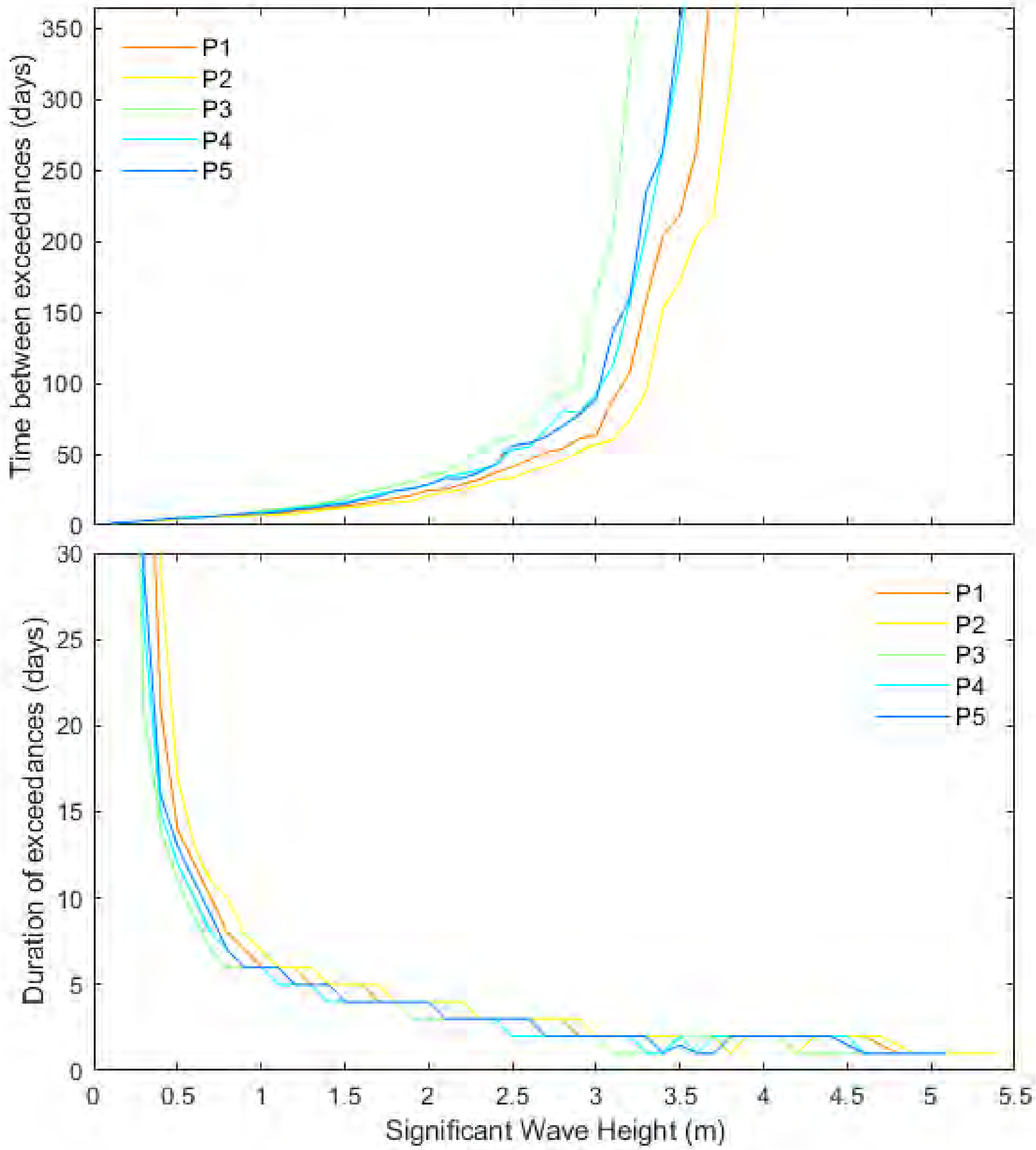


Figure 12. Median time between exceedences of significant wave height and the median duration of these exceedances.

Summary

Waves propagate in the NW/SE direction and are of variable intensity. Sufficiently long periods exist between large wave events to perform maintenance on the farm and to harvest stock. Waves over 2 m occur almost monthly and wave events larger than 3 m take place bi-annually. Farm structures will need to be sufficiently engineered to withstand the variable, and at times, intense wave environment.

4.1.3. Temperature, salinity and turbidity

Water temperature, salinity and turbidity provide important information about the vertical density structure of the water column within the proposed farm area. The seasonal variation of these factors affects the carrying capacity of the environment and thus we consider them here. In theory, it is possible that small changes in temperature could occur due to energy losses associated with the metabolic heat loss of large numbers of farmed salmon, frictional losses from current/structure interactions or electrical/mechanical energy inputs from equipment used at the site (Gillespie et al. 2011). Reduced stratification due to increased vertical mixing has also been documented around other aquaculture structures (e.g. Plew et al. 2005), so it seems possible that some stratification changes are possible.

Continuous temperature and salinity measurements were taken from thermistors/thermometers (1 m, 10 m, and 66 m) and salinity meters (10 m and 66 m) moored on a buoy at Station 3. Temperature and salinity data were also collected using similar instrumentation at Station 2 (96 m). Conductivity, temperature, and depth (CTD) casts were carried out on three occasions (7 August 2018; 6 October 2018; 25 January 2019) at 7 stations within the proposed farm area. Turbidity was also measured by a sensor moored at station 3 (11 m depth). These data were obtained to build a more complete picture of water column characteristics across the proposed farm area and to provide empirical data for hydrodynamic modelling purposes.

Water temperature steadily increased from approximately 12.5 °C in early October (Figure 13). As the water warmed, the temperature became increasingly variable across different depths, and within a given depth. By the end of January 2019, temperature ranged between a high of 19 °C in surface waters and 14.5 °C at 66 m (the deepest sensor, on the ADCP at Station 2, was removed in early January).

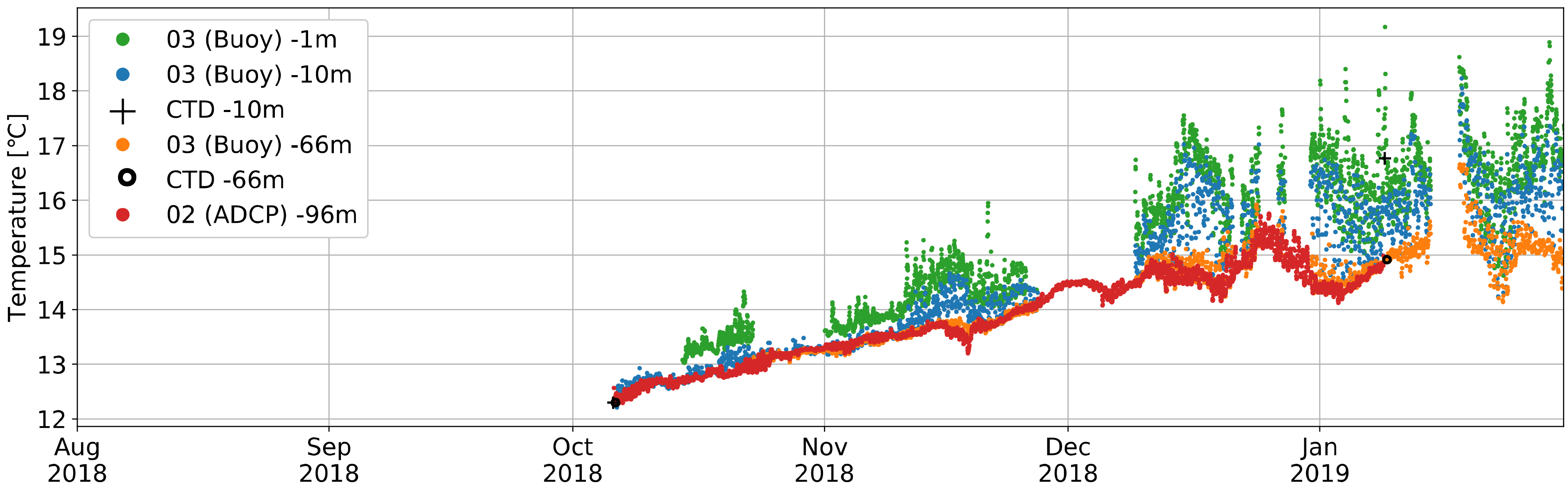


Figure 13. Time series of water temperature at stations 2 and 3 from 6 October 2018 to 25 January 2019. Black symbols indicate temperatures from CTD casts.

The CTD casts through the water column reflect the same pattern of increasingly high and variable water temperatures into summer. Below approximately 30 m, temperatures were relatively stable with depth. A temperature increase from 12–13 °C in August and October to approximately 15 °C in January is also evident in the profiles (Figure 14).

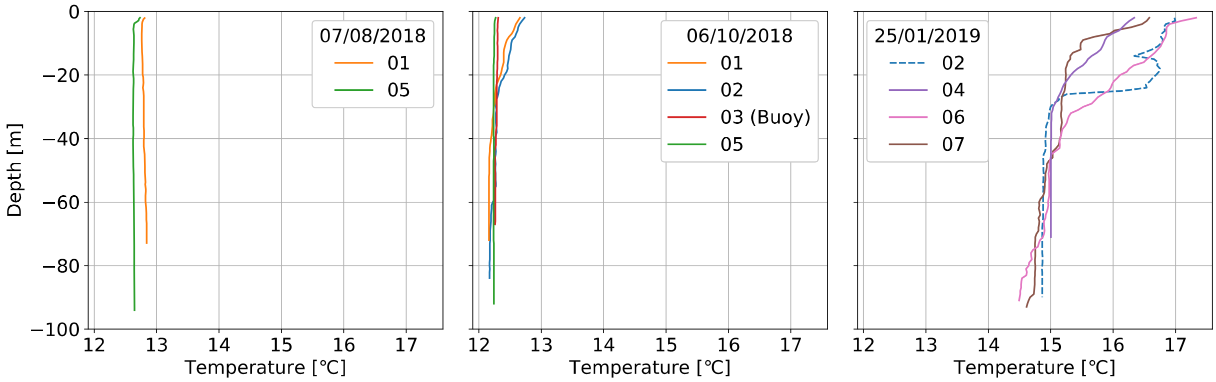


Figure 14. Variation of temperature with depth at 7 stations on 7 August 2018, 6 October 2018 and 25 January 2019. Station 02 is dashed in January to indicate that this cast was taken on 9 January 2019.

A comparison of CTD data with moored data at the same depth shows good agreement between both sets of instruments (see Appendix 5).

The highest temperatures recorded in the survey (approximately 19 °C) are higher than those reported by Broekhuizen (2015) and the means modelled by Chiswell et al. (2016). This is likely due to the high number of measurements recorded by the moored instrumentation (buoy data were not averaged) and the fact that, in the summer of 2018/19, New Zealand waters were affected by a 'marine heat wave' with average surface water temperatures about 1.5 °C higher than normal (Appendix 6). This undoubtedly affected measurements presented here, and hence these results may not be representative of typical conditions in the region.

Salinities measured by moored instruments ranged from 34.5 psu to 35.1 psu (Figure 15). Despite this narrow range, salinity increased slightly in December and was generally higher in shallower (10 m depth) than in deeper waters (66 m depth). Over the period for which data were available from the buoy, salinity averaged 34.8 psu at 10 m depth, and 34.7 psu at 66 m depth.

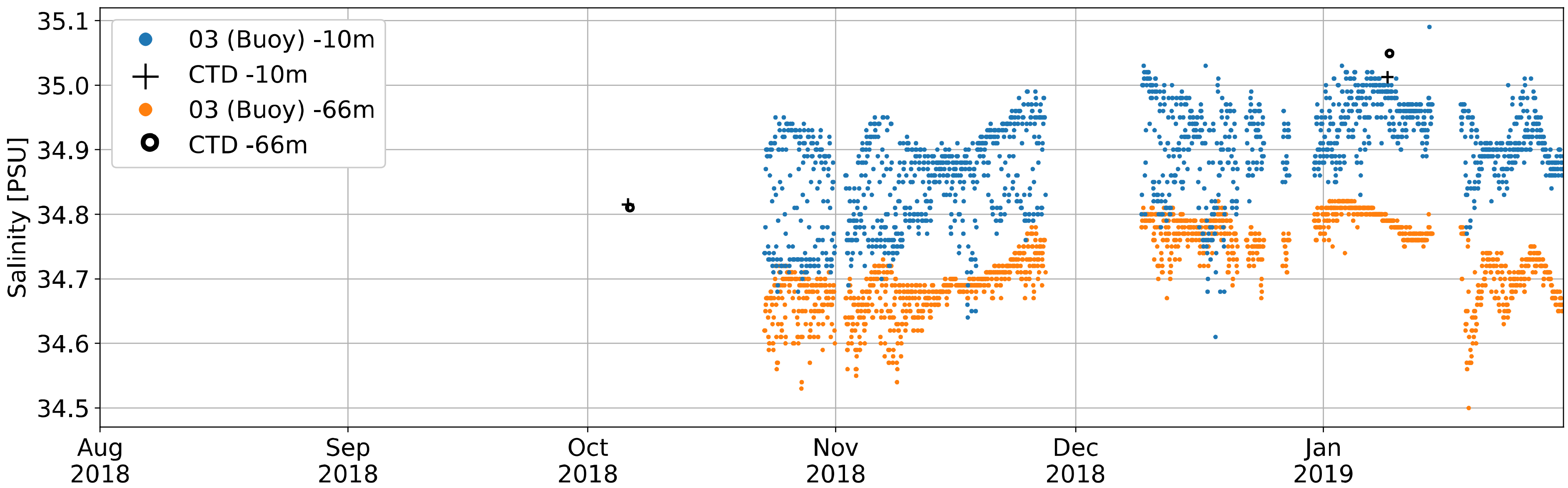


Figure 15. Time series of salinity at station 3 from October 2018 to January 2019. Black symbols indicate salinities from CTD casts.

CTD casts taken throughout the water column showed only minor variability in salinity (< 0.2 ppt) on any sampling occasion (Figure 16). Some small increase in salinity was also recorded in waters shallower than 30 m in January 2019 (note, casts were taken on two dates in January). These higher salinities are likely to be associated with evaporation of surface waters during the period of warm weather.

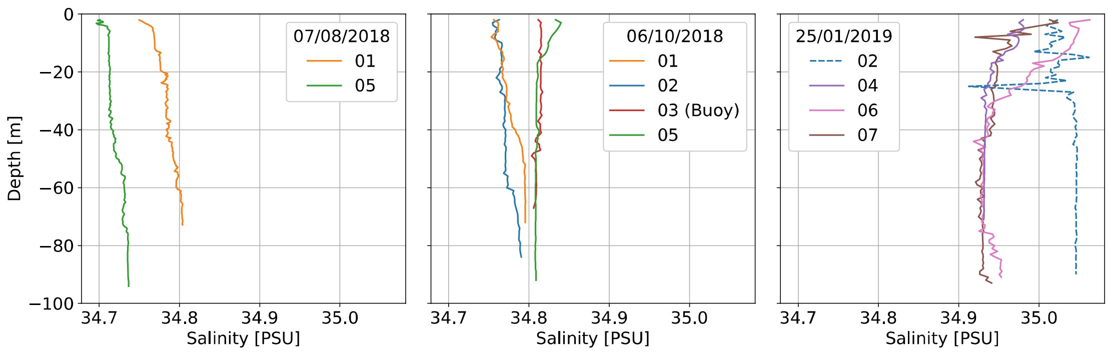


Figure 16. Variation of salinity with depth at 7 stations on 7 August 2018, 6 October 2018 and 25 January 2019. Station 02 is dashed in January to indicate that this cast was taken on 9 January 2019.

Subsampling of CTD data for comparison with data from moored instruments at the same depth showed that the CTD recorded very similar salinities at both depths and did not reflect the approximately 2-point difference that the high-resolution moored instrument data displayed. During the January sampling, for which both data types were available, the CTD measurements were at the upper end of the range recorded by the moored instruments.

The salinity results within the proposed farm area were less variable than those at the more nearshore site in Port Gore monitored as part of the NZ King Salmon/MDC monitoring (Broekhuizen 2015). Nearshore salinity is expected to be more variable because of land runoff and evaporation in warmer waters. The relatively uniform salinity observed in the proposed farm area both on spatial and temporal scales is typical of an offshore site subject to minor freshwater inputs and strong water mixing.

Turbidity levels in surface waters over the period 1 November 2018–25 January 2019 were variable, ranging from 0.02 to 2.23 NTU (Figure 17). Periods of relatively clear waters (< 0.5 NTU) were common during the monitoring period. However, ocean colour satellite imagery indicates that some variation in surface water turbidity around the farm site is likely, as illustrated by the slightly milky colouration in the image (Figure 18). Subsampling of CTD data for comparison with moored instruments at the same depth showed a good agreement between instruments (see Appendix 7).

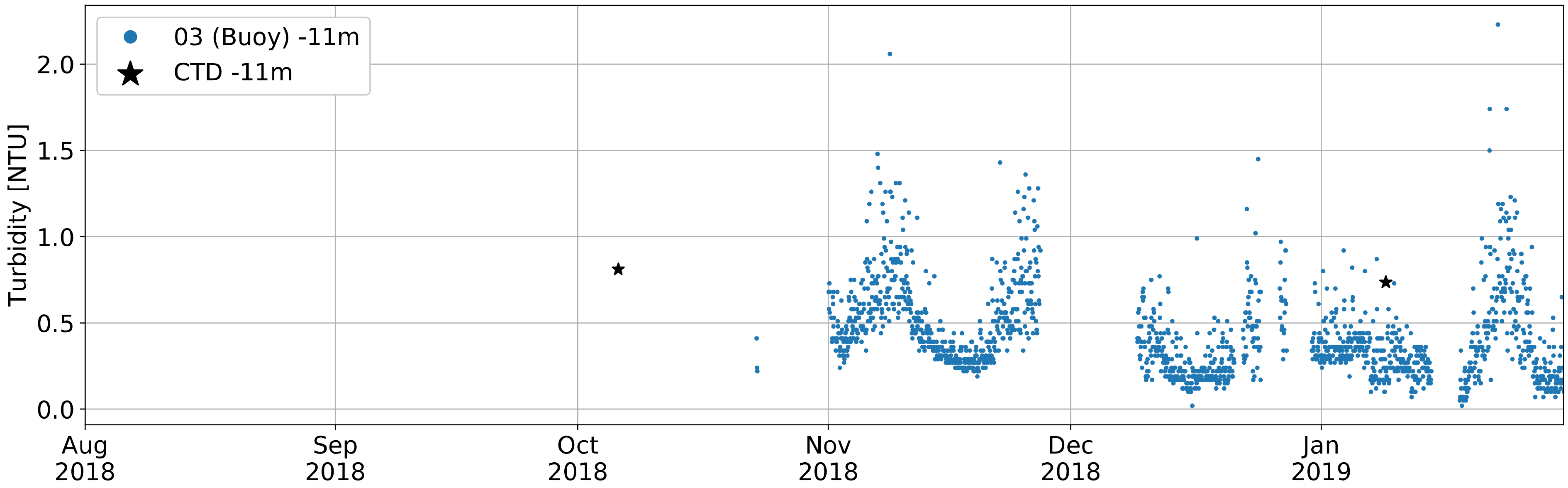


Figure 17. Time series of turbidity at station 3 from 1 November 2018 to 25 January 2019. Black symbols indicate turbidity concentrations from CTD casts.

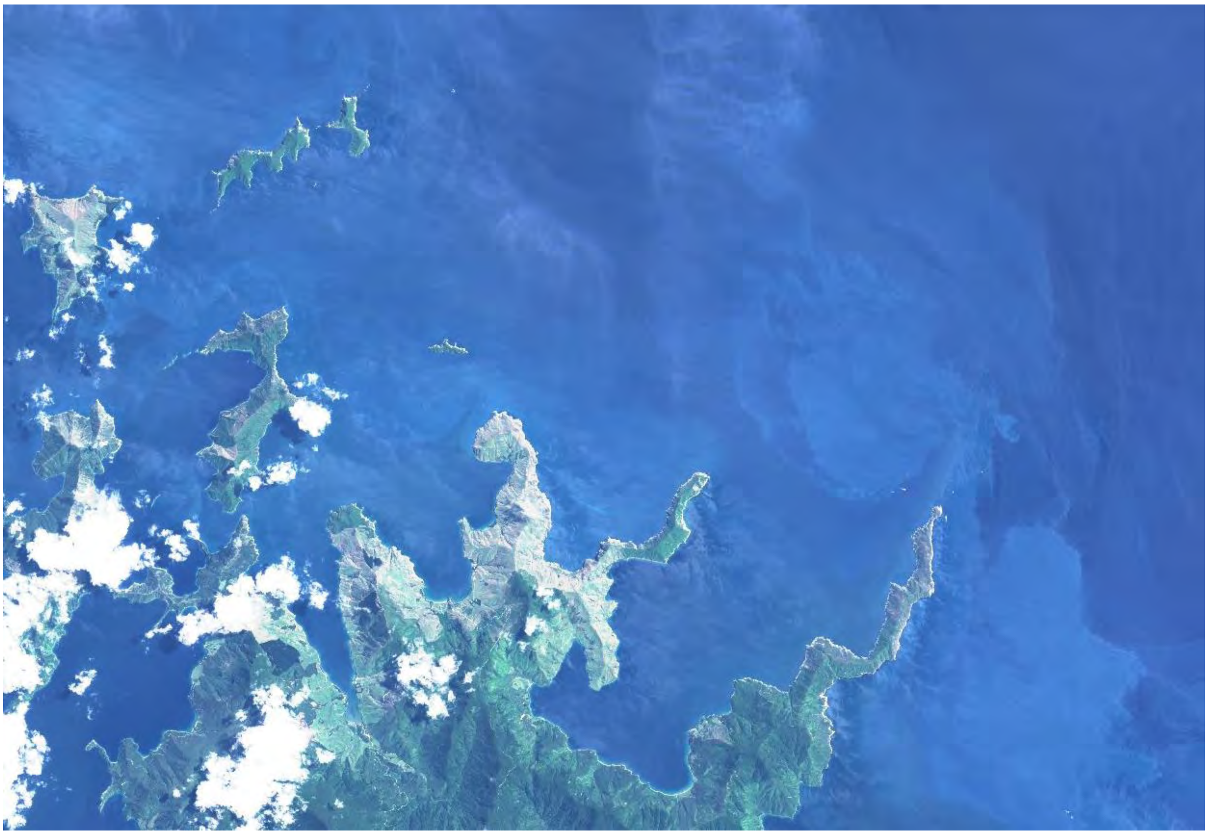


Figure 18. LandSat 8 ocean colour scene showing surface water conditions around Port Gore and the proposed farm site on 20 January 2018. This image was collected five days before sampling was undertaken at the site. Source: USGS/NASA.

Figure 19 shows that turbidity variation was generally uniform throughout the water column on 7 August and 6 October 2018 and increased with depth at all stations on 25 January 2019.

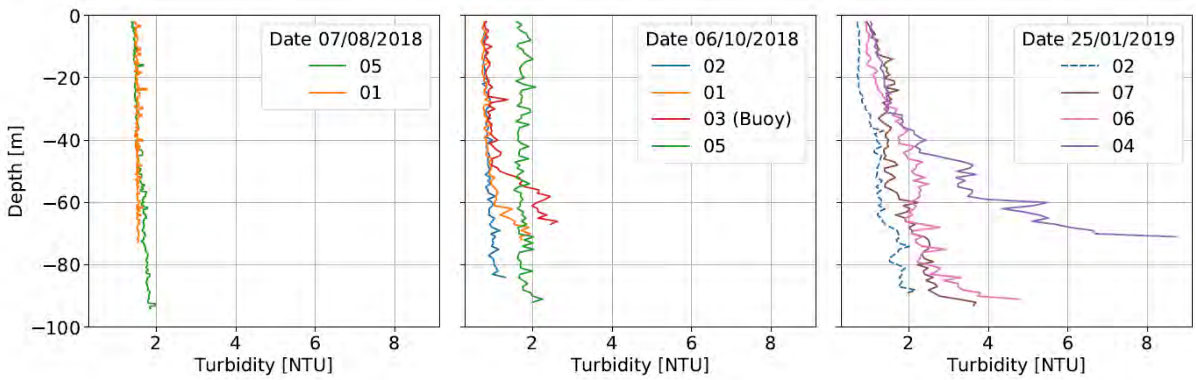


Figure 19. Variation of turbidity with depth at 7 stations on 7 August 2018, 6 October 2018 and 25 January 2019. Station 02 is dashed in January to indicate that this cast was taken on 9 January 2019.

The upper measurements of turbidity recorded in the surveys are lower than those seen at the Port Gore sampling station nearer shore (Broekhuizen 2015). This would be expected because offshore waters normally have lower turbidity and because the offshore data did not include stormy winter periods[4].

Concentrations of suspended sediments were analysed from water samples collected on two occasions and are reported here to supplement turbidity information. The results of these samples were:

- triplicate samples taken at station 3 (buoy) (10 m) in October 2018: 1.1, 1.5, and 3.1 g/m^3
- individual samples taken at three stations (5 m) in January 2019: 1.5 g/m^3 (station 4), 3.56 g/m^3 (station 6), 1.71 g/m^3 (station 7).

It should be noted that although suspended sediment content of water samples is related to water clarity it cannot be used to accurately predict turbidity (which is a measure of the reflectance of light in the water column). These results do however indicate a degree of variability within a site at approximately the same scale as variability between sites.

4.2. Nutrient and biological characteristics

4.2.1. Nutrients

Table 1 summarises concentrations of various nutrient species in the water samples. Concentrations of TN ranged from 137 to 185 mg/m^3. These values are within, but at the lower end of the range seen at the nearshore sampling site in Port Gore (120–450 mg/m^3) reported by Broekhuizen (2015). The data are also consistent with data from other established salmon farms in the Marlborough Sounds[5] (see Broekhuizen & Plew 2018).

Ammonium (NH_4-N) values in the proposed aquaculture site were quite low compared to the range recorded for Port Gore. Neither TN nor NH_4-N appeared to be lower in summer than winter in the proposed aquaculture site. However, there is some indication that nitrate (NO_3-N) concentrations were lower in summer than winter. Low NO_3-N in summer could indicate nitrogen limitation. Nitrate is variable year-round in the Tory Channel, but often displays a pattern of winter variability and low summer concentrations in the Pelorus Sound (Broekhuizen & Plew 2018). In this Sound, Nitrate+Nitrite (NO_3-N+NO_2-N) concentrations are frequently < 5 mg/m^3 (and often < 30 mg/m^3) over several monthly surveys. Nitrate concentrations in January 2019

[4] Note that due to a lack of validation of the data from the the NZ King Salmon monitoring and the MDC state of the environment water quality monitoring programme, and the frequency of out-of-range measurements of turbidity, we do not include a comparison with that data set here.
[5] https://cawthron.shinyapps.io/WQ-Marlborough/

ranged from 20 to 35 mg/m^3, indicating that the proposed offshore aquaculture site (at least on the day of sampling) is not extremely nutrient-limited relative to nearshore environments. Concentrations of other important nutrient species, such as dissolved reactive silica (DRSi) and dissolved reactive phosphorus (DRP) were very similar to concentrations reported for the nearshore Port Gore sampling station. The nutrient data presented here provide an indication of the nutrient status of the waters in the proposed area but are insufficient to fully assess limitations on phytoplankton production in the area although N is likely to be the limiting nutrient.

Table 1. Summary of nutrient concentrations (mg/m^3) in water samples collected on three occasions at 6 stations in the proposed farm area.

Collection date	Station	Sample depth (m)	TN	PN	TDN	NO_2-N	NO_3-N	NO_3-N +NO_2-N	NH_4-N	DIN	TP	DRP	DRSi
7 Aug 2018	1	0–15	163	12.8	162	3.9	53	57	4.2	61	78	24	129
	2		142	8.19	135	2.8	41	44	3.9	48	18	15.1	211
6 Oct 2018	3 (buoy)	1	N/A	N/A	158	N/A	N/A	66	2	68	N/A	17	116
		5	N/A	N/A	149	N/A	N/A	65	3	68	N/A	17	96
		10	N/A	N/A	152	N/A	N/A	65	4	69	N/A	15	124
		15	N/A	N/A	153	N/A	N/A	66	5	71	N/A	21	114
		20	N/A	N/A	168	N/A	N/A	66	4	70	N/A	16	105
		25	N/A	N/A	168	N/A	N/A	66	5	71	N/A	16	117
		30	N/A	N/A	156	N/A	N/A	63	2	65	N/A	24	111
25 Jan 2019	4	5	137	N/A	108	N/A	35	N/A	2.1	N/A	N/A	7.3	46
	6		162	N/A	135	N/A	29	N/A	5.9	N/A	N/A	2.4	50
	7		185	N/A	141	N/A	20	N/A	5.9	N/A	N/A	2.5	34

TN: total nitrogen; PN: particulate nitrogen; TDN: total dissolved nitrogen; NO_2-N: nitrite-nitrogen;
NO_3-N: nitrate-nitrogen; NH_4-N: ammonium-nitrogen; DIN: dissolved inorganic nitrogen;
TP: total phosphorus; DRP: dissolved reactive phosphorus; DRSi: dissolved reactive silica.
Some nutrient data are not available (N/A) due to a series of field and laboratory errors.

4.2.2. Chlorophyll-a and phytoplankton communities

Natural chlorophyll-*a* levels and the phytoplankton communities associated with a marine area have the potential to affect the response to nutrient enrichment from finfish aquaculture. For instance, the growth of phytoplankton can be governed by the existing phytoplankton biomass (often described by chlorophyll-*a*). For example, while phytoplankton in marine systems are generally nitrogen limited, if sufficient phytoplankton biomass is not available, phytoplankton production may be retarded. Similarly, a site may be more susceptible to harmful algal issues, if species that can cause the issues are already present in the phytoplankton community. Consequently, site characterisation of these properties is an important undertaking and was conducted for this assessment.

Chlorophyll-*a*

Concentrations of chlorophyll-*a* (used as a proxy for phytoplankton biomass) monitored during the period October 2018–January 2019 ranged from 0.09 to 3.93 mg/m^3 (Figure 20). The mean concentration was 0.84 mg/m^3 and the median was slightly lower (0.67 mg/m^3). This difference reflects the greater variability of concentrations in the upper part of the range on the mean concentration.

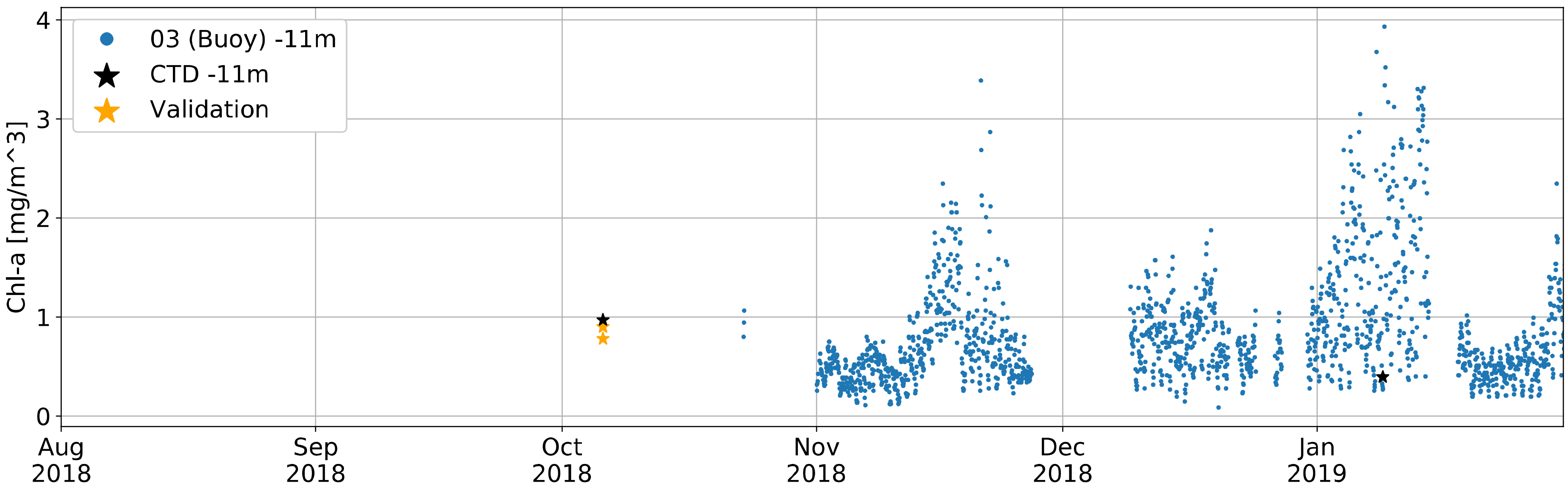


Figure 20. Time series of chlorophyll-*a* measured at station 3 from October 2018 to January 2019. Black stars indicate chl-*a* measurements from CTD casts and orange star indicates data validation date.

Cast data from the fluorometer attached to the CTD unit showed that chlorophyll-*a* was quite evenly distributed throughout the water column. However, in one cast in October (station 1), a peak in chlorophyll-*a* was apparent in the top 20 m of the water column (Figure 21).

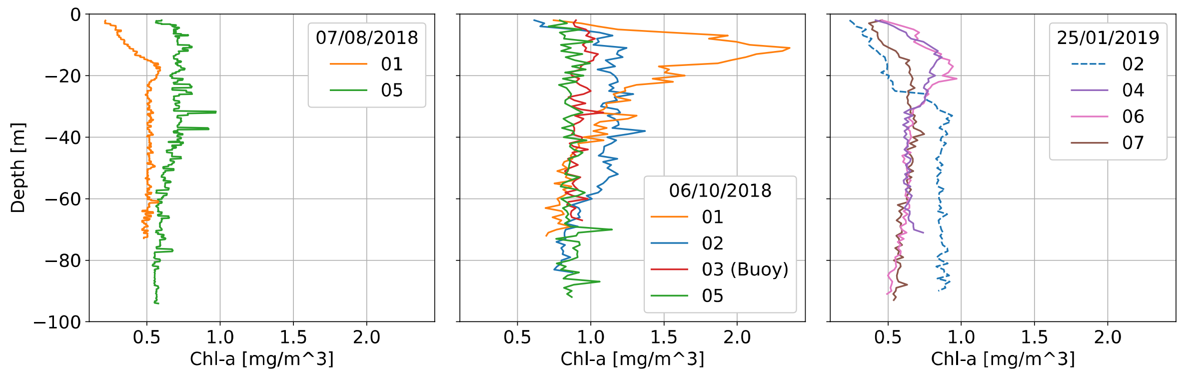


Figure 21. Variation of chlorophyll-*a* with depth at 7 stations on 7 August 2018, 6 October 2018 and 25 January 2019. Station 2 is dashed in January to indicate that this cast was taken on 9 January 2019.

Subsampling of CTD data for comparison with moored instruments at the same depth did not indicate inconsistency between instruments (see Appendices 6 and 8). However, only one CTD cast was taken in the period for which data from the moored instruments are available. Physical water samples available for validation of the moored instruments were taken only prior to the deployment of the fluorometer meter but results were very similar to the mean from the moored instrument (see the yellow symbols in Appendix 7).

The high frequency of chlorophyll-*a* concentrations < 1 mg/m^3 is consistent with results obtained for the nearshore site in Port Gore, as are the peak values recorded by the offshore buoy.

Reference stations in existing salmon farms in the Marlborough Sounds[6] appear to have a tendency towards higher peak values of chlorophyll-*a* than offshore sites. This would be expected to occur in more enclosed nearshore waters, where phytoplankton productivity is likely to be higher. This suggests the phytoplankton community response to new nutrients could be slightly lower at the proposal site than the Marlborough Sounds, as there is less phytoplankton biomass is available to assimilate the nutrients.

[6] https://cawthron.shinyapps.io/WQ-Marlborough/

Phytoplankton

Table 2 presents phytoplankton composition and abundance in water samples collected at stations 1, 4, 5, 6 and 7 on 7 August 2018 and 25 January 2019.

On both sampling occasions, the phytoplankton community was dominated by diatoms. In samples collected on 7 August, *Chaetoceros* spp. were the most abundant followed by *Thallasiosira* and *Nitzchia*. In January 2019 samples, *Leptocylindricus* and *Pseudonitzschia* spp. predominated (Table 2). The latter are potentially toxic, although toxic species are very rarely detected in the Marlborough Sounds.

Flagellate phytoplankton (dinoflagellates, etc.) were only present in low numbers and the predominance of diatoms is indicative of a fertile, well-mixed water column. It is likely that phytoplankton communities of this nature are the norm for this area.

Low numbers of a few species potentially hazardous to sea-pen fish were identified in the samples (*Chaetoceros convolutus, Fibrocapsa japonica, Heterosigma akashiwo, Karenia umbella, Chrysochromulina* spp.). However, these are all common species in the phytoplankton in the Marlborough Sounds and would not have harmful effects unless occurring as intense blooms which are (possibly with the exception of *C. convolutus*) most likely in sheltered, enclosed waters with strong stratification and limited water exchange characteristic.

Collection of phytoplankton data across the year would supplement the information presented here. We also note that phytoplankton has been surveyed approximately fortnightly over a period of 18 months in association with a mussel farming consent held on the west of D'Urville Island. Comparison of this species list (if publicly available) with that from existing NZ King Salmon monitoring datasets may also provide an indication of the similarities in phytoplankton community structure inside and outside of the Marlborough Sounds.

Table 2. Phytoplankton taxa from the proposed aquaculture area. Greater abundances are indicated by the bright red shading, lower abundances with progressively cooler colours.

Sampling date	7/08/2018							7/08/2018							25/01/2019		
Sampling site	1 (NE)							5 (SW)							04	06	07
Depth (m)	1	5	10	15	20	25	30	1	5	10	15	20	25	30	5	5	5
Diatoms (Bacillariophyceae)																	
Achnanthes sp.								200									
Actinoptychus spp.																	200
Chaetoceros spp.	23000	13000	32000	19000	52000	4600	20000	3400	5000	7600	2600	11000	1600	5200	1600	3000	9000
Chaetoceros convolutus							200									200	
Corethron sp.														200	200		
Cylindrotheca sp.																	200
Diploneis sp.					200	200		400		200	200	200		400			
Ditylum sp.	200	400		400	200							200					
Entomoneis sp.			200								200					200	
Eucampia spp.	600																
Guinardia sp.	200		800												2000	2400	4200
Hemiaulus sp.																	2200
Lauderia sp.	600	600			2400				200								
Leptocylindricus spp.															22000	63000	37000
Navicula spp.		400	200	200			400		400		200		200			600	200
Nitzschia spp.	400	1000	600	800	1000	1600	1000	1000	800	800	400	800	1200	800	200	800	200
Pleurosigma sp.			200	600				200						200			
Pseudonitzschia spp.		400								400			1000		51000	66000	114000
Rhizosolenia sp.												200			2800	8800	14000
Skeletonema costatum		7000		1400			2000				2000		1600		2400		1800
Thallasionema sp.										800							
Thalassiosira spp.	1200	2200	1800	1400	2200	600	3800	2600	800	600	800	800	600	2400			
Dinoflagellates (Dinophyceae)																	
cf. *Azadinum* sp.																	400
Diplopsalis sp.	200																
Gymnodinium spp.		400	400		1000	800	400	600	200	800	200	200				600	1200
Gyrodinium spp.				200			200		200			200					400
Heterocapsa spp.	200	200					200										200
Karlodinium sp.												200					
Katodinium sp.					200												
cf Karenia umbella																	200
Peridinium sp.		200		200		200											600
Prorocentrum sp.																	200
Protoperidinium spp.	200		200	400						200	200						200
Scrippsiella sp.	200																200
Torodinium sp.	200											200					
Dictyochophyceae																	
Dictyocha sp.																	200

Sampling date	7/08/2018							7/08/2018							25/01/2019		
Sampling site	1 (NE)							5 (SW)							04	06	07
Depth (m)	1	5	10	15	20	25	30	1	5	10	15	20	25	30	5	5	5
Pyramimonadaceae																	
Pyramimonas sp.	200																
Prymnesiophceae																	
Chrysochromulina spp.									200								
Phaeocystis sp.																	4400
Raphidophyceae																	
Fibrocapsa japonica		200															
Heterosigma akashiwo																	400
Cryptophyceae																	
Cryptomonas sp.											200	200	200				200
Euglenophyceae																	
Euglena sp.	200				200				400	400	200						
Other																	
Unidentified flagellates	600	400	200	200							1000	200	400			200	1800
Mesodinium rubrum	400	600						200			200						800
Unidentified ciliate	600	400	800	200	600	200	600	600	600	800	800				400	400	3800

4.3. Dissolved oxygen

In this section, we present results of continuous DO measurements taken at station 3 during the period 6 October 2018–25 January 2019 and depth profiles of DO at stations 1–7 on the first and last days of this monitoring period.

During the monitoring period, DO concentrations at station 3 ranged from 7.0 to 8.9 mg/L (Figure 22). The monitoring data indicate a decreasing trend in DO concentrations over time which is mainly due to the waters warming into the summer period (colder waters can hold more oxygen than warmer waters). Percent saturation data were available for a slightly shorter time period as their calculation from absolute concentrations requires temperature and salinity data that were not available for some periods during deployment.

Percent saturation of DO ranged from 84 to 111% (Figure 22). In deep waters (66 m), the mean oxygen saturation was 93% and waters never became oversaturated (i.e. did not exceed 100% saturation). In shallow waters (10 m), the mean saturation was 98% and the water was frequently oversaturated. Oversaturation can be caused by phytoplankton producing oxygen as they photosynthesise.

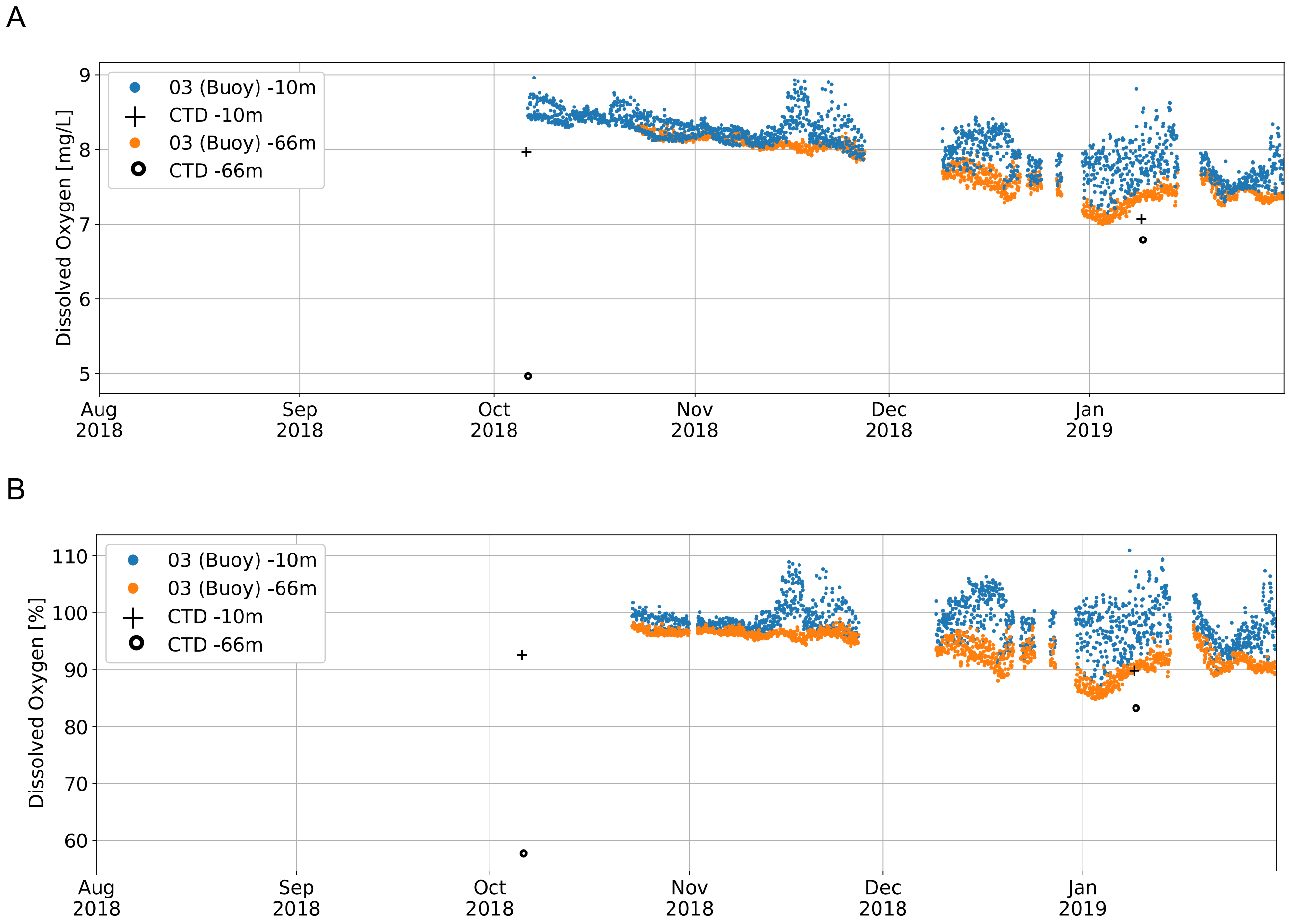


Figure 22. Time series of dissolved oxygen at station 3 expressed as absolute concentration (A) and percent saturation for dates with supporting temperature and salinity data available (B) from October 2018 to January 2019. Black symbols indicate dissolved oxygen concentrations from CTD casts.

Water column profiles of DO showed very uniform variations with depth (Figure 23). One notable exception occurred at station 3 (buoy) in October. This low DO concentration near the seabed was associated with an increase in turbidity (Appendix 5). Therefore, it is possible that a sediment plume was created by some disturbance of the seabed causing low DO to be recorded in the water column, although we note that, on other occasions, turbidity increased without a corresponding decrease in DO.

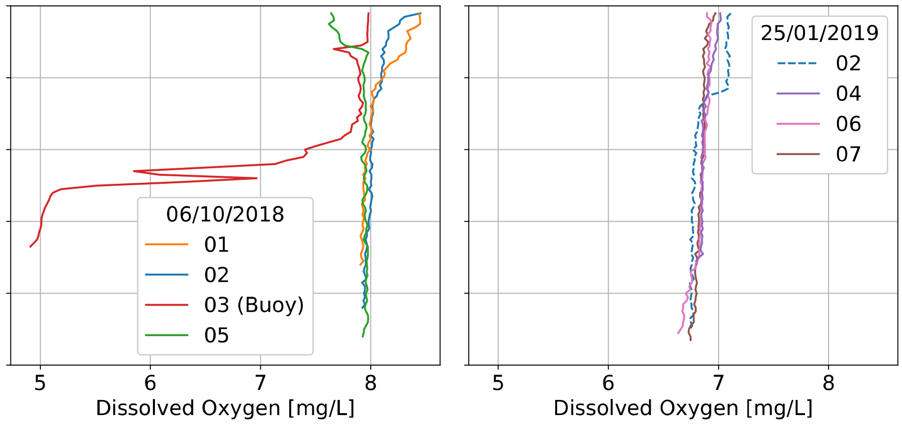


Figure 23. Variation of dissolved oxygen with depth at 7 stations on 6 October 2018 and 25 January 2019. Station 02 is dashed in January to indicate that this cast was taken on 9 January 2019. Note that the O_2 meter on the CTD was faulty on the 7 August 2018 so data for this survey are not presented.

Subsampling of CTD data for comparison with moored instruments at the same depth indicated that the CTDs tended to measure lower DO than the moored instruments (see Appendices 6, 8). The very low measurement recorded near the seabed at the buoy is a notable outlier with respect to all other data and may therefore be the result of some unusual occurrence.

5. ASSESSMENT OF NUTRIENT EFFECTS

In this section, we present estimates of Total Nitrogen (TN) inputs from rivers into the greater Cook Strait and results of an assessment of TN changes in surface waters resulting from the proposed farm.

Nitrogen is considered to be the most important nutrient limiting primary production in the Marlborough Sounds and surrounding area. Therefore, it is important to consider its potential effects in more detail. To estimate riverine inputs into the greater Cook Strait, inputs of TN from rivers in Tasman Bay and Golden Bay, Marlborough, Wellington, and Manawatu were calculated from nutrient and flow data obtained from NZ River Maps[7]. Total nitrogen NZ River Maps TN figures are an 'estimate of the median from many samples'. The results indicate that approximately 1,500 tonnes of TN flow into the Tasman and Golden bays annually. The Wairau River contributes 700 tonnes to eastern Cook Strait, and over 2,000 tonnes enters the Strait from the Ruamahanga River via Lake Onoke (Table 3).

To place TN riverine inputs in context, if net flux (the total amount of water that passes through the Strait) is 250,000 m^3/s as estimated by Stevens (2014) and TN concentrations are about 150 mg/m^3 then approximately 37.5 kg of nitrogen flows south out of Cook Strait per second. This equates to a mean annual flux of 1.2 million tonnes of TN. If the total transport of 4.1 million m^3/s (as estimated by Vennell 2011) is used in this calculation, 19 million tonnes of TN are estimated to pass through the Strait annually. Taken together, these results indicate that TN from terrestrial sources is likely to be a small proportion of the nitrogen flux through the offshore waters of Cook Strait. It also suggests that even relatively large anthropogenic inputs of nitrogen could be considered small in the context of the natural flows through the strait (e.g. 1% of 1.2 million tonnes of TN = 12,000 tonnes of TN). Consequently, at a broad scale, the Cook Strait region would seem to be a reasonable place to consider potentially large releases of nitrogen.

[7] https://shiny.niwa.co.nz/nzrivermaps/

Table 3. Annual total nitrogen inputs from rivers flowing into or near Cook Strait. Results calculated from modelled data available from NZ River Maps (https://shiny.niwa.co.nz/nzrivermaps/)

	Total nitrogen (tonnes per year)
Nelson/Tasman	
All Tasman Bay rivers	954
All Golden Bay rivers	640
Marlborough	
Pelorus	229
Kaituna	42
Wairau	702
Awatere	149
Wellington	
Otaki	143
Waikanae	70
Hutt	228
Wainuiomata	34
Ruamahanga River/ Lake Onoke	2,003
Manawatu	
Rangitikei	951

5.1. Near farm changes in nitrogen

A variety of dissolved and organically-bound nutrients are released by salmon farms (of which nitrogen is of most relevance to marine ecosystems). The effect of these nutrients can be to stimulate the production of marine macro- and microalgae (phytoplankton) when such nutrients are limiting. These autotrophic (self-fuelled) organisms sit at the base of the marine food chain and support a wide diversity of marine life. They do, however, have the potential to cause issues when their abundance and subsequent decay affects the life-supporting properties in the water (e.g. dissolved oxygen availability). Provided concentrations of nitrogen do not deviate greatly from their natural concentrations, the potential for dystrophic effects, such as dissolved oxygen issues or changes in phytoplankton, are unlikely to occur.

We used simple calculations to assess the magnitude of increases in total nitrogen (TN) associated with the proposed Stage 1 feed loading. This is a very simple calculation which takes the approach described for DO (see Section 5.1) and calculates the amount of nitrogen released by the biomass of salmon in the time the water takes to pass through the pens. The approach also assumes a 70% reduction in the ambient current due to the nets (Johansson et al. 2007) and no horizontal mixing with the surrounding water. The calculations also assume a fish biomass density in the net pens of about 10 kg/m^3. Due to the simple nature of the calculations a linear change in our results would be expected for any deviations from this. For example, doubling the density of fish in the pens, or the number of cages parallel to the current, would double the expected downstream nitrogen concentration changes.

5.1.1. Nitrogen loss from salmon

The expected average nitrogen release rate was calculated assuming that the nitrogen released to the environment is simply the difference between the nitrogen fed to fish minus the nitrogen assimilated by fish and removed at harvest (e.g. Gowen & Bradbury 1987). The key factors in this calculation are the protein content of the feed (which is assumed to be 40% based on recent NZKS data) and the amount of dry weight feed required to produce a given amount of wet fish (the feed conversion ratio). For our calculations, a feed conversion ratio of 1.81 is assumed, based on data provided in the New Zealand King Salmon Annual Report (2018). This ratio means every 1 tonne of wet fish produced will require 1.81 tonne of dry feed and excrete about 89 kg of total nitrogen (Table 4). Of that 89 kg of N, about 70 kg of it will be in a dissolved form (mainly ammonium), with the remaining 19 kg associated with the solid waste, e.g. undigested protein, or within the water component of the faeces. For the purposes of our analysis, we use the feed as a basis for our calculations, for which total nitrogen loss is about 49 kg per tonne of feed (Table 4).

Table 4. Calculations required to estimate the total nitrogen (TN) and dissolved nitrogen (DN) released per tonne of feed given or fish produced. Input values and their references are provided in the top half of the table.

Description	Value
Feed conversion ratio (FCR) (NZKS annual report 2018)	**1.81**
Percentage Protein in Feed (Avg. NZKS 2017/2018)	**40%**
Percentage N in protein (16%; Stead and Laird 2000)	16%
Fish N (kg retained/tonne of fish; Bromley and Smart 1981)	27.20
Faeces production (Butz & Vens-Cappell, 1982)	26%
N % in faeces (Penczak et al. 1982)	4%
Feed N (kg/t feed)	64
Feed N (kg/tonne of fish produced)	115.84
Lost TN (kg/tonne feed)	**48.97**
Faeces production (kg/tonne fish)	470.6
Faeces N lost (kg/tonne fish)	18.82
DN excretion (kg N/tonne feed)	**38.57**

5.1.2. Potential total nitrogen changes

The results of the downstream net pen concentration changes suggest that during periods of low flow (< 10 cm/s currents) the concentrations downstream of the net pens can become very high (> 180 mg/m^3; Figure 24). However, given that mean current speeds at the site are about 40 cm/s, periods of low flow seem unlikely to occur for more than four hours per day[8]. Estimated changes in TN concentrations around the mean current speed relate to a peak increase in nitrogen concentrations of about 54 mg/m^3 immediately downstream from the net pens (about a 30% increase in ambient TN concentrations; Figure 24).

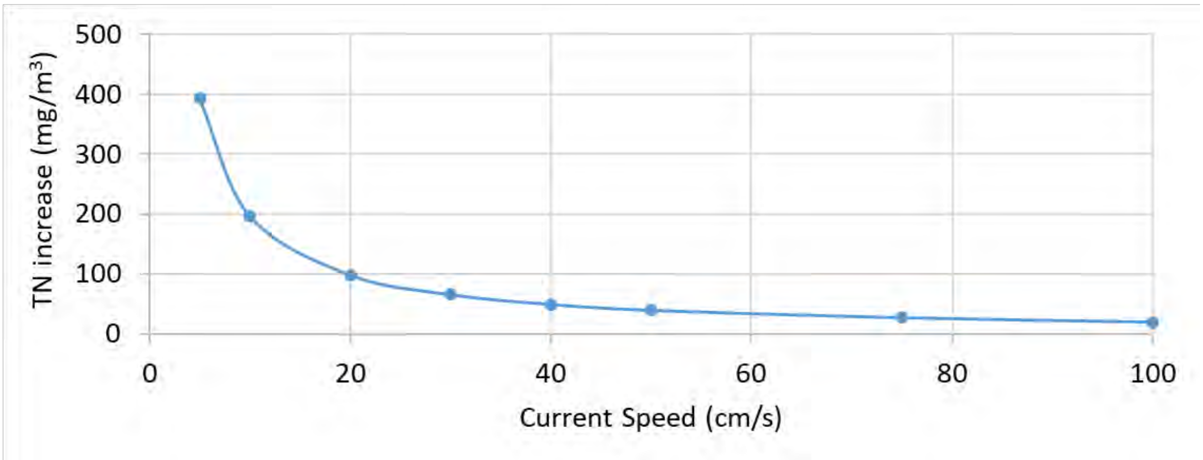


Figure 24. Simple calculation estimating the near net pen change in total nitrogen that is possible under different ambient current conditions due to the nitrogen excretion from farmed salmon. The values are expressed as an increase in upstream TN.

While the calculations are stated as TN concentration changes, the nitrogen excreted from the salmon is likely to be in a dissolved form (mainly ammonium, but also urea). Guidelines for ammonia exist (e.g. Batley & Simpson 2009), but these suggest a very high trigger value of 460 NH_4-N mg/m^3 is appropriate for slightly to moderately disturbed systems. Our calculations presented here, suggest that such a high trigger value is highly unlikely to reached, even right beside the farm. As nitrogen is a sought-after element in the marine environment, dissolved forms of N are also likely to be short lived and will be quickly assimilated by pelagic phytoplankton and bacteria. Therefore, the degree of dissolved N change would be unlikely to be associated with any toxicity and will be rapidly (i.e. within hours) be represented as TN concentrations around the farm.

Given the large volumes of water interacting with the site and the natural assimilation and denitrification processes that occur, it seems likely that nitrogen changes would be very hard to detect around the site, except directly beside the net pens during a

[8] Assuming up to an hour around slack tide, up to four times per day.

periods of low to moderate flow (i.e. < 50 cm/s current). Our experience with monitoring smaller inshore sites (e.g. Bennett et al. 2018a, 2018b, 2018c) suggests that the maximum TN concentration changes associated with these farms are unlikely to be measured beyond 500 m from the net pens. Given that the currents are much stronger than those in the Sounds it is possible that the nitrogen 'footprint' of the farm could be greater than observed in inshore sites. Consequently, it may not be possible to achieve some of the objectives that were stated for the inshore sites. For example, the current objectives for the recently consented inshore farms state that the farms shall be operated at all times so as 'To not cause elevation of nutrient concentrations outside the confines of established natural variation for the location and time of year, beyond 250 m from the edge of the net pens'. If a stated 'boundary of acceptable effects' is deemed necessary for the water column, this should be based on either improved modelling, or extrapolation of inshore site measurements to the higher currents at the proposed site.

Limitations of the calculations

As with any modelling exercise, simplifications have been required to undertake our calculations. For instance, because our calculation approach assumes no horizontal mixing occurs and there is a 70% reduction in currents, this approach would be expected to overestimate the likely average changes in nitrogen concentrations at the downstream boundary of the net pens when compared to the upstream boundary. We also do not attempt to address any of the transport and dispersion effects that act on the water that has left the net pens. However, as the calculation also assumes a simple unidirectional flow, the absolute quantum of concentration change can also be underestimated when compared a tidally reversing flow. Given the recent availability of a new 3D hydrodynamic model for this region, updated modelling is planned to address this issue.

As well as the dilution and accumulation that can occur if transport processes are included, subsequent biological transformations of nitrogen can also occur in the real world and can lead to removal of nitrogen as gas (denitrification) or incorporation of nitrogen into biological material that can affect coastal ecosystems (e.g. harmful algal blooms). While this modelling exercise does not attempt to quantify these risks, we consider that this site presents lower risks of adverse water column effects when compared to inshore sites. This is because it is further removed from areas where high phytoplankton biomass events are known to occur (e.g. Opua and Nydia bays in the Marlborough Sounds).

5.2. Potential effects of nutrients on chlorophyll-*a* and phytoplankton

Although there is general consensus that fish farms can cause localised nutrient enrichment, the effects on phytoplankton communities in general (e.g. species composition and abundance) are not well understood for coastal waters (Gillespie et al. 2011). While it is possible for additional nutrients (particularly nitrogen) to create additional phytoplankton, changes in the grazing communities that consume phytoplankton can ultimately affect their abundance, therefore predicting such changes is difficult. One way to estimate the potential effects on phytoplankton communities is to model their interactions with nutrients and grazing populations within a 3D hydrodynamic model, as has been done by NIWA researchers in recent years in the Marlborough Sounds (Broekhuizen & Hadfield 2016).

These biophysical models are useful, because the nutrient-gearing effect of nitrogen[9] means that the amount of indirect organic matter created through salmon nitrogen increasing phytoplankton can be many times higher than the direct organic deposition from fish faeces. However, as this deposition occurs over a very wide area, its effects are typically small and difficult to detect in the benthic environment away from the farms. However, if new nutrients are large enough, or are combined with other activities, there exists the potential for cumulative enrichment, which could be significant.

5.2.1. Potential for cumulative effects

Analysis of the currents from the site suggest that at least some of the nutrients from the farm could be transported into Pelorus Sound (see Section 4.1.1), so it is possible that phytoplankton changes could be realised at this distant location. In a way, this represents a worst-case scenario, as existing farms are located here and potential new farms are also being considered.

Potential further expansion of farming in Pelorus Sound is being considered under a relocation scheme which proposes to relocate farms from Queen Charlotte Sound. While the proposed relocations have not been decided, an independent panel report has recommended that the highest degree of potential new discharges are not considered (i.e. recommended relocations are much less than 22,600 tpa feed). Hence, while there is still some uncertainty around the potential future development that could occur in that area, it appears unlikely that a full 22,600 tpa of new feed inputs proposed under the largest scenario considered would occur. However, it is possible that some fraction of the nutrients from the proposal considered here could cumulatively add to the existing and potential 'relocated' farms. We consider this a worst-case scenario for the fate of nutrients from the offshore proposal, as it considers the potential for offshore farm nutrients to interact with existing nutrient pressures in a region where high phytoplankton biomass events occasionally occur and where recent HAB events have occurred[10].

[9] For every 16 mol of nitrogen, phytoplankton can capture 106 mol of carbon (Redfield 1934), i.e. about 5.6 grams of carbon for every gram of nitrogen.

[10] E.g. https://www.stuff.co.nz/business/104289991/algal-blooms-in-marlborough-sounds-could-be-an-annual-issue-for-mussel-farmers (accessed 13 June 2019)

Although the offshore proposal is a long way from the entrances of either Sound, the modelled currents suggest that some net toward-shore flow is possible. Initial particle modelling has allowed us to quantify the nutrient load from the offshore farms that could enter both sounds and the outer embayments near to the proposal. This simulates the release of nutrients as neutrally buoyant particles with a given load matching the release rate estimated for the farm (Figure 25). The release rate of the particle was such that 131,000 particles were released over 90 days (i.e. about 1,350 per day).

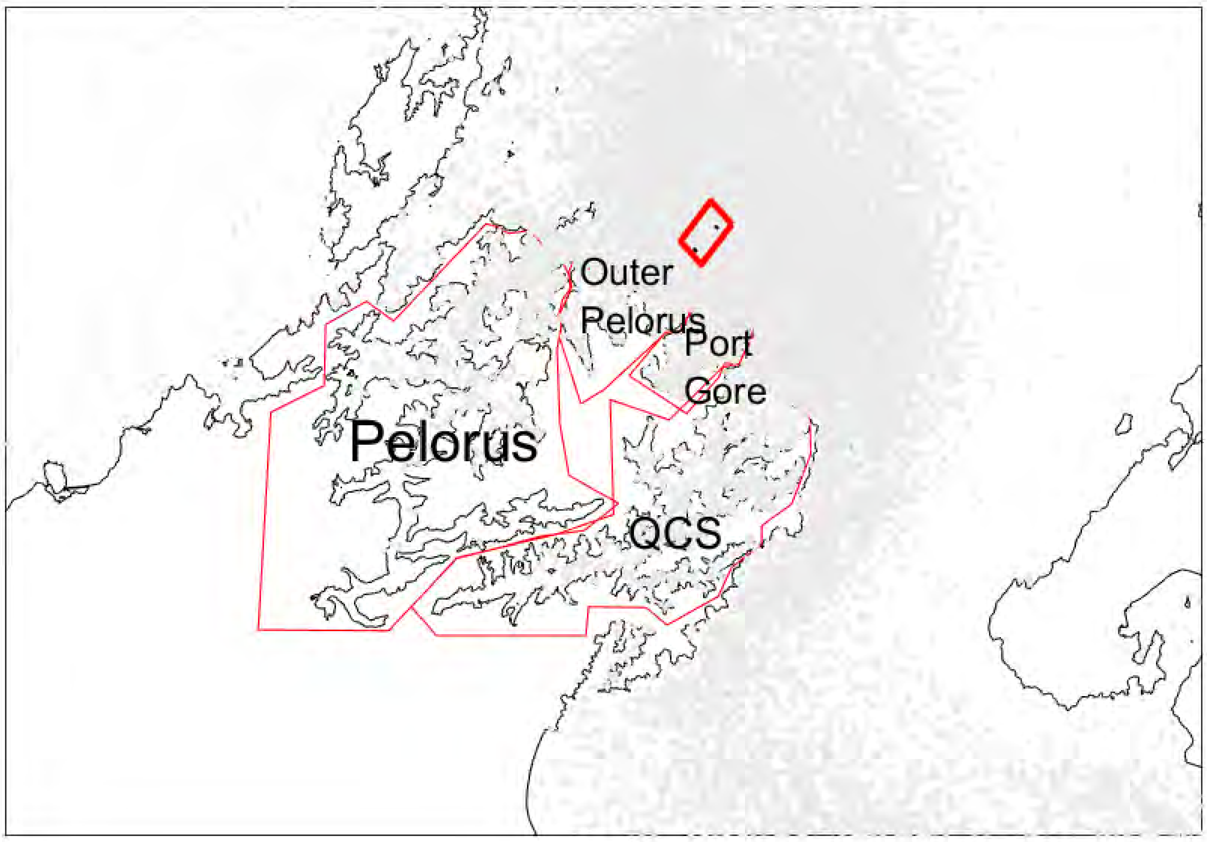


Figure 25. Particles locations released by the model after 90 days (grey dots) and regions in which statistics were calculated. The lines around each area were used to define the regions. The red box to the north of the sounds shows the proposal area.

Based on a simple analysis of the model simulations, it appears that Queen Charlotte Sound would receive the highest proportion of the released nitrogen from the farm, assuming no loss of nitrogen due to biological processes (e.g. denitrification). However, even in Queen Charlotte Sound, after 90 days less than 1% of the released nitrogen is predicted to enter the region (Figure 26). For all the other regions, e.g. Pelorus Sound, less than about 0.6% of the nitrogen is predicted to enter after 90 days.

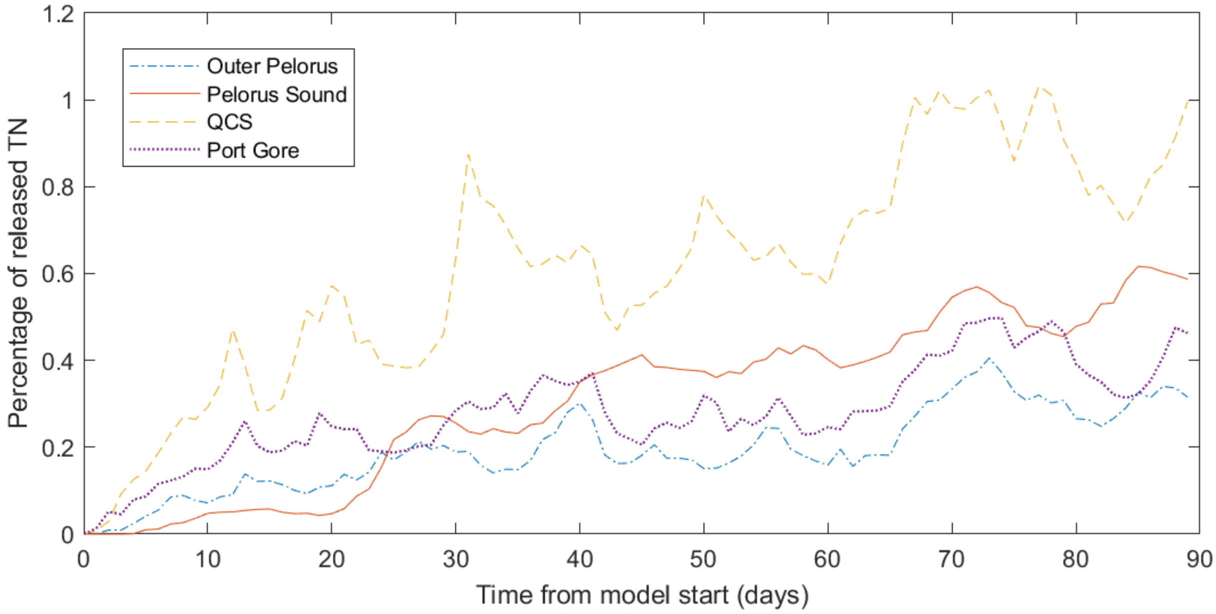


Figure 26. Proportion of total nitrogen, relative to the released nitrogen from the proposal, predicted to enter the different areas of the Marlborough Sounds over the period 1 July to 29 September 2017, assuming no decay. Refer to Figure 25 for the locations.

In order to present a more realistic scenario, where some nitrogen loss could occur, a second calculation was undertaken to downscale the load of nitrogen present in older particles. In order to do this, a decay rate was calculated assuming a time for 90% decay of 22 days[11]. When the decay rate was applied, a lowering in the proportion of TN entering the regions was noted, but the same general patterns were evident in the data (Figure 27). In the updated modelling, a decrease of about 10% was evident, such that the proportion entering Queen Charlotte Sound was reduced to about 0.9%. However, some caution needs to be applied to these results as it is apparent in the graphs that the proportion of nutrient could still increase if the model was run for longer than 90 days.

[11] This was calculated from information provided in two key references, Caffery et al. (1993) and Vant and Williams (1992) who calculated a net daily ammonium loss of 12%.

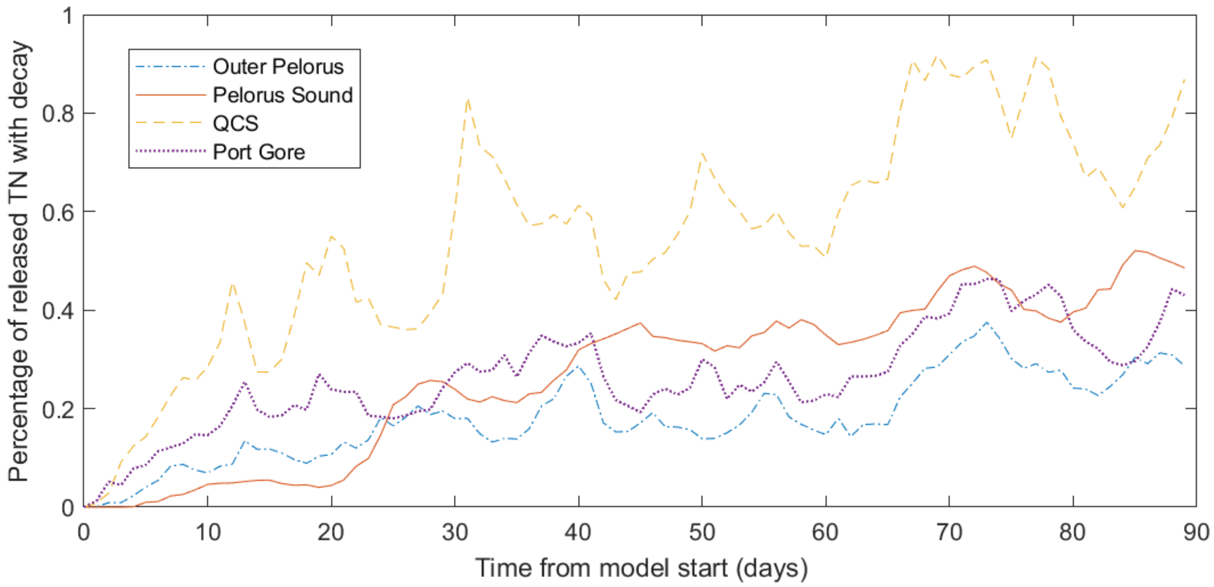


Figure 27. Proportion of total nitrogen, relative to the released nitrogen from the proposal, predicted to enter the different areas of the Marlborough Sounds over the period 1 July to 29 September 2017, assuming 90% decay over 22 days. Refer to Figure 25 for the locations.

In order to account for this, we assume that a maximum value could be twice as high as the 90-day simulations shown here; this means that we assume that up to about 2% of the total nutrient load could enter Queen Charlotte Sound. A simple way to interpret this result, is to consider the proportion of feed that could end up in these regions. In the case of the first stage at the site, 20,000 tpa of feed is proposed. If 2% of this could end up in Queen Charlotte Sound, then this is the equivalent of a 400 tpa feed farm located throughout the sound (say half in Tory Channel and half in outer Queen Charlotte Sound). Current feed levels in Tory Channel are about 10,000 tpa, so this represents an increase of about 2%.

Similarly, for Pelorus Sound, our modelling suggests that approximately 1% of the nutrients could end up in that region, equivalent to a 200 tpa feed farm in the region (this is equivalent to an extra 10 tonnes of nitrogen over a year). Again, this is a small fraction of the existing salmon aquaculture in that region and the additional nitrogen load is small when compared to existing nutrient inputs (both natural and anthropogenic).

5.2.2. Evaluating the potential for cumulative effects in Pelorus Sound

Basic modelling has only been undertaken to assess the effect of the farm in isolation, recent biophysical modelling in the Pelorus Sound was undertaken to assess the cumulative effects from potential relocations by Broekhuizen and Hadfield (2016).

While numerous limitations are associated with this type of modelling (see review by Knight 2016), it still provides the best predictions of potential effects of large nutrient loading in this area. This modelling considered feed load increases within Pelorus Sound of between 1,500 to 22,600 tpa of additional feed loading, with analysis of model predictions estimating a mean TN change of about 3.3% under the largest changes considered.

The changes to the mean TN concentrations in the model runs were approximately linear and relatively independent of the source location of the nutrients, meaning that limited extrapolation of the results to consider additional offshore nutrient sources is plausible. In addition, the effects on chlorophyll-*a* also follow the TN changes, with relatively small changes in mean chlorophyll-*a* in summer (less than 2%[12]) also predicted under the highest feed scenario[13]. Based on linear extrapolation of the model results, this suggests that a new '200 tpa farm' in Pelorus Sound, brought into effect by the offshore proposal could add an additional 0.03% increase to the mean TN concentrations and 0.02% to the largest mean chlorophyll-*a* changes in the region. These effects would be cumulative to whatever is decided for the relocation farms.

Other considerations

It is also notable that when the modelling work of Broekhuizen and Hadfield (2016) was conducted, no significant harmful algal events had occurred in the Pelorus Sound area for a number of years. However, since its publication a recent arrival of a new species in the region, *Alexandrium pacificum* that produces a potent neurotoxin, has caused closures of mussel farms in the autumns of 2018 and 2019 (see Section 3.3). It may therefore be relevant to reconsider the relevance of the model results to what appear to be small changes resulting from additional nutrients. This is beyond the scope of this assessment given the very small contribution of this proposal at the first stage, but could become important at later stages if a large relocation scenario occurs.

[12] Episodic chlorophyll-*a* increases of up to 10% were also noted in the report.
[13] This maximum scenario is referred to as "scenario 13" in the report of Broekhuizen and Hadfield (2016).

6. ASSESSMENT OF DISSOLVED OXYGEN EFFECTS

Dissolved oxygen (DO) is critical for the survival and good performance of salmon farms. Depletion of DO can occur within and around finfish farms due to the respiratory activities of the farmed fish and microbial degradation of waste materials in seabed sediments (Gillespie et al. 2011). In this section, we present results of simple calculations developed to estimate potential changes in DO concentrations associated with fish respiration downstream of the net pen DO concentrations recorded during the monitoring period.

6.1. Potential near-farm changes in dissolved oxygen

Fish respire—reducing DO concentrations, and exhaling carbon dioxide (CO_2) into the water. The degree of respiration is a function of the fish size, temperature and activity (i.e. swimming speed). In general, King salmon respire less per gram of body weight as they get larger and respire more under increasing temperature and activity. Several studies on oxygen uptake are available for Atlantic salmon (e.g. Hvas et al. 2018), but limited information is available for King salmon, with the most useful information available in an older paper (e.g. Stewart & Ibarra 1991).

Oxygen consumption was estimated based on the model information provided in Stewart and Ibarra (1991) for a variety of swimming velocities based on currents measured at the site (Figure 28). The model also assumes a fish size of 3,500 g (a harvest-sized fish)[14] and a temperature of 18 °C[15].

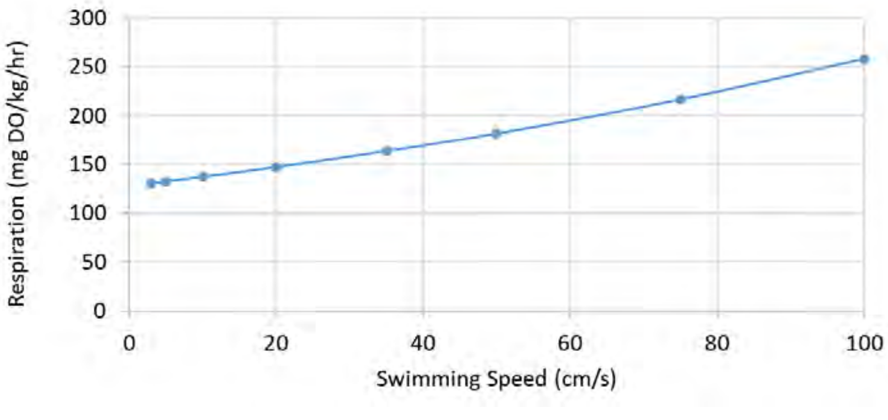


Figure 28. Calculated respiration rate per kg of biomass per hour for a range of swimming speeds for 3.5 kg Chinook salmon at a temperature of 18 °C, based on data provided in Stewart and Ibarra (1991).

[14] Harvest fish sizes are estimated to be in the range of 3.5 kg to 4 kg; a lower fish size is used to provide conservative (higher) respiration estimates.
[15] The respiration rate per kg of fish increases as the temperature increases and the fish size decreases. 18 °C is used as a worst-case maximum temperature, with observed temperatures typically 17 °C or less.

The downstream-net pen DO decrease is then calculated using the geometry of the net configurations relative to the current direction. For the purposes of the calculations, the net pen configurations are based on one group of the proposal, with eight 48-m diameter net pens aligned in two columns of four pens parallel to the current (Figure 2). In this scenario, the maximum possible biomass at harvest is estimated by halving the feed given to the fish over a year. Therefore, a total biomass of 5,000 tonnes is assumed for the eight net pens. This equates to a fish biomass density in the net pens of about 10 kg/m^3. The flow of current is estimated to be 30% of the ambient current speed (i.e. a 70% reduction) based on measured current reductions of between 60 to 77% by Johansson et al. (2007).

The DO decrease downstream of the net pen is calculated by first calculating the time for the water to pass through the four rows of pens, then calculating the amount of oxygen removed in this time by the biomass of fish in the pens, assuming no mixing with the surrounding water. This approach should produce a result that estimates the maximum oxygen change possible under a unidirectional flow. Using this approach, we show a range of potential changes, from the potential for complete consumption of oxygen at low flows (< 3 cm/s), to decreases in DO of less than 20% when currents are > 20 cm/s (Figure 29).

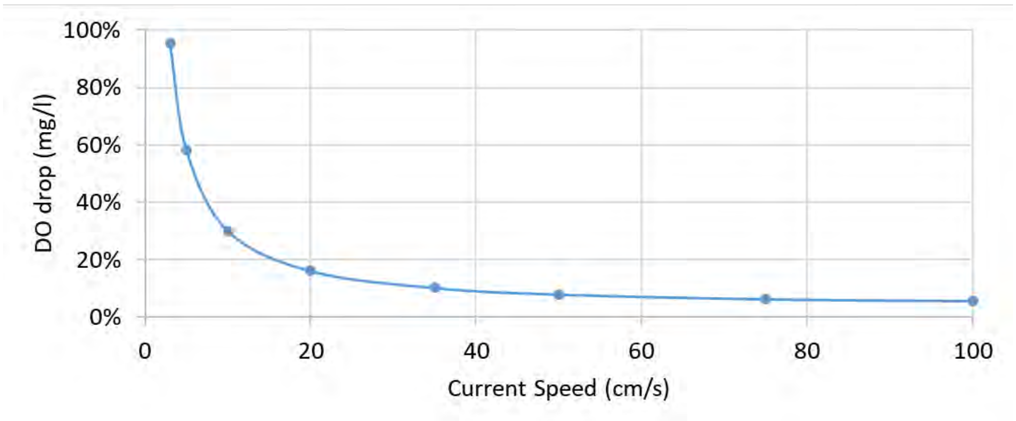


Figure 29. Estimated relative dissolved oxygen decreases downstream of the net pen for given ambient current speeds at the proposed farm site assuming average background DO concentrations of 8 mg/L. Calculations assume no mixing with the surrounding water, a temperature of 18 °C and fish are 3.5 kg in size.

Given that some additional mixing is likely, the likelihood of farmed fish suffocating from the lack of oxygen during slack tide seems very unlikely. Similarly, the mean current speed in the surface waters around the proposed site is also about 40 cm/s (Figure 29) which is associated with DO reductions of about 10%. This means that most of the time the DO decrease immediately downstream of the farm would be expected to be less than 20%. However, given that tidally reversing flows could lead to cumulative decreases in DO (particularly during the night), it is possible that larger cumulative decreases in DO occur over time.

In order to gauge the relevance of these theoretical estimates to real world (tidally reversing flow) measurements, we applied and compared this calculation approach with reported oxygen changes from an Atlantic salmon farm presented in Johansson et al. (2007). Comparison with these data suggest that the approach presented here produces differences that range from an overestimate of 28% to an underestimate of 56%. However, it is relevant that the sites measured by Johansson et al. (2007) were for a different salmon species and that the sites were relatively low flow (10–20 cm/s mean current speeds)[16]. While this is not a thorough validation of the calculations employed here, it nevertheless shows that the results are at least comparable to real world changes. It also shows that the mean current speed from the site used in this approach provides a reasonable estimate of mean DO changes beside the net pens.

Given the deep water of the site and large distance to coastline (6 km north of Cape Lambert) and shallow reef features that could be directly affected by lower DO, we do not consider the changes estimated to extend beyond farm boundaries and cause issues for the wider environment around the farm at the 20,000 tonnes feed load (i.e. 10,000 tonnes fish biomass). However, beyond this level of biomass/feed, we would recommend revisiting our assessment with collected data from Stage 1 and modelling comparisons to these data to ensure effects remained limited to the farm area at future stages.

[16] Note that the highest flow site of Johansson et al. (2007) was associated with the calculations producing higher than observed DO changes.

7. POTENTIAL EFFECTS OF ARTIFICIAL LIGHTING ON PLANKTON

NZ King Salmon propose to install submerged artificial lighting (artificial lighting) in grow-out pens, in the first year of operation. The proposed lighting will consist of up to ten 640W LED fittings per pen, deployed at 5–7 m below the surface. The fittings are installed with a downward light dispersion and have little horizontal diffusion.

Artificial lighting inhibits the rate of maturation (grilsing) in Atlantic salmon that arises as a function of seasonal changes in the day/night cycle, or 'photoperiod' (e.g. Porter et al. 1999). Continuous artificial lighting for farming of King salmon in New Zealand similarly inhibits maturation (Unwin et al. 2005). The benefits of artificial lighting to the aquaculture industry are significant; by virtually removing changes in light as an environmental variable, farms can greatly increase production and reduce the risk of maturation prior to harvest. Placing lights at depth (versus near the surface) during night-time hours also assists in evenly distributing the fish in net pens and reducing fish densities near the surface (Juell et al. 2003). Artificial lighting directly affects the physical characteristics of the water column and, as a result, has the potential to affect a number of biological processes both within and adjacent to the pens. The following section summarises the potential effects to zooplankton based on a review of the literature and observations made on salmon farms in New Zealand where artificial lighting is currently used (Cornelisen & Quarterman 2010; Cornelisen et al. 2013; Bennett & Cornelisen 2018).

The potential effects of artificial lighting to water column biology on finfish farms identified in the literature can be categorised as follows:

- ***Attraction of phototaxic organisms:*** Organisms such as zooplankton and larval fish may be attracted to the lights and accumulate near and/or within the farm structures.
- ***Vertical migration and benthic settlement:*** Vertical migration in the water column by some phytoplankton and zooplankton species may be influenced by light. There may also be enhanced settlement of organisms attracted by the light onto the seabed near farm structures.
- ***Aggregation and visibility of prey and enhanced predation***: Baitfish may be attracted to the lights and aggregate near and/or within illuminated pens. Visibility of prey during night-time hours will increase. Increased aggregation and visibility of prey could in turn increase rates of predation by the farmed salmon as well as fish and marine mammals (e.g. seals) outside the pens (risks considered in the marine mammal assessment, Clement & Elvines 2019).

Artificial lighting affects the physical environment, which in turn has the potential to influence important biological processes as described above. In order to assess the environmental effects of artificial lighting, the extent of changes to the physical environment from the artificial lighting needs to be described first. This includes determining the spatial 'footprint' of the artificial lights (i.e. the depths that the light penetrates to and the size of the area affected within and around the pen structures). The effects of lighting will depend on the type and power of lights used, and the number of lights and their configuration in the water column. Factors such as the clarity of the water, and presence of objects including pen structures and mesh, and the salmon themselves, attenuate the extent to which the light is able to penetrate the surrounding water column. Research on the use of artificial lighting associated with other salmon farming operations in New Zealand observed that the 'footprint' of the lights is mainly confined to the fish pens and to mid-water depths (Cornelisen & Quarterman 2010; Cornelisen et al. 2013; Bennett & Cornelisen 2018).

7.1. Predicted footprint at the proposed farm

The proposed farm is likely to use LED bulbs, which have a considerably smaller visual 'footprint' than those reported for lighting arrays that use halogen bulbs (Bennett & Cornelisen 2018). The visual footprint of artificial lights reported for another salmon farm in the Marlborough Sounds using LED bulbs was reported to be reduced to a weak glow within 10 m of the farm. Measurable light (above water) was confined to the pens. Within the pen, only very low levels (< 1 μmol /m^2/s) were detected around the depth at which the lights were suspended. This suggests that any effects due to artificial lighting will be localised due to the limited area affected by the lights.

7.1.1. Attraction of positively phototactic organisms

Illuminated salmon pens have the potential to attract phototaxic organisms (including larval fish) to the edge of the pen structures, and within the pen for those organisms small enough to fit through the mesh. Fish that enter the pens could become trapped once they are too large to exit the pens through the mesh and could be preyed on by the salmon. McConnell et al. (2010) found that while the same lights used in salmon farming attracted marginally larger numbers of zooplankton than non-illuminated net pens, a significantly higher abundance of larval fish were observed in the water column. The level of predation on baitfish by salmon will depend on the life stage of the salmon within the pens and will be limited due to the fact that the salmon are fed an artificial diet, and any baitfish trapped within the pens will be released during harvest. Additionally, it is unlikely that larval fish would be able to sustain their position within the pens for longer than a few hours during slack tide, due to the strong currents at the proposal area.

Surveys at salmon farms with high current flows in the Marlborough Sounds demonstrated that artificial lighting does not have measurable effects on the aggregation and distribution of zooplankton. Additionally, larval fish represented a very small fraction of the zooplankton sampled in these surveys (Cornelisen et al.

2013; Bennett & Cornelisen 2018). Marlborough Sounds support large populations of blue cod (*Parapercis colias*) (Beentjes et al. 2017). However, blue cod larvae have a relatively short pelagic stage, the larvae are pelagic for about five days before settling to the seabed (Henderson 2009). Therefore, effects of artificial lighting on blue cod populations are likely to be minimal due to the confined nature of the lighting and the distance of the pens from typical blue cod habitat.

7.1.2. Vertical migration and benthic settlement

Artificial lighting has the potential to influence vertical migration of zooplankton surrounding the area illuminated by the lights. The extent to which artificial lighting will influence vertical migration will depend on the depth to which the light penetrates relative to the bottom, the communities living beneath and around the farm structures, the level of water column currents around the pens, and the spatial distribution and abundance of zooplankton.

The effects of artificial lighting on vertical migration will be highly localised and positioning of the farms in deep waters with high currents will largely mitigate effects. With strong tidal flow, the volume of water and associated plankton flowing beneath and around the lights is only temporarily affected as the water flows past, and except for during periods of slack tide, are unlikely to be affected. Due to the depths at the proposed site, it is unlikely lights will penetrate to the sea floor. Furthermore, Cook Strait is a dynamic coastal region with strong, tidally-driven flows. Based on the size of the proposed farm in relation to this large and energetic body of water, the subsequent effects of artificial lighting on benthic settlement of planktonic organisms is expected to be very small.

7.1.3. Aggregation and visibility of prey and enhanced predation

Some fish species are known to aggregate around artificial lighting, which in turn increases the visibility of prey and possibly levels of predation (McConnell et al. 2010). It is therefore likely that there will be a higher abundance of baitfish within illuminated pens than those without artificial lighting. It then follows that there could be an increase in night-time predation on baitfish by the salmon due to enhanced aggregation and an increase in prey visibility. However, any elevated level of predation is likely to be of minor ecological significance because the salmon are fed an artificial diet, which would minimise their need to feed on wild fish. In the Marlborough Sounds farms, wild fish that have survived within the pens and grown to a size unable to leave, are apparently released during harvest (based on personal communication (C. Cornelisen) with NZ King Salmon farm staff).

7.1.4. Fish and marine mammals

Attraction and aggregation of baitfish adjacent to illuminated pen structures could enhance night-time predation by fish and marine mammals such as seals along the outside edge of the pens. For example, a study on feeding by harbour seals in a British Columbia river demonstrated that artificial lighting on bridges was partly responsible for enhanced night-time predation on salmon smolt (Yurk & Trites 2000). During evening site surveys at Marlborough Sounds salmon farms, there was no observed evidence of predator activity by fish or marine mammals around the illuminated pens, nor were seabirds seen feeding around the farms (Cornelisen & Quarterman 2010; Cornelisen et al. 2013; Bennett & Cornelisen 2018). It is predicted that marine mammals will be more attracted to any increase in noise and activity of caged or wild fish in response to the lights rather than the lights themselves. This attraction is suggested to then become an entanglement issue (associated risks considered in the marine mammal assessment (Clement & Elvines 2019)).

7.1.5. Other potential environmental effects

Other potential environmental effects of artificial lighting (i.e. those that are not specific to water column biology) have not been considered in this assessment. These include, but are not limited to the following example regarding parasitism.

Vertical distribution of salmon and risk of parasitism

Artificial lighting influences the vertical distribution of salmon within pen structures (Oppedal et al. 2001). Increased densities of salmon at a given depth (i.e. near the surface) due to artificial lighting have been shown to coincide with an increased risk of parasitism on salmon by copepods such as sea lice that are attracted by the lights (Heuch et al. 1995; Hevroy et al. 2003; Genna et al. 2005). Parasitism can result in increased fish mortality; hence, consideration of the effect of artificial lighting on the depth distribution of salmon and the frequency and intensity of parasite infestations is of particular importance to the productivity of the farms. At present, native parasitic copepods such as sea lice are not problematic in the culture of King salmon in New Zealand; however, they could become problematic under the use of artificial lighting if host switching occurs (Diggles 2011).

8. SUMMARY AND SYNTHESIS OF FINDINGS

This report considers the effects of the proposed salmon farm on the water column environment offshore of the Marlborough Sounds. Our assessment is based on analysis of field water quality survey data and desktop reviews of information relevant to effects associated with dissolved oxygen (DO) depletion through respiration of cultured fish, nutrient enrichment associated with the addition of feed and production of fish wastes and associated changes in phytoplankton species composition and abundance, and the use of submerged artificial lighting in the proposed farm.

8.1. Site characterisation

The proposed farm site is located in 60–110 m water depth in an area of strong water currents (mean mid-depth current speeds = 40 cm/s). The water column in the area is subject to strong vertical mixing and horizontal transport causing little variation in temperature and salinity with depth. The well-mixed water column will assist with the rapid dilution of nutrients away from farm boundaries, and fast current speeds will limit the build-up of nutrient wastes within the body of water. Although the proposed farm is at some distance from the coastline (7 km north of Cape Lambert), current velocity fields indicate that there is likely to be interaction with both Pelorus and Queen Charlotte Sounds. Measured and modelled current and wave data indicate that the site should be relatively accessible most of the time and that it has the potential to sustain a relatively large production with an 'acceptable level' of impact. From this perspective, the environment is very favourable to salmon farming.

The area proposed for aquaculture development is large compared to other existing finfish developments in New Zealand, and large production volumes have been proposed (up to 10,000 tonnes of fish farmed in the short to medium-term (up to 20,000 tonnes of feed per annum discharged) in Stage 1 potentially increasing to up to 40,000 tpa feed in Stage 2. It is important to mention that there have been few opportunities to assess the effects of offshore aquaculture on the water column and seabed environments (Welch et al. 2019) and lack of evidence for an effect does not equate to certainty that no effect is occurring. We understand that NZ King Salmon intends to undertake an effects-based approach to farm development, which can be based on water quality management objectives. This would be supported by additional monitoring to be determined by the regulator to provide the best information on the effects of the activity on the environment. For this assessment, we have assumed that the water quality management objectives would be similar to the objectives set by the Board of Inquiry report 2013 and adopted for existing farms in the Marlborough Sounds.

8.2. Summary of effects and their magnitude

8.2.1. Dissolved oxygen

Depletion of DO is usually an issue if multiple farms are in close proximity, for example, which is not the case in the proposed farm. Furthermore, the placement of the farm in a high-flow environment will further mitigate effects of the fish on DO levels (Gillespie et al. 2011). Evidence from monitoring existing salmon farms in the Marlborough Sounds indicates that water column DO concentrations do not get significantly depleted (Forrest et al. 2007).

The percent saturation of DO measured on three occasions in the survey area during the summer months ranged from 84 to 111% indicating a well-oxygenated water column. The range of DO concentrations is similar to that recorded in Port Gore by Broekhuizen (2015). At reference stations in salmon farming sites in the Sounds, DO saturation in surface waters is rarely below 90% and frequently between 80 and 90% in near-seabed waters in the Tory Channel and Pelorus Sound. This is consistent with the data presented here. In the Tory Channel, greater reductions are common, including saturations < 70% recorded approximately annually in monthly surveys. The Marlborough Sounds therefore appear to have a greater range of DO concentrations than those in the proposed farm site. We note however that our monitoring data are high frequency and collected over a few months while the Marlborough Sounds data are low frequency and long-term (> 5 years of monthly sampling).

We estimated potential DO reductions downstream of the net pens ranging from a hypothetical scenario of complete oxygen consumption at very low flows (< 3.5 cm/s) to reductions in DO levels of < 10% when current speeds are > 50 cm/s. Considering that the mean current speed in the proposed farm area is about 40 cm/s, we estimated that, on average, the near-field DO reductions would be < 20%. Because the proposed farm area is in deep waters and at a large distance from the coastline, we do not consider these DO changes to cause issues for the water column environment around the farm at the proposed 20,000 tpa feed load. However, beyond this feed level, we suggest more targeted monitoring and adaptive management, potentially involving altering feed capacities and farm production/intensity, to reduce stress of farmed fish and other pelagic organisms.

8.2.2. Nutrients

The range of nutrient concentrations measured in the survey area was comparable to that found in nearshore waters at other finfish sites in New Zealand. We also found some evidence of lower nitrate concentrations in summer than in winter suggesting nitrogen limitation. A pattern of winter variability and low summer nitrate concentrations is characteristic of sites in Pelorus Sound (Marlborough Sounds) (Broekhuizen & Plew 2018). However, the data also indicate that the proposed offshore aquaculture site is not extremely nutrient limited relative to nearshore environments.

We quantified the concentrations of TN released by the total biomass of salmon anticipated for Stage 1 and concentration changes downstream of the net pens. Our calculations are conservative, i.e. we assumed a 70% reduction in the ambient water current due to the nets and no horizontal mixing with the surrounding water. Our estimates indicate changes in TN concentrations for the mean current speed (40 cm/s) of about 54 mg/m^3. This represents a 30% increase in ambient TN concentrations.

We quantified the concentrations of TN released by the total biomass of salmon anticipated for Stage 1 (20,000 tpa feed) and concentration changes downstream of the net pens. Our calculations assumed a 70% reduction in the ambient water current due to the nets and no horizontal mixing with the surrounding water. Our estimates indicate changes in TN concentrations of about 54 mg/m^3 (about 30% increase in ambient TN concentrations) are possible for a unidirectional mean current speed of 40 cm/s at the site.

Nitrogen excreted from the salmon is likely to be in a dissolved form (mainly ammonium, but also urea). Because dissolved forms of N are likely to be short lived and will be quickly assimilated by pelagic phytoplankton and bacteria, we therefore anticipate that the 30% increase in TN concentrations is unlikely to be associated with any toxicity. Basic modelling of nutrient dispersal suggests a small amount could enter the Marlborough Sounds, up to 2% of released nutrients in Queen Charlotte Sound and up to 1% in Pelorus Sound. Other sophisticated biogeochemical modelling suggests a relatively linear response to nutrients in these systems and hence very little change in water quality would be expected with Stage 1 of this proposal.

An increase in nitrogen loading to the offshore waters of Cook Strait (e.g. about 1,000 tonnes of nitrogen at Stage 1) is not expected to be of concern as the mean annual flux of TN through the offshore waters of Cook Strait is very high (1.2 million tonnes) and even relatively large anthropogenic inputs of nitrogen could be considered small in the context of the natural flows through the Strait. Our experience with monitoring smaller inshore farms further suggests that the maximum TN concentration changes associated with these farms are unlikely to be measured beyond 500 m from the net pens (e.g. Bennett et al. 2018a, 2018b, 2018c). Because of the large volumes of water and the natural assimilation and denitrification processes that occur offshore of the Marlborough Sounds, it is unlikely that nitrogen changes would be detectable outside of the proposed consent area at the initial proposed feeding levels.

8.2.3. Phytoplankton and Chlorophyll-a

While specific modelling has not been undertaken to assess effects on phytoplankton and chlorophyll-*a* directly, recent biophysical modelling in Pelorus Sound has been undertaken to assess increased feeding scenarios by Broekhuizen and Hadfield (2016). This modelling considered feed load increases within the sound of between 1,500 to 22,600 tpa of additional feed loading, with analysis of model predictions estimating a mean TN change of about 3.3% under the largest changes considered.

We estimate that 1% of the feed from the first stage of the proposal could equate to a '200 tpa' farm in Pelorus Sound. We considered this a worst-case scenario, given the potential for cumulative effects with existing and potential future farming in this area. Based on linear extrapolation of the Broekhuizen and Hadfield (2016) model results, we estimate '200 tpa' farm in Pelorus Sound brought into effect by the offshore proposal could add an additional 0.03% increase to the mean TN concentrations[17] and 0.02% to the largest mean chlorophyll-*a* changes in the region. However, these effects would be cumulative to whatever is decided for the relocation farms.

8.2.4. Lighting effects

As part of our assessment, we also considered the effects of submerged artificial lighting associated with the proposed farm. Based on a review of the literature and observations made at existing salmon farms in New Zealand, we concluded that the effects on small phototactic organisms, such as some zooplankton, will be limited to perhaps small, periodic increases in organism abundances within illuminated pens. The proposed farm will be situated in deep water with high currents; hence any aggregations of small organisms within the illuminated pens will be temporary and limited to periods of low currents (i.e. slack tide). The most likely effect of artificial lighting associated with the proposed farm will be the enhanced attraction of baitfish during night hours. These fish could become trapped once they become too large to exit the pens through the mesh and then could be preyed upon by the salmon.

The total volume of water (and associated organisms) affected by the lights will vary in time depending on currents, which are likely to mitigate the extent the illuminated lights attract and aggregate organisms. This is particularly relevant for the proposal area, a large dynamic body of water with strong, tidally-driven flows. Based on the physical characteristics of the proposed site, the scale of the proposed farm, and the small spatial scale predicted for the footprint of the artificial lights, it is unlikely that farm structures would act as significant 'sinks' for organisms attracted to the lights While the effects of artificial lighting may be measurable at some level within the pen structures themselves, the effects in terms of the wider Cook Strait region will be very small and unlikely measurable.

[17] 0.03% is based on the 3.3% change predicted under a 22,600 tpa feed addition scenario, i.e. 3.3% x 200/22,600 = 0.03%.

9. DATA REQUIREMENTS AND MONITORING CONSIDERATIONS

Creation of detailed monitoring plans to detect any environmental changes from the proposed farm is outside the scope of this assessment. We understand that NZ King Salmon intends to undertake a ‘precautionary effects-based approach’ to farm development, which can be based on water quality management objectives. This would be supported by additional monitoring, which would be determined by the regulator to provide the best information on the effects of the activity on the wider environment. If this monitoring identifies that impacts are exceeding allowable limits to identified water column communities, then we recommend that NZ King Salmon implement changes to farm management practices to ensure impacts are reduced or mitigated.

The proposed farm site does not have the same restrictions on its capacity as inshore sites in the Marlborough Sounds and the large area, covering most of the 1,792 ha, could theoretically be occupied by net structures. Therefore, care should be taken in progressing beyond known levels of feed (e.g. up to approximately 13,000 tpa feed in Tory Channel). Given that a large separation (> 1 km) between the two 10,000 tpa farms is initially proposed for Stage 1, it seems unlikely that effects beyond those currently observed in Tory Channel would be likely. However, NZKS has proposed an additional 20,000 tpa feed for Stage 2. To ensure that a high level of confidence is placed in future effects assessments at feeding levels beyond what is known, improved modelling and comprehensive monitoring would be required.

Given that the currents are much stronger than those in the Sounds, it is possible that the nitrogen ‘footprint’ of the farm could be greater than that observed in inshore farms and changes could be detectable outside of the proposed consent area at higher than initial feed levels. We note that the large depth of water and distance from land or shallow reefs, means that interactions of nutrient-enriched water with sensitive sessile organisms is likely to be much less than the same level of feed at a typical inshore site. Nevertheless, if a stated ‘boundary of acceptable effects’ is considered necessary for the water column environment at this site as has been stated for the inshore sites, we would recommend that this is based on either additional modelling, or extrapolation of inshore site measurements to reflect the higher water currents at the proposed site.

If a boundary is considered necessary, it should also consider the proximity to potentially sensitive organisms. While it seems unlikely nitrogen compounds would cause serious issues and can be estimated based on the feeding rates, the removal of oxygen by the fish could potentially cause sublethal effects. Accordingly, we recommend that DO should be monitored beside the farm and ideally near sensitive areas, at least during the initial stages of the farm development to offer better predictions for effects at future stages. Ideally, accurate models could be developed, phasing out the need for additional far-field monitoring in future and offering the potential to get an accurate spatial map of effects at all areas around the proposal.

In terms of areas that should be considered for monitoring, the closest areas to the proposal are Port Gore and the Allen Strait-Waitui Bay complex of bays, which are hydrodynamically separated from the Sounds. While we have considered the cumulative effects in Pelorus Sound, it is possible that a small fraction of the nutrients from the farms could also be retained in these areas. A variety of conditions exist in these bays, but as with any tidally-dominated bay, a range of conditions will exist in them. High currents near their entrances, while lower currents near the heads of the bays are more likely. On the basis of the biophysical modelling of Broekhuizen and Hadfield (2016) it is apparent that the lower flow areas of the Sounds are more susceptible to larger chlorophyll-*a* changes and that matches our field observations[18]. Consequently, if expansion of monitoring to include new areas occurs, we would recommend that at least one low flow area (see e.g. Figure 30) be tracked for signs of potential enrichment (e.g. TN or chlorophyll-*a* concentration increases over time).

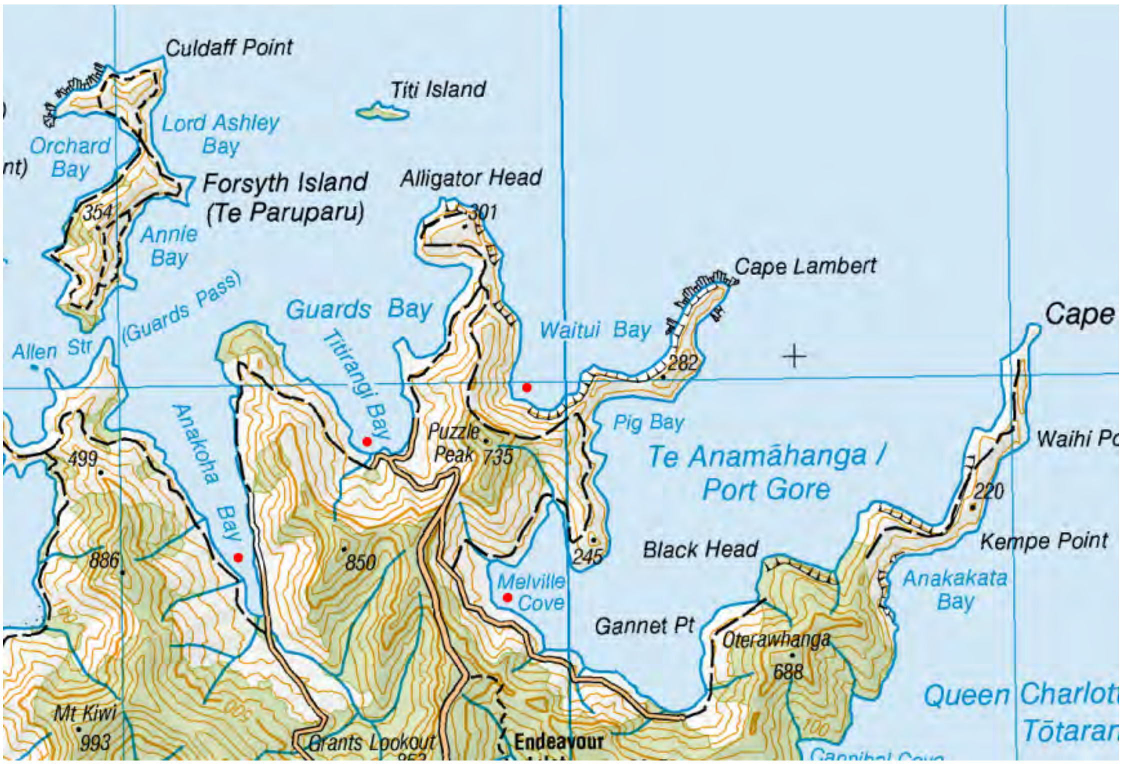


Figure 30. Examples of potentially low flow areas (indicated by red dots) located near the proposal that could be considered for monitoring for chlorophyll-*a* trends.

[18] The largest blooms we see are in the heads of long sheltered bays (e.g. Opua Bay, Nydia Bay, the head of Kenepuru Sound)

Given that effects of large inputs in the relatively enclosed areas of Pelorus and Queen Charlotte Sound are modelled to be small (Broekhuizen & Hadfield 2016), and recent changes have observed to be small (Broekhuizen & Plew 2018), it seems highly likely that effects from this proposal would also be very small. Nevertheless, in terms of areas that are most likely to be affected, even by a small amount, it seems that having at least one water column monitoring location in nearby bays could be useful for interpreting the water column effects of the proposal in isolation from other anthropogenic influences.

Nutrient data from the proposed site are limited, but it is likely that monitoring data from the Port Gore site obtained as part of the NZ King Salmon and MDC state of the environment monitoring programme are relevant to the proposed site. Additional nutrient samples would help to establish the suitability of these data. This could be achieved with opportunistic sampling, and depending on the results of these analyses, three further sampling surveys at the proposed aquaculture site may be sufficient to establish the suitability of the Port Gore data to represent baseline conditions and to support modelling of nitrogen footprint from the farm.

The assessment of submerged artificial lighting on the water column biology is based primarily on observations from other salmon farms in the Marlborough Sounds and knowledge from overseas studies. It is possible that the effects of artificial lighting will vary according to site-specific conditions. We therefore recommend a one-off targeted survey at the proposed farm when lights are fully operational to further confirm that effects are minimal.

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12. APPENDICES

Appendix 1. Methods and data collected in the field surveys.

- A series of instruments were moored on a buoy at Station 02. The buoy instrumentation included:
    - a downward-facing Acoustic Doppler Current Profiler (ADCP)
    - a fluorometer for measuring chlorophyll-*a* (a proxy for phytoplankton concentration) at 11m
    - dissolved oxygen (DO) meters at 10 m and 66 m
    - salinity meters at 10 m and 66 m
    - thermistors/thermometers at 1 m, 10 m, and 66 m
    - a turbidity sensor at 11 m
- An upward-facing ADCP was deployed on the seabed at Station 03.
- Water column profiles were collected on 7 August 2018, 6 October 2018 and 25 January 2019 at a number of sampling stations. A CTD (conductivity, temperature, depth) instrument was fitted with additional instruments for the collection of data on fluorescence, dissolved oxygen concentration, and turbidity.
- Physical water samples were collected for laboratory analysis of nutrients, chlorophyll-*a*, phytoplankton identity and abundance, and suspended solids.

Data collected or modelled for each parameter were:

- Water currents
    - timeseries from an ADCP deployment on buoy at Station 03
    - timeseries from an ADCP deployment on the seabed at Station 02
- Waves
    - timeseries from the ADCP on buoy at Station 03
    - a ten-year wave hindcast data series from MetOcean Solutions Ltd.
- Dissolved oxygen (DO)
    - timeseries from buoy at Station 03, at 10 m and 66 m depth
    - water column profiles (surface to seabed) at a range of stations (two timepoints)
- Temperature[19] and salinity
    - timeseries from buoy at Station 3 (1 m [ADCP], 10 m, 66 m)
    - timeseries from ADCP at Stations 2 (96 m)

[19] An additional string of thermistors (at 5 m, 20 m, 30 m, 40 m, 50 m, and near bed) were deployed on the buoy at Station 3.

- water column profiles (surface to seabed) at a range of stations (three timepoints)
- Phytoplankton and chlorophyll-*a*
  - chl-*a* timeseries from buoy at Station 03, at 10 m
  - chl-*a* water column profiles (surface to seabed) at a range of stations (three timepoints)
  - chl-*a* in water samples (3 timepoints)
  - phytoplankton samples taken on in August 2018 (stratified) and January 2019 (3 sampling stations)
- Turbidity
  - NTU at 10m from buoy deployment duration
  - TSS in water samples to validate NTU (3x on 6 October 2018)
- Nutrients (various P and N and Si from water samples).

Appendix 2. Locations and data collection periods of ADCP deployments.

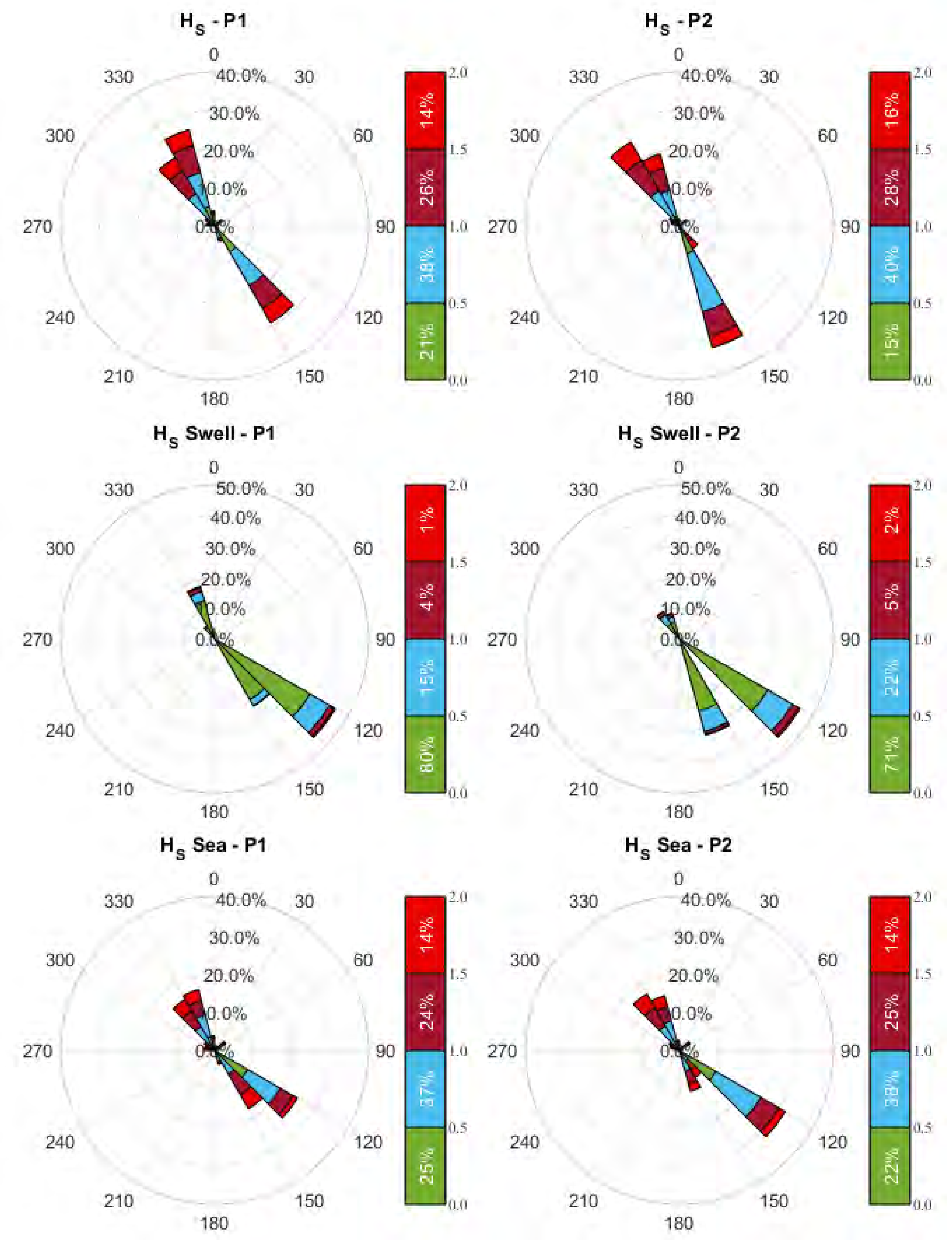
	Upward-facing ADCP (Sentinel)	Downward-facing ADCP (Buoy)
Latitude	40.90° S	40.92° S
Longitude	174.26° E	174.24° E
Deployment start	5 October 2018	14 October 2018
Deployment end	9 January 2019	26 February 2019
Depth at deployment	92 m	67 m
Bin size	3 m	2 m
Burst frequency	1 Hz	4 Hz
Averaging interval	3 minutes	3 minutes
Sampling frequency	30 minutes	30 minutes
Near surface depth (metres below mean sea level; MSL)	15	4
Mid depth (m below MSL)	42	30
Near seabed depth (m below MSL)	87	58
Total depth at site (m below MSL)	92	67

Appendix 3. Location of the wave model data points and field sampling station.

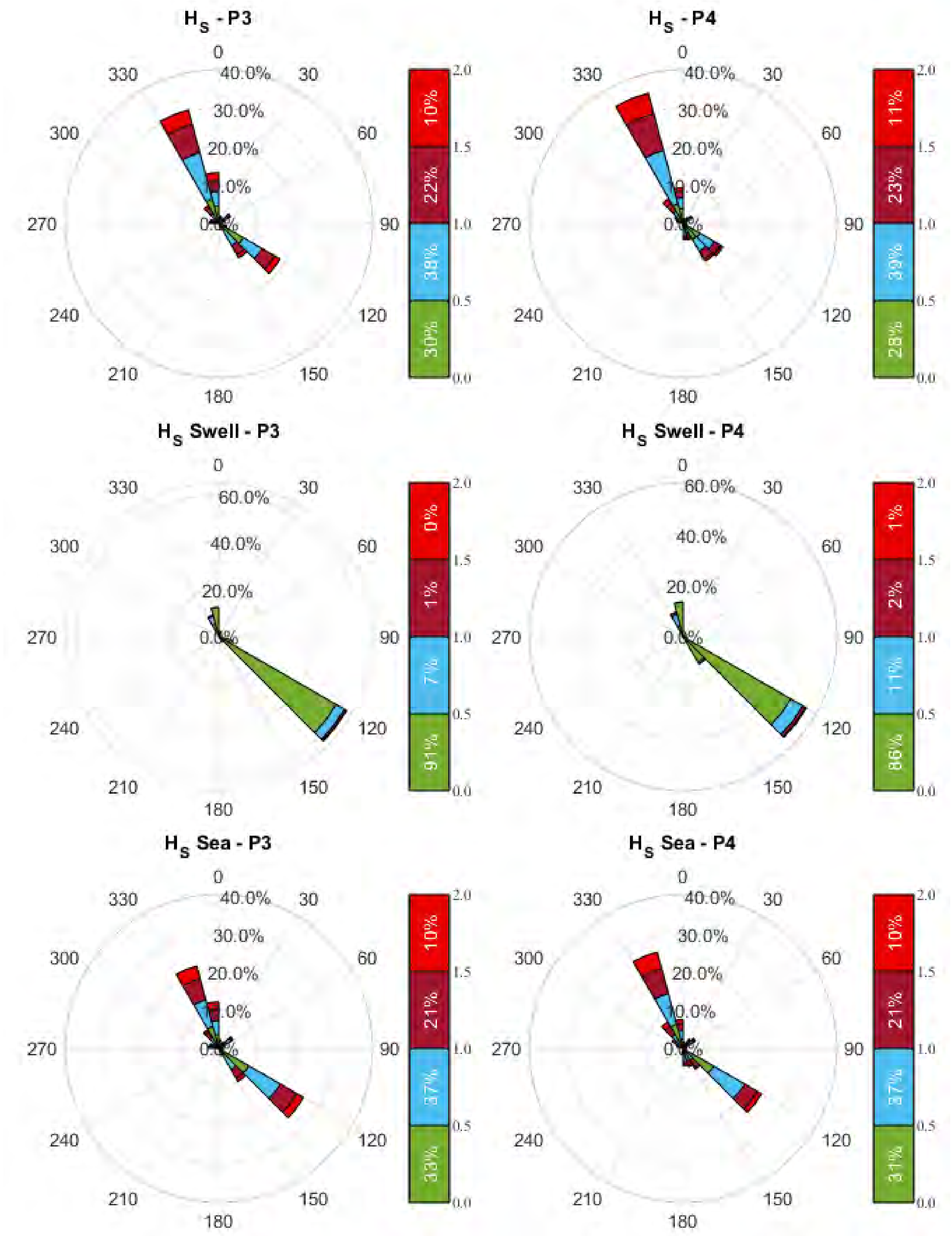
Wave modelling site	Latitude	Longitude
P1	40.86° S	174.24° E
P2	40.90° S	174.31° E
P3	40.91° S	174.19° E
P4	40.95° S	174.26° E
P5 (accelerometer station)	40.92° S	174.24° E

Appendix 4. Wave roses comparing modelled and measured data for sites P1–P4.

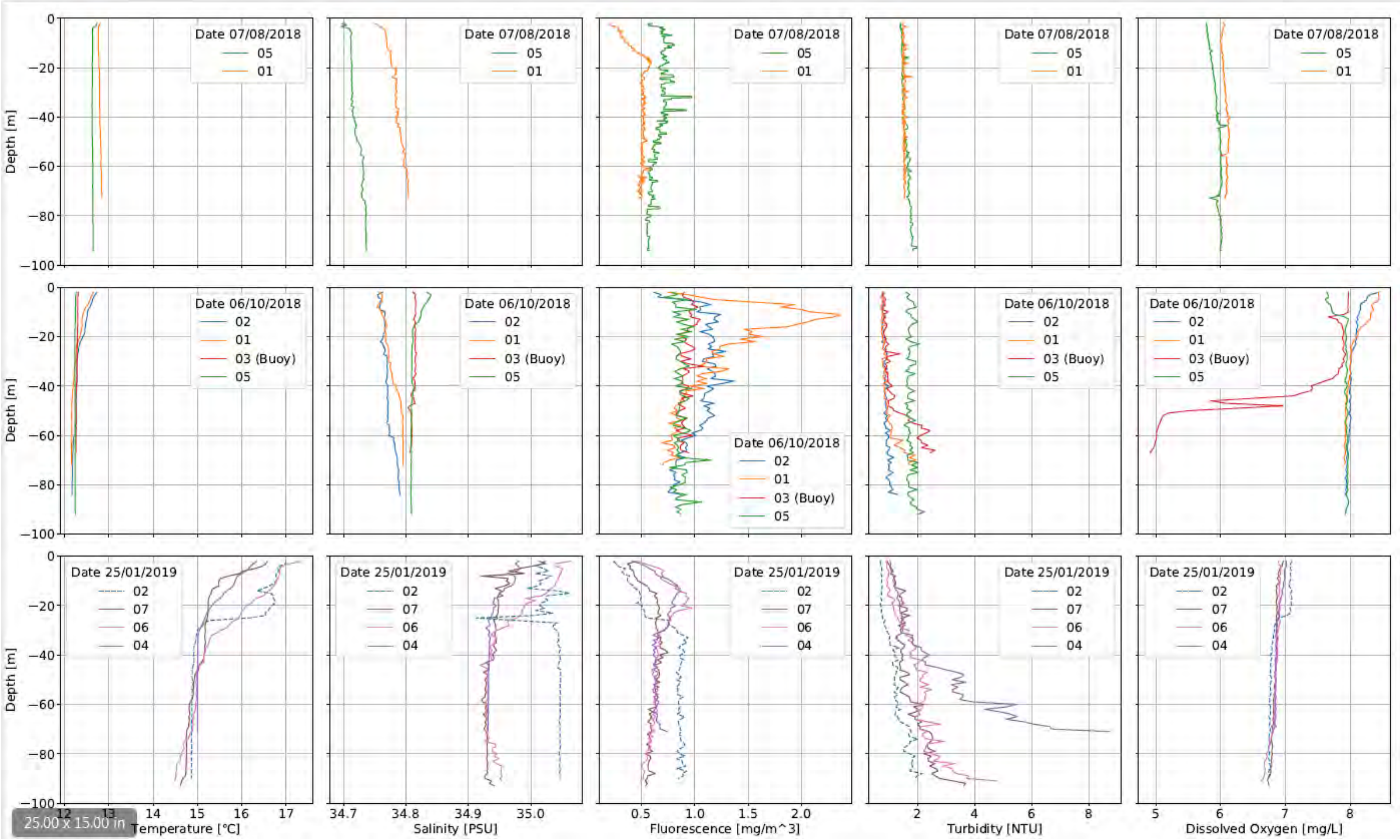
Modelled wave heights for sea and swell components at sites P1 and P2. The directions are in the 'coming from' sense; that is, waves at 90 degrees in the rose plot would be travelling from east to west.



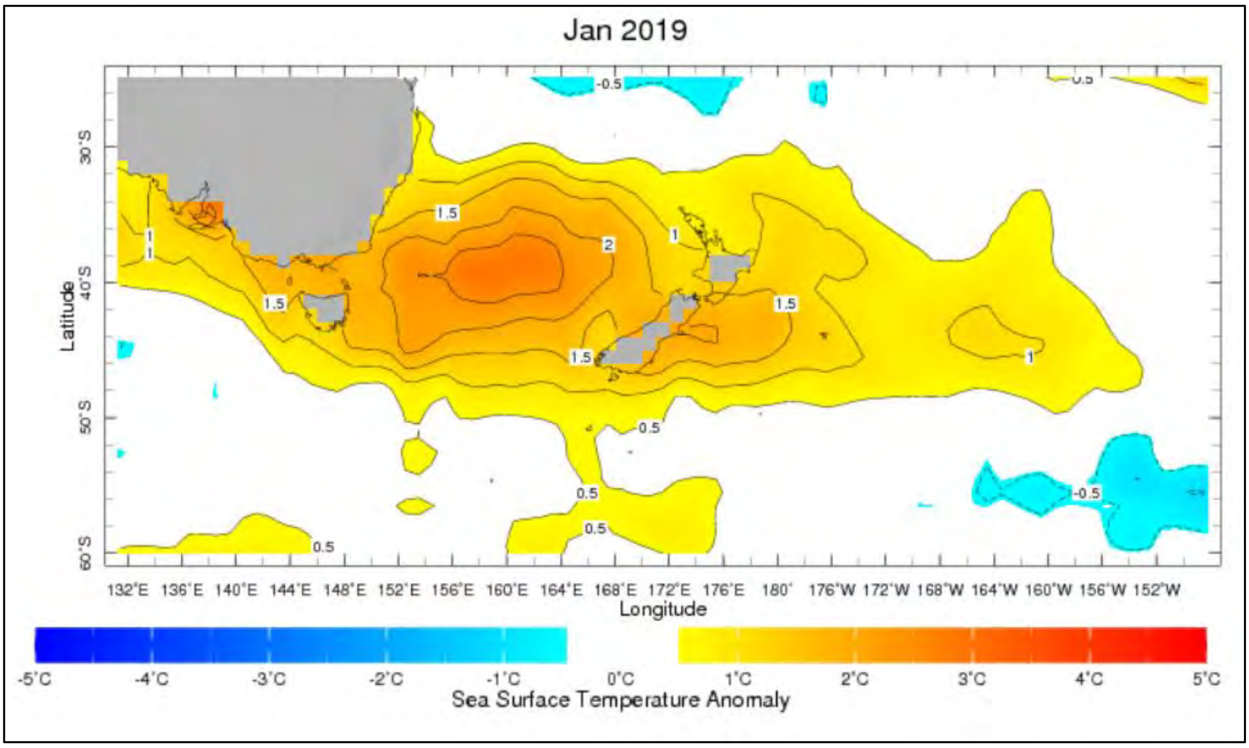
Modelled wave heights for sea and swell components at sites P3 and P4. The directions are in the 'coming from' sense; that is, waves at 90 degrees in the rose plot would be travelling from east to west.



Appendix 5. Depth profiles of temperature, salinity, fluorescence, turbidity and dissolved oxygen used for comparison of cast and moored data collected at stations in the proposed farm area on three sampling occasions.

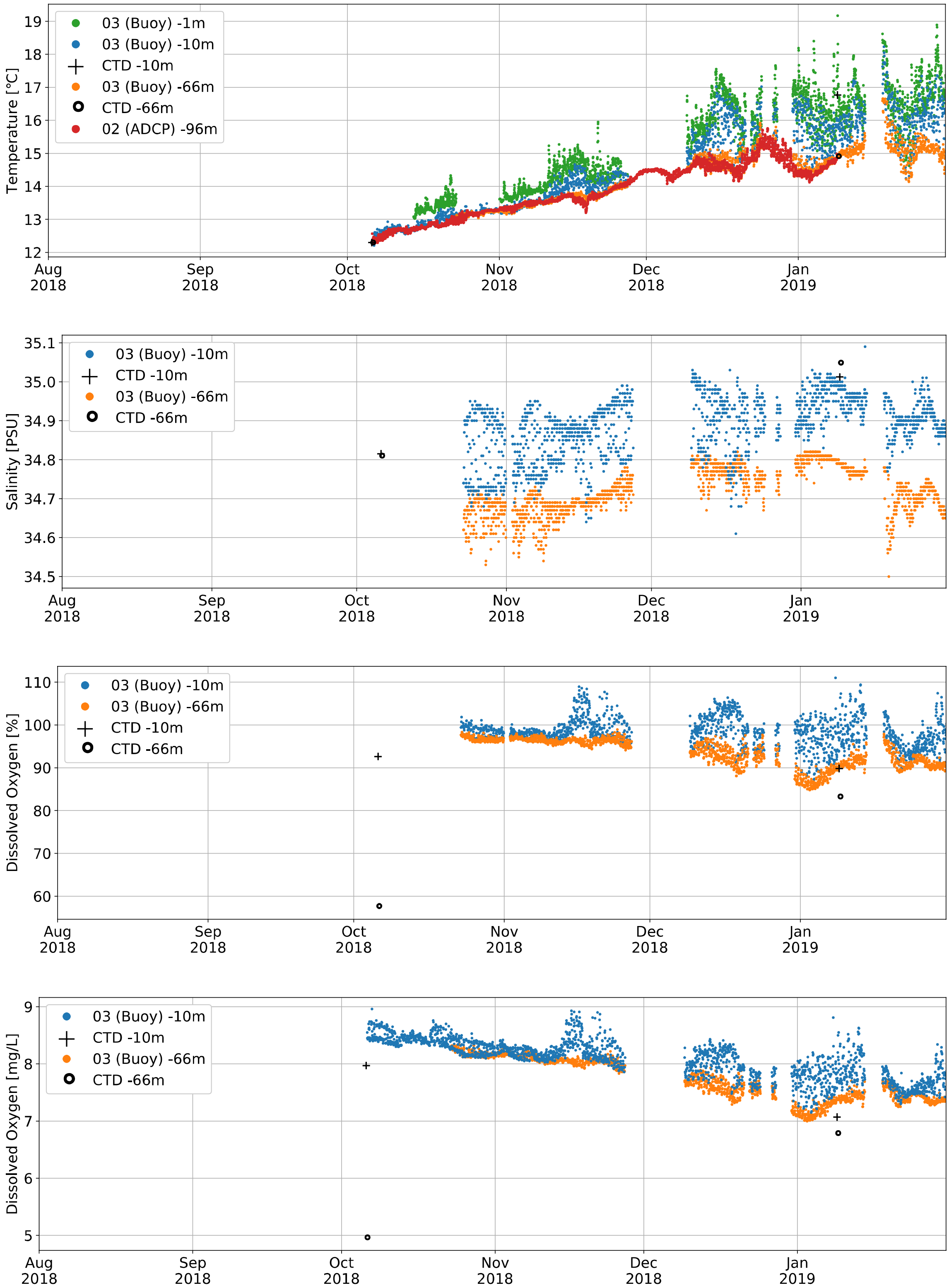


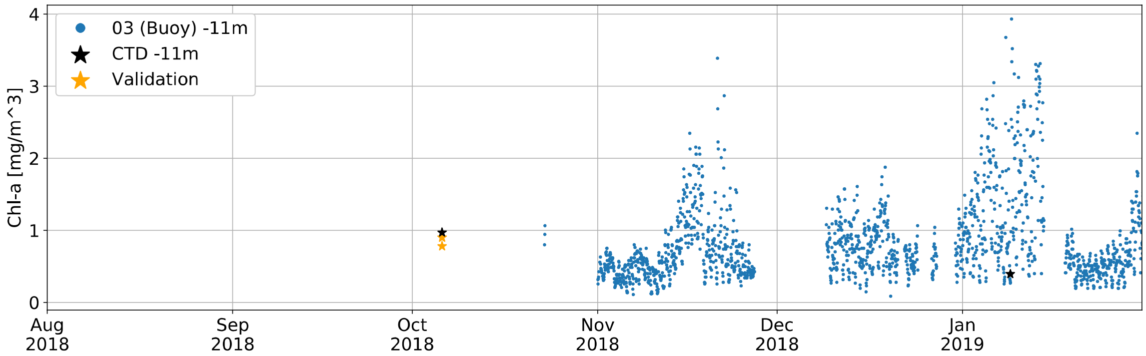
Appendix 6. Sea surface temperature anomaly for New Zealand in January 2019.

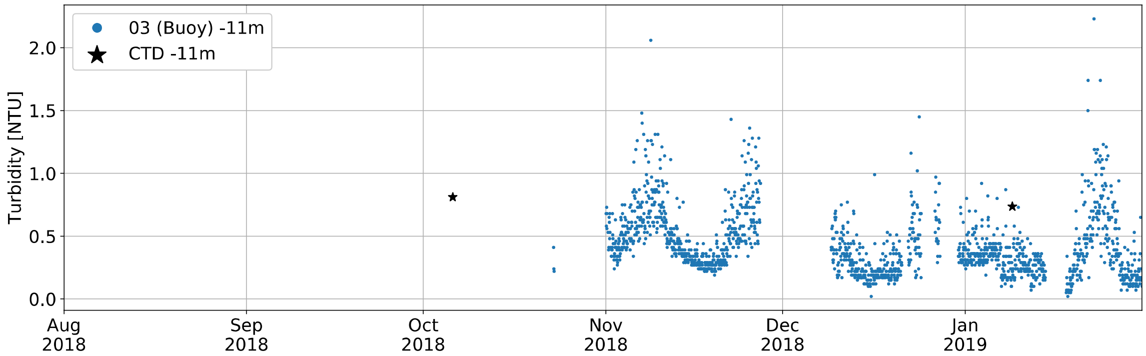


Source: International Research Institute for Climate and Society (https://iri.columbia.edu/?bbox=bb%3A131.23%3A-60.03%3A211.83%3A-24.86%3Abb).

Appendix 7. Time series of temperature, salinity, fluorescence, turbidity and dissolved oxygen used for comparison of cast and moored data collected at stations in the proposed farm area.




03 (Buoy) -11m
CTD -11m
Validation
Chl-a [mg/m^3]
0
1
2
3
4
Aug 2018
Sep 2018
Oct 2018
Nov 2018
Dec 2018
Jan 2019


03 (Buoy) -11m
CTD -11m
Turbidity [NTU]
0.0
0.5
1.0
1.5
2.0
Aug 2018
Sep 2018
Oct 2018
Nov 2018
Dec 2018
Jan 2019

APPENDIX F: Navigation Report

Report

North Marlborough Farm Development Navigational Risk Assessment

Prepared for New Zealand King Salmon

by

Navigatus Consulting

26 July 2019

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Prepared for New Zealand King Salmon

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Revision	Revision Type	Date	Authorised By
Ver 0	Draft for client review	24 June 2019	
Ver 0.1	Final Draft	24 June 2019	
Ver 1	Issued	15 July 2019	
Ver 1.1	Minor revision	26 July 2019	

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1 Executive Summary

1.1 Introduction

This report was commissioned by New Zealand King Salmon (NZKS) in support of a proposed off shore development. It sets out an assessment of the level of navigational risk associated with the siting of a salmon farming area located off shore from the Marlborough Sounds to the North West of Cape Jackson.

The proposed development area is intended to enable the positioning of a number of farms in an offshore maritime environment – a physical environment that differs from the current operation and positioning of salmon farms employed in New Zealand. The key in the design requirements of the farm structures and the whole development is driven by the fact that the farms must operate in the more energetic and demanding coastal conditions versus the more traditional farm locations within sheltered inlets, bays, or sounds. This requires that the farms are able to be secured in deep water and able to withstand higher sea states than has been the norm to date. It also results in the farms being located nearer to large vessel routes and activity.

In order to make best use of the rapidly developing technology in the global off shore aquaculture industry NZKS has concluded design options must remain available and so is not able to provide a detailed design, final layout, or number of structures located inside the proposed area at this stage. This will enable flexibility to choose the most appropriate design from the latest technology that is most suitable for the proposed location at a later date. It is understood that once the design details have been finalised and peer reviewed, the finalised design will be submitted to council in accordance with the proposed conditions of consent.

To enable this approach this report considers the general navigational aspects of a salmon farming development in the proposed area. The work has however been undertaken so as to ensure the assessment of the viability of the proposed area from a maritime navigational risk perspective remains sound.

The work undertaken to prepare this report included sourcing international research and information, conducting a detailed risk assessment, and reviewing information and knowledge gathered by Navigatus for previous fin fish farm risk assessments during public, commercial, and council consultation during development of farms across New Zealand.

1.2 Risk assessment

The risk assessment undertaken to support this work adheres to the internationally established process for risk assessments as set out in AS/NZS ISO31000: 2009 (Risk management) and the associated AS/NZS HB 89 (Risk analysis). Primarily, this consists of establishing the context, undertaking risk identification, completing risk analysis and then evaluating the risk against appropriate criteria.

The risk assessment utilises a methodology that was developed by Navigatus for generic open ocean considerations and makes an assessment referenced to a generic 'benchmark' farm development. This benchmark assessment is then used as a foundation for the assessment of the proposed farm development to ensure consistency of assessments between this proposal and any future developments.

1.3 Context and key assumption

The proposed farm area is located in the vicinity of three natural vessel transit routes - these can be separated in to three distinct categories

- Inshore coastal route – The traffic following the natural transit route created by the dangers extending from Cape Jackson and the entrance to Pelorus Sound.
- Coastal transit route – The traffic following the natural transit route from the North of Stephens Island and the entrance to the Cook Straight, passing to the South of Witts Rock and the North of McManaway Rock.
- Offshore transit route – The traffic following the natural transit route from the North of Stephens Island and the entrance to the Cook Straight, passing to the North of Witts Rock.

As part of understanding the context, it was assessed that vessels that currently choose to pass to the North of the local unmarked navigational danger associated with Witts Rock will not be influenced or impacted by the presence of the farm development at the proposed location. The presence and activity of any such vessels have therefore not been included in the navigation risk assessment.

The proximity to the inshore and coastal transit routes is such that they create an inherent navigational risk and so are of relevance to this assessment.[1] This risk is assessed against the inherent risk that results from the expected normal navigation behaviour of both small and large vessels operating in the vicinity of the proposed farm location.

A crucial second area of risk considered is a potential for a farm mooring failure or functional failure of any submerged features. While the farms' specific design is still to be confirmed, and that detailed work will be undertaken to understand the local conditions, it is concluded that practical risk controls are available in the current market that can reduce the probability of such an event to an acceptable level regardless of the detailed design features.

A key assumption is that the design process includes expert design and peer review by suitably experienced and professionally qualified design engineers[2], and learning from and following best overseas practice where relevant. This includes the use of technology to enable early warning monitoring systems and the associated emergency procedures in the event of a failure of the mooring line or lines.

---

[1] *Note that the term 'hazard' means 'source of risk'. For a hazard to result in 'risk' there has to be exposure and a potential for that hazard to have an impact on the defined objectives. In this case, the objective is taken to be the continued safe navigation of vessels and the safety of farm staff from the effects of maritime activity.*

[2] *Normally designated by PE(Int) or similar to designate professional membership of an engineering institute.*

1.4 Serendipitous benefits

It is concluded that, although not a defined aim of the development, that there could be clear benefits to mariners of the proposed farm development. Given the area and the farms will be at known locations, and that they will be marked, they will in effect become an Aid to Navigation (AtN).

The addition of a virtual Automatic Identification System (AIS) marks on the navigation dangers associated with Witts Rock and McManaway Rock as proposed by the risk assessment, will enhance situational awareness.

A further potential benefit of the proposed location will be that the farm could be fitted with an automatic radio weather reporting station and thus give significantly improved real-time navigational information to all mariners – in particular for local fishing and commercial vessels, as well as recreational traffic.

1.5 Overall conclusions

The proposed farm area is located in an area that is not navigationally complex. It has generally low levels of small and medium-sized marine craft traffic. It is however in an area that currently has a compression of traffic flow between two rocks that can be considered dangerous to navigation to deeper draught vessels.

As the development is in an area that is more environmentally challenging than what is found in areas currently being farmed, it will be essential that the design undergoes a detailed engineering risk assessment as part of the design process.

Having carried out the assessment of the navigational hazards of the proposed farm development area, it is concluded that given suitable practical mitigations, the risk associated with the proposed development location can be adequately managed. The resulting risk will not be significantly different than the existing situation created by the natural features. In some respect it is assessed that the presence of these mitigations can actually improve on the current level of navigational risk.

2 Introduction

This risk assessment, produced for New Zealand King Salmon, assesses the *navigational risks* associated with a proposed fin-fish farming area located off shore from the Marlborough Sounds to the North West of Cape Jackson as shown in Figure 2.1. This work is intended to assist New Zealand King Salmon and other parties to understand if the site is viable in terms of *navigational risk* for locating a fin-fish farm, for use as part of a resource consent application and to enable ongoing support of the farms. The navigational implications are considered in order to support decision making, with regard to the proposed farming location in general terms and subsequent detailed design of the farm and any operational and maritime controls required.

The scope of this risk assessment is limited to the *navigational risk* associated with farms at the proposed development location (Figure 4.1). Any other types of risk that may be associated with the farms and their operation are not considered unless there is the potential to influence *navigational risk.* The term *navigational hazard/risk* used throughout this assessment refers to the hazards/risks[3] the farm presents or may present to marine craft and vessels and the associated maritime activity and the dangers to crews as well as to farm staff from vessels operating nearby.

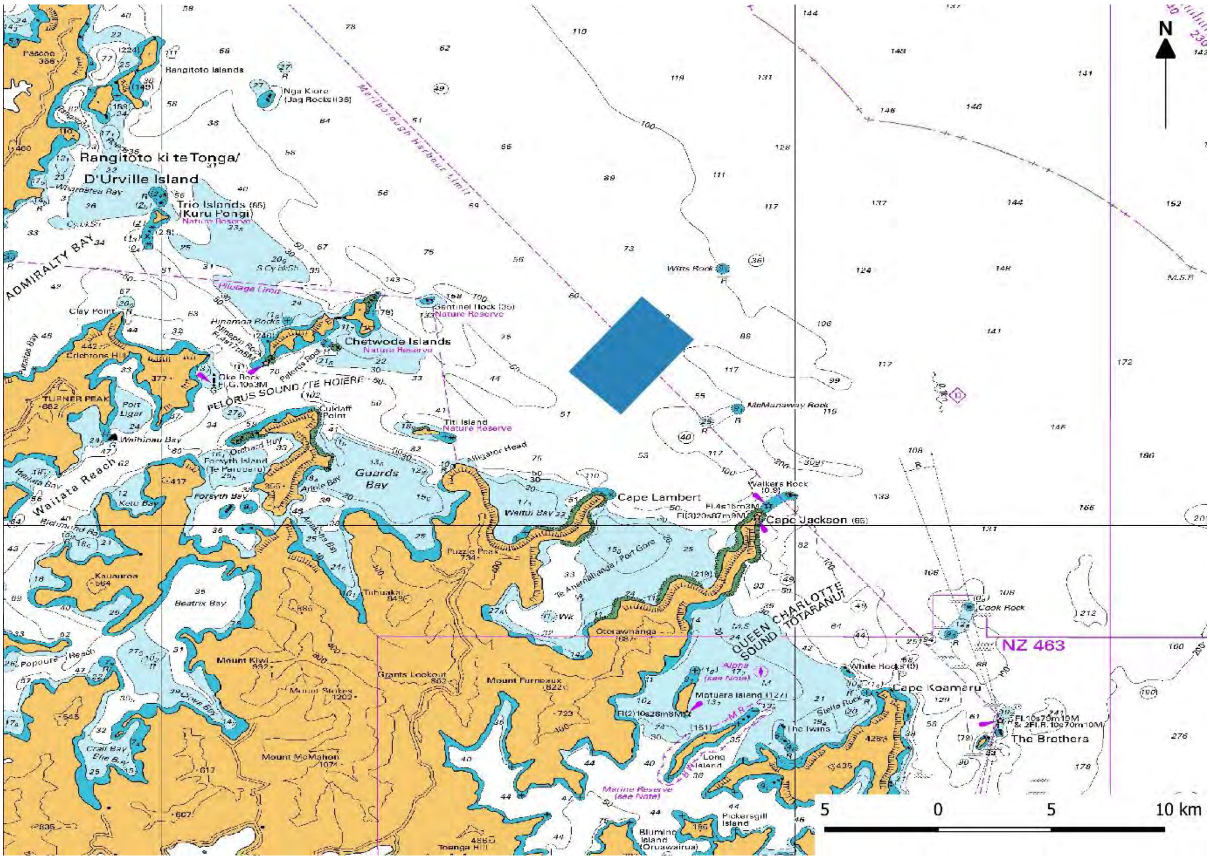

Figure 2.1: Location of proposed farm site in North Marlborough.

[3] Note that the term 'danger' is traditionally used in the maritime sector to mean a navigational or sea going 'hazard'. The term 'hazard' is typically used in risk assessments. Within this report the terms can be read interchangeably.

3 Report Methodology

This report utilises the methodology for assessing the marine navigational safety risks for open ocean aquaculture that was developed for New Zealand King Salmon[4], and incorporates the requirements and guidance within the published Maritime New Zealand marine farm guidelines: navigational safety[5].

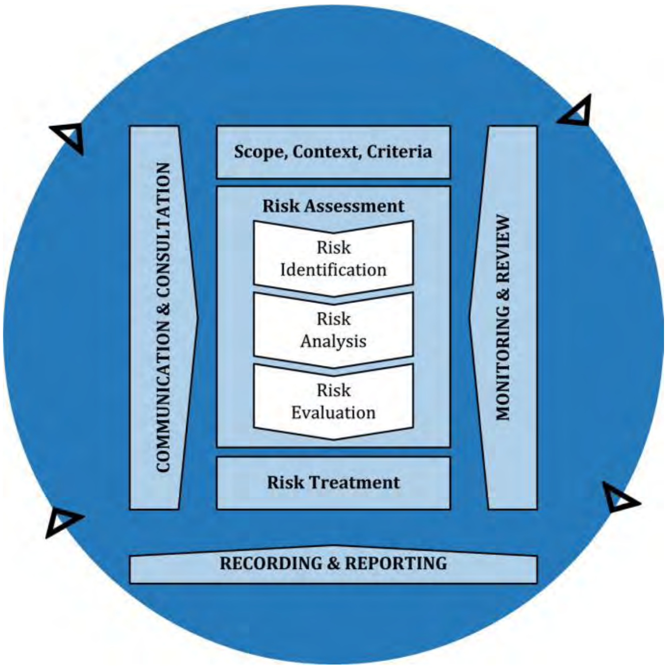

Figure 3.1: ISO 31000 Risk Management Process.

3.1 Staged approach

The assessment methodology adopted to assess the navigational risk of the proposed farm development generally follows the globally accepted staged risk assessment process. That process is shown in Figure 3.1 which is reproduced from international standard[6].

3.1.1 Stage 1.1 –Maritime Context

- Establish and define the scope of the review.
- Describe the proposed development.
- Initial and broad review of the expected hazards.
- Assess suitability against standing guidelines.
- Identify any local or site-specific risk criteria.
- Specify the tools and techniques to be used for the assessment stage.

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[4] Navigatus report for NZKS - Open Ocean Aquaculture Sites – Navigational Considerations
[5] Maritime New Zealand (2018). *Marine Farm Guidelines": navigational safety*. Wellington, New Zealand
[6] ISO31000:2018 Risk management (also refer AS/NZS ISO3100:2009).

3.1.2 Stage 1.2 – Specific context

- Understand the legal and regulatory context.
- Understanding the local maritime activity, traffic densities and types of traffic.
- Understanding the local traffic routing – small and large vessels.
- Researching and defining future activity, densities and types of traffic.

3.1.3 Stage 2 – Risk assessment

- Hazard identification.
- Risk analysis.
- Risk evaluation against criteria.

3.1.4 Stage 3 – Risk mitigation[7]

- Identify and develop proposed risk mitigation options and controls.
- Risk control register (proposed design and procedural requirements to control risk).
- Re-evaluation against criteria.

3.1.5 Stage 4 – Final risk evaluation

- Internal and client review and feedback.
- Final risk evaluations
- Refining risk control options and advice.
- Recording and reporting.

[7] Mitigation is termed “treatment' in ISO3100o0 to reflect that some risk can be valuable. Mitigation is used in this report as navigational risk is taken to be something to be avoided.

4 Stage 1 –Specific Context and Scope

4.1 Stage 1.1 – Maritime context

4.1.1 Legislative framework

The information below is taken from Maritime New Zealand guidelines[8] and extracts from sections from the Maritime Transport Act and the Resource Management Act as applicable to navigational safety.

Maritime Transport Act 1994

Maritime NZ ensures international obligations are met through a specific approval process for aids to navigation. Under section 200(7) of the Maritime Transport Act 1994 (MTA), no person may erect, place, alter or remove a 'navigational aid' without the approval of the Director of Maritime NZ (the Director). This applies irrespective of the owner (e.g. even Maritime NZ officials seek approval to place, alter or remove aids to navigation operated by Maritime NZ). As part of the approval process, IALA guidance will be considered and recommendations may be incorporated into any conditions. In some parts of New Zealand, the MTA section 200(7) power to approve aids to navigation has been delegated to named harbourmasters in relation to aids to navigation for marine farms.

Responsibility of marine farm operators

Section 200(2) of the MTA provides that the operator of any marine farm is responsible for providing and maintaining aids to navigation for the facility. It is recommended that you engage with your local harbourmaster when establishing marine farms and associated aids to navigation

International agreement regarding aids to navigation

New Zealand is a signatory to the SOLAS (International Convention on the Safety of Life at Sea) Convention. As a result, New Zealand is to, 'take into account the international recommendations and guidelines when establishing such aids' (Chapter V, Regulation 13 - Establishment and operation of aids to navigation). Maritime NZ is the authority responsible for giving effect to this international obligation.

Harbourmaster delegations

When the MTA section 200(7) power to approve aids to navigation has been delegated to harbourmasters, the delegation includes a condition that the delegate 'must have regard to' relevant guidance from Maritime NZ. This guidance must be given due weight and consideration when exercising the delegated power. Applicants for aids to navigation should be mindful of this expectation on the local harbourmaster when they are the delegated decision maker. Harbourmasters should seek advice from Maritime NZ regarding unusual or unfamiliar situations. The Director remains responsible for decisions made under delegation and can withdraw the delegation at any time, if necessary.

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[8] Maritime New Zealand (2018). *Marine Farm Guidelines": navigational safety*. Wellington, New Zealand

4.2 Marine environment description for the intended site

4.2.1 General description of the farm location including key navigational hazards and features.

The proposed farm development, is located off shore from the Marlborough Sounds to the North West of Cape Jackson (Figure 4.1).

The selected location sits between two main traffic routes (Figure 4.2). To the North is typically traffic consisting of larger vessels on coastal passage approaching and departing the Cook Strait, and to the South smaller commercial vessels that operate in and out of the Marlborough Sounds and recreational vessels based in the Sounds or those visiting.

There are four shoal areas that can be considered navigational hazards that will generally influence the routes vessels take when transiting the area of the farms (Figure 4.3). The shoal water and dangers that extend off Cape Jackson and Sentinel Rock, as well as Witts Rock and McManaway Rock, that have a charted depth of 9.1 metres, pose a danger to large and relatively deep draught vessels and may pose a danger to smaller vessels under poor sea conditions.

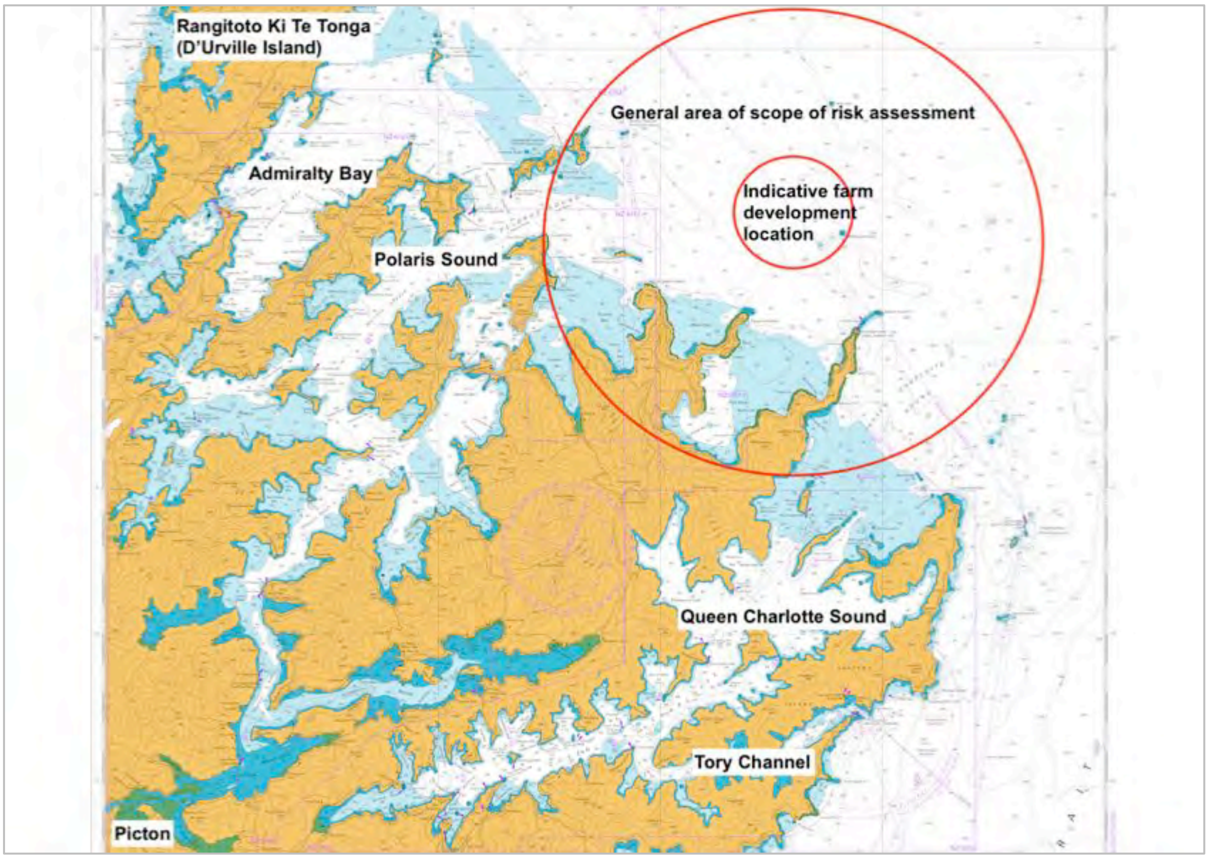

Figure 4.1: Part image of chart of area showing general area for the development and scope of risk assessment

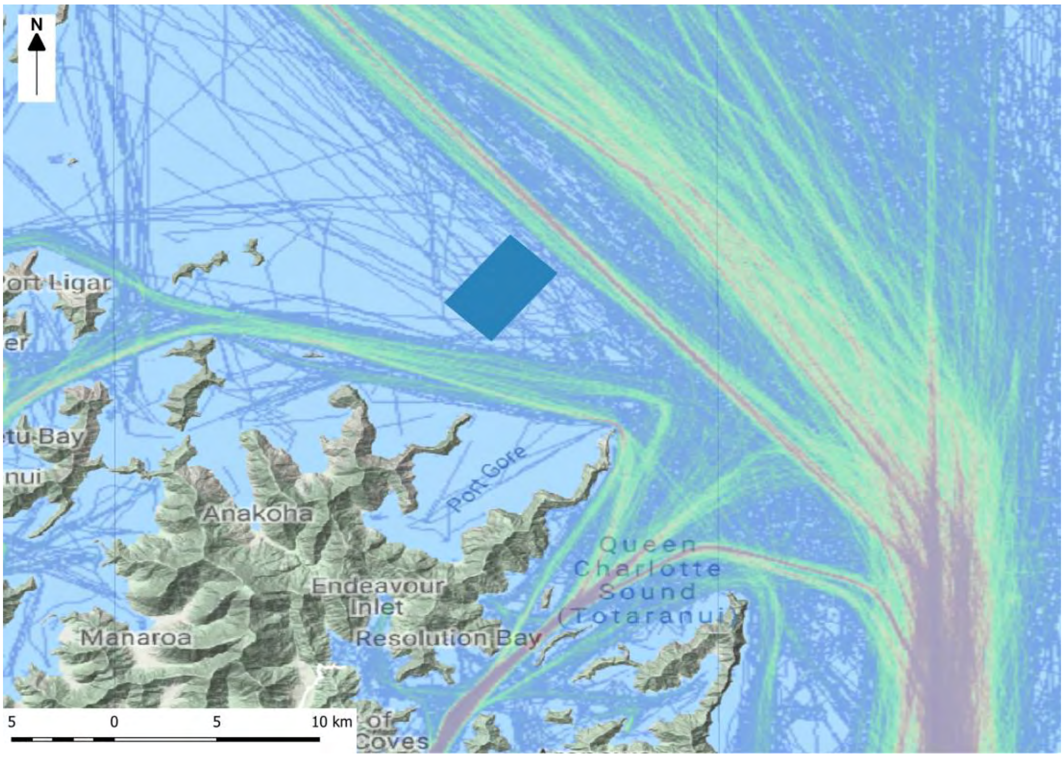

Figure 4.2: Image showing general traffic flow in the area with proposed farm development overlaid (dark blue).

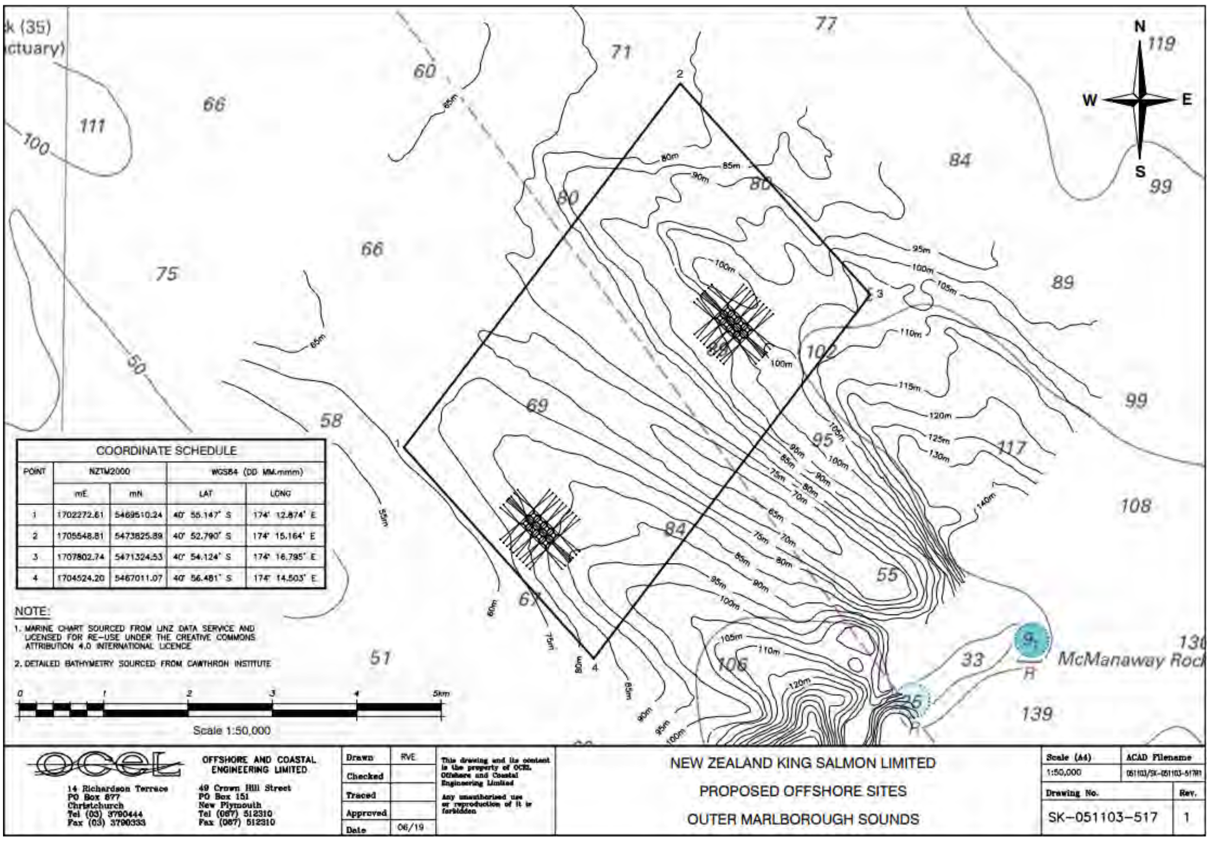

Figure 4.3: OCEL drawing of proposed site[9] showing water depth, shoals and indicative farms and moorings

[9] OCEL Drawing No. SK-051103-517 Rev 1.

The charted sea floor in the proposed location of the farm is relatively benign from a navigational perspective and consistent with the larger nearby areas. The depth ranges from 60-102 metres (Figure 4.3). There are some locations with shoals and holes in the area around the proposed location of the farm. At the entrance to Pelorus Sound the seabed is reported to be coarse sand, mud, and broken shell, while further in to Cook Strait there is indication of mud, sand, fine sand, shells and rock. It is expected that in the sea bed in the proposed location it will be a transition consistent with the surrounding area. It is understood that further specific detail will be provided by Cawthron Institute[10].

4.2.2 Prevailing weather conditions

The prevailing weather for the proposed location is summarised below[11] (Figure 4.4). This shows that predominantly the stronger winds follow the coast from the North West, and from the Cook Strait to the South. This is likely to the topography of the proposed location in relation to the coastline.

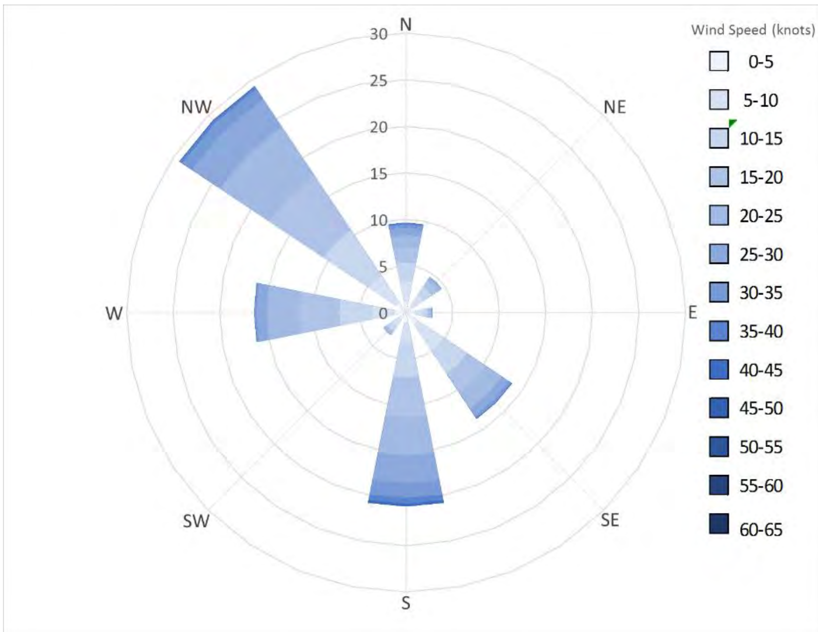

Figure 4.4: Wind rose for North Marlborough site[12].

The wave rose (Figure 4.5) is much as would be expected from the wind rose above and has the predominant wave action from the North West and to a lesser extent, the South East.

[10] Cawthron Institute | Report No. 3317 June 2019 - Assessment of Seabed Effects from an Open Ocean Salmon Farm Proposal in the Marlborough Coastal Area

[11] Not intended as design criteria

[12] Data obtained from https://app.metoceanview.com/hindcast/sites/nz/-40.9/174.25#!.

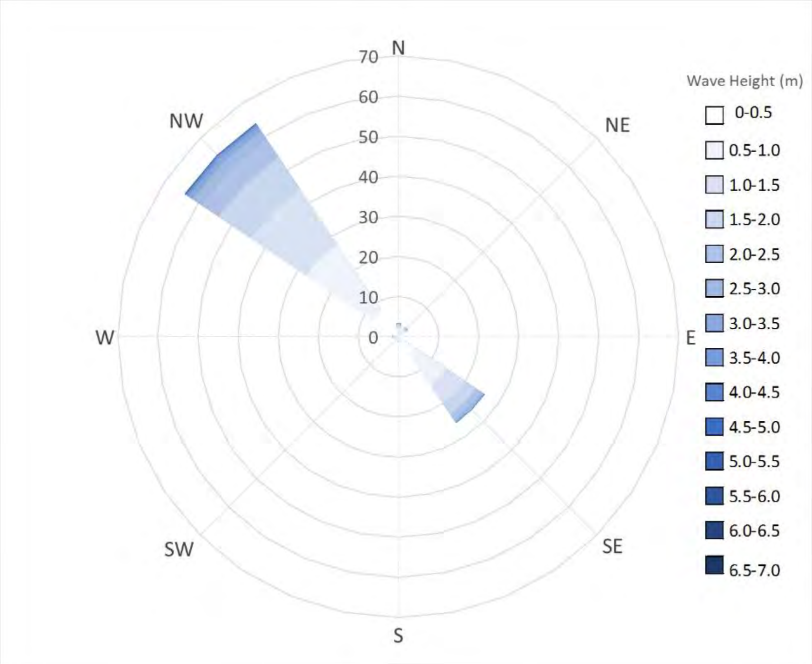

Figure 4.5: Wave rose for North Marlborough site[13].

4.2.3 Extreme weather events

It has been assessed by NZKS that the recorded extreme weather events (Table 4.1) are such that there is current technology available to allow an appropriate farm design and mooring solution to be developed for the proposed location.

Table 4.1: Return period of extreme weather events at the North Marlborough site.

	Return Period	
	10 years	100 years
Significant Wave Height (m)	4.4	5.4
Wind Speed (Knots)	42	47

4.2.4 Existing aids to navigation (AtoN)

There are three existing AtoN in the area. These are lights with a nominal range that would allow them to be visible from the proposed location

- Cape Jackson light – Flash three white every 20 seconds, nominal range of 9 miles. This light will be seen in the South East from the farm location.
- Ninepin Rock light – One white flash every four seconds, nominal range 8 miles. This light is located on the Southern end of the Chetwode Islands in the entrance to Pelorus sound and so to the South West of the farm.

[13] Data obtained from https://app.metoceanview.com/hindcast/sites/nz/-40.9/174.25#!.

- Stephens Island light – One white flash every six seconds, nominal range 18 miles. This light is located to the North West of the proposed farm location high on Stephens Island.

There are a number of other AtoN in the area, however these are not visible from the proposed farm location. More detail of these can be seen on the appropriate chart for the specific location[14].

4.2.5 Isolated navigational dangers

As mentioned above, there are four isolated navigational dangers that interact with vessels and route selection. There are also a number of headlands and bays that impact the natural transit routes. These are as detailed in Section 4.2.1 above.

Whilst none of the four dangers are marked by an AtoN, they can be separated in to visual and non-visual. Sentinel Rock and Walkers Rock dangers have structure that is visual at chart datum. The shoal water and rocks that extend from these are in close proximity, charted, and the approximate location can be expected to be known by mariners in the area. The other two dangers being McManaway Rock and Witts Rock have a charted depth of 9.1 metres and whilst marked on the chart their location may not be as readily apparent as dangers close to shore or islands. There are a number of large vessels that choose to take the shortest route and transit between these two dangers with the centre of the track approximately 1 Nautical Mile (NM) south of Witts Rock and approximately 1.4 NM to the North of McManaway Rock.

4.2.6 Proximity to dwellings amenity and access including jetties and moorings

As there are no natural destination locations on the nearby shore line there is no reason for vessels to be intending to access the immediate shoreline and so the proposed farm will not have any impact on navigating the local shore line.

The visual amenity aspects of the farm development are outside the scope of this navigational safety report. However, from a navigational safety and risk perspective, it is essential that the farm development's presence is visible to mariners or made apparent to mariners by all practical means. It is imperative that any of the farm structure that is on or near the surface and any buoys used to mark the farm are clearly visible to mariners under as wide a range of conditions in so far as reasonably practicable. Given the understanding that the farm should not unnecessarily impact visual amenity or be any more visually prominent than is required, care needs to be taken to ensure markings are effective in a maritime sense but not otherwise overly prominent. Maritime visibility in its broadest sense can be enhanced by means of radar reflectors, navigational lights, buoys, maritime day-shapes, and by virtual means.

[14] Chart NZ 615.

4.2.7 Commercial fishing activity

Commercial fishing activity in the area is split between charter vessels and commercial fishing vessels (Taylor & Dempster, 2018). Commercial fishing vessels operate more commonly in the waters towards the North of the proposed site. Apart from an area to the East of the site, the majority of commercial fishing activity occurs in close proximity to Port Ligar, circled in Figure 4.6, and the waters to the North-East of the proposed site. There is evidence of light to moderate activity in the waters in close proximity to the proposed site but this is relatively small compared to the volume of operations in the areas mentioned previously.

Charter fishing vessels account for a smaller volume of the activity in the area and primarily visit the waters to the South of the proposed site around Port Gore. These areas are circled in Figure 4.6. The waters West of Waitui Bay and East of Forsyth Island form an area with relatively low charter vessel activity. This illustrates a divide between charter fishing activities in the Sounds and those in the nearby open water. The number of charter fishing vessels operating around the water in close proximity to the proposed site is much smaller than that of commercial fishing vessels.

AIS data viewed by Navigatus and shown in Appendix A shows evidence of at least some fishing activity in and around the proposed location. The location of the farm boundaries has been adjusted to minimise impact on known fishing operations that occur near Sentinel Rock.

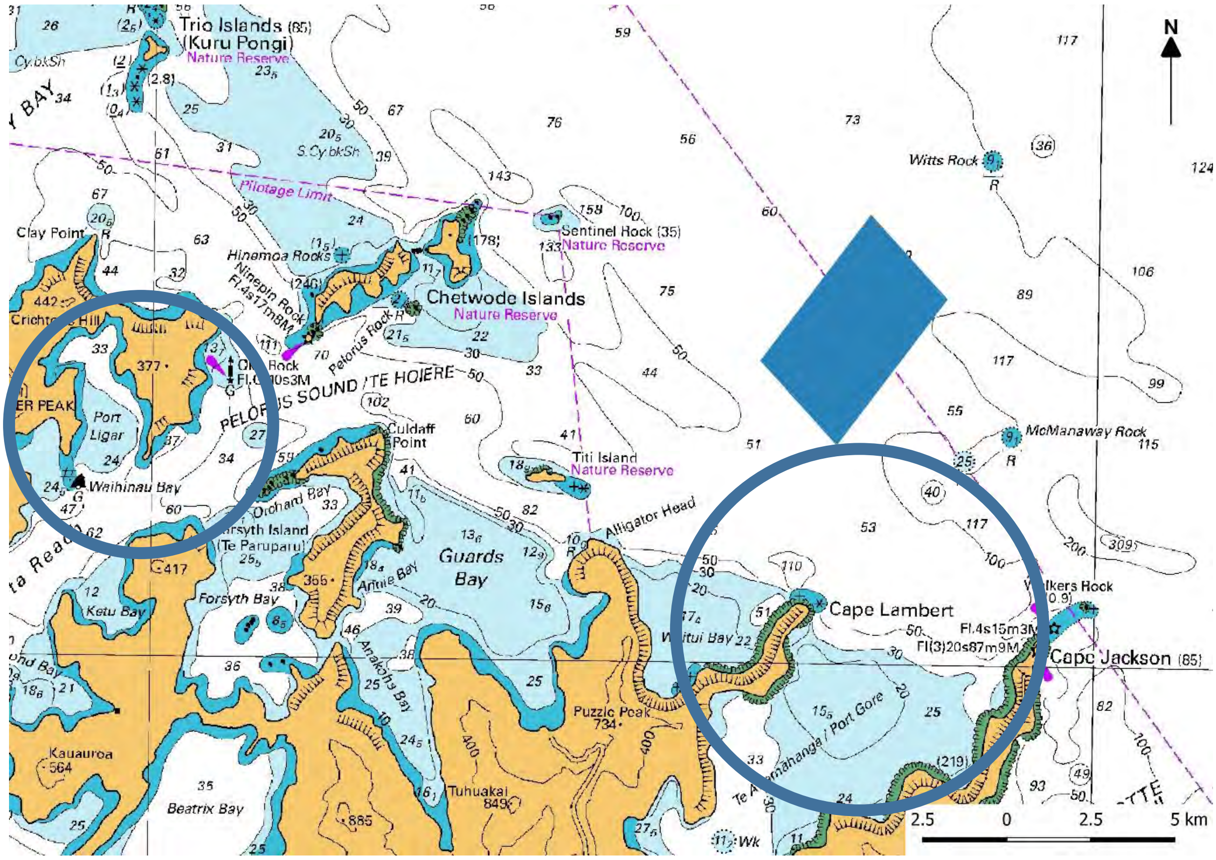

Figure 4.6: Part copy of Chart NZ 615 with proposed farm site marked and areas of high fishing activity circled.

4.3 Description of the proposed infrastructure and moorings

While a detailed design, final layout, or the number of structures located inside the proposed area has not yet been determined, an assessment of the general navigational aspects of a farm development in the proposed area has been undertaken. The work methodology does however ensure the assessment of the viability of the proposed area from a maritime navigational risk perspective remains sound.

The final design will influence the Navigational Risk Reduction Management Plan (NRRMP) or Structures Management Plan that will have to be submitted for approval prior to construction.

The infrastructure needs to be designed to withstand the most extreme weather conditions it may encounter. The NZKS methodology states that the design must be based on a 50-year return period condition, and must take in to account the through life fatigue. The methodology goes on to state that the fatigue assessment must provide the periodicity for replacement of components if required. The details must be transferred in to the maintenance routine as mandatory maintenance requirements.

In order to provide confidence, the design of the proposed infrastructure including mooring structures is required to be peer reviewed.

To minimise the area that poses a hazard to surface navigation the following base requirements are recommended to reduce the overall risk to small vessels operating near the farm and should be factored in to the design.

- All dangers to surface navigation of a vessel with a draught of 5 metres are to be marked by a special mark[15].
- No dangers to surface navigation of a vessel with a draught of 5m outside buoyed extent, no dangers to surface navigation of a vessel with a draught of 10m within 100 metres of buoyed extent, no dangers to surface navigation of a vessel with a draught of 20m within 400 metres of buoyed farm extent.

The above requirements are included in the proposed conditions of consent.

It is noted that should the situation arise where NZKS are unable to meet the requirement to mark the area dangerous to navigation detailed above in the selected design of the farm, an assessment of the navigation risk associated with the specific design must be conducted and acceptable to the Harbourmaster.

4.3.1 Extent and number of farms within the development

As above, the exact technology and associated number of farms has not been decided at this stage and will be included in the NRRMP or structures management plan prior to construction.

[15] These marks indicate a special area or feature, which can be identified on a chart or another nautical document. They are yellow and may carry a yellow ‘X’ top mark, and if they have a light, it will be yellow - https://www.maritimenz.govt.nz/magazines/lookout/issue-25/issue-25-4.asp

4.3.2 Proposed location of the farm(s) and extend of occupied water space

The proposed location of the farm development has been through a series of refinements in order to minimise the impact across a number of aspects.

From a navigation risk perspective, the boundaries of the farm development have been adjusted from those originally identified. In particular, the outer boundary position has been altered in order to minimise the interaction with the natural vessel transit routes in the area. The boundaries have also been adjusted to minimise the overlap with the known fishing area (as mentioned above).

4.3.3 Proximity to ports or places of refuge

The proposed location is between Pelorus Sound and Marlborough Sounds which offer numerous safe havens and places of refuge. The Port of Picton and Nelson are the closest major facilities from which the farm could be operated. Smaller vessels may operate from Havelock North located at the head of Pelorus Sound.

4.3.4 Type of farm infrastructure and structural details

While the detail of the structural design is yet to be defined, the details will influence and be included in the NRRMP as well as any through life maintenance and upkeep planning and operational procedures.

With regard to the positioning and the effect on navigation safety, so that the layout and safe and proper passage routes past the farm area can be generally disenable from the bridge of a ship, surface structures should, where possible, be configured or assembled in sets that are aligned parallel to the general direction of traffic flow as seen in Figure 4.3.

Any obstruction to surface navigation extending between pens or from feed barges and pens will have to be clearly marked and be located and secured at all times inside the buoyed extent of the farm.

4.3.5 Proposed farm location

As a result of inspection of traffic data, the proposed farm area has been shaped so that the northern border lies parallel to the general direction of traffic flow (Figure 4.2). This orientation of the border helps to generally align the border of the proposed development and the natural traffic flow in the area. The proposed farm development area is shown in Figure 4.7 below.

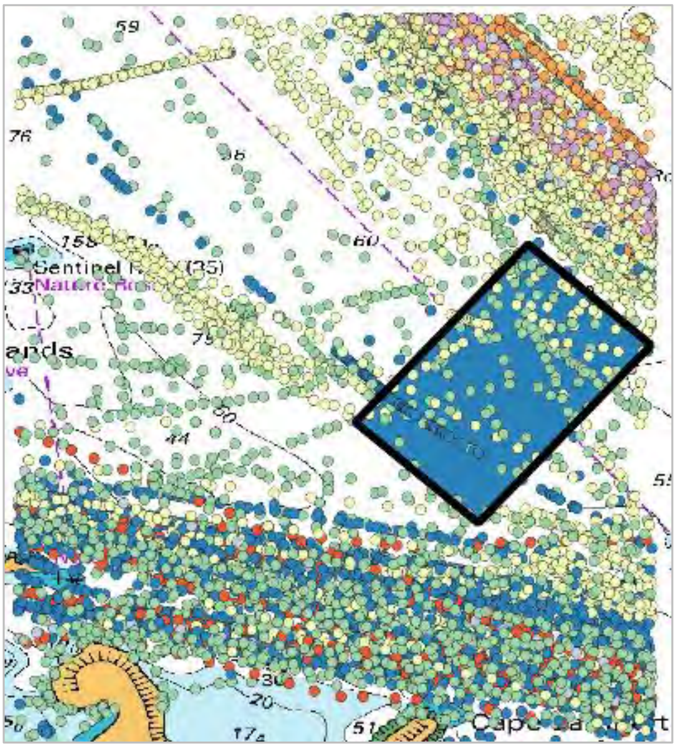

Figure 4.7: Proposed site for North Marlborough farm with AIS data in the background.

The location of the border of the proposed site area aims to reduce any inherent tendency to compress traffic flow and so limit interference to the natural traffic flow.

4.3.6 Intended construction, operation, and removal phases

While the final technology and detailed design will not have been determined at the time of the consent application, it is not possible to detail the full details of the navigational aspects of the construction, operation and removal phases. However, there is no reason to believe that there are any issues that cannot be managed under a suitable risk management plan. A Navigation Risk Reduction Management Plan (NRRMP) should therefore be developed. This should address the construction methodology and the effects of additional vessels during construction as well as normal operations and in due course the removal phase.

Operations and maintenance will be managed through New Zealand King Salmon standard operating and maintenance routine developed for their existing operations.

4.3.7 Intended aids to navigation suite

All Aids to Navigation (AtoN) must be to a level that is to the satisfaction of the Harbourmaster and meet Maritime NZ requirements. The following is the recommended minimum that will be required.

- A full cardinal buoyage system is required in order to indicate the extent of the farming area.
- Extent of physical farm or mooring structures need to be marked where they pose a risk to vessel navigation. It is considered that the buoys should be placed to ensure a minimum static[16] safe clearance depth of at least 4 metres. It is probably the case that not all individual buoys will need to be lit, however the outer corners and the centres on the longest side will need to be lit to ensure the extent of the farm is clear. Any additional permanent support structure and barges associated with the farm also require to be lit. To avoid confusion and ensure clarity, all lights will need to be time synchronised to flash in unison.

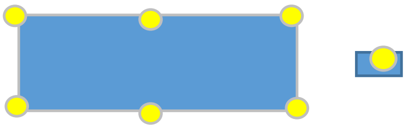

Figure 4.8: Indicative illustration of farm lighting.

- Automatic Identification System (AIS) fitted and programmed to broadcast the extent of the farm location and any individual structures that may pose a risk to navigation – that is any part having a minimum static safe clearance depth of 5 metres and any other dangers to vessel navigation.
- A virtual[17] AtoN may also be required to be placed on Witts Rock and McManaway Rock located to the North and East of the farm's location.

4.3.8 Visual appearance

As previously mentioned, (Section 4.2.4), efforts to limit the visual amenity impacts must not compromise navigational safety. This aspect extends to AtoN. The lights and shapes shown must be as required to ensure mariners can see and discern the location and extent of the farm area and farm structures, compliant with regulations and so prevent undue navigational risk.

[16] Does not include vertical movement induced by swell and wave conditions

[17] Traditionally, AtoN have been physical aids such as lighthouses, buoys, and beacons. However, AIS is one tool that has been used to provide mariners with "virtual ATON", where no physical object or structure is associated with the navigational aid.

4.4 Farm development Navigation Risk Reduction Management Plan (NRRMP)

In accordance with the proposed conditions of consent, prior to the installation of structures, the consent holder shall prepare and lodge a NRRMP with the appropriate local authority. The purpose of the NRRMP is to reasonably minimise risks in accordance with the New Zealand Port and Harbour Marine Safety Code. That Code requires the Plan to:

- Identify all relevant risks in accordance with the New Zealand Port and Harbour Marine Safety Code;
- Detail the appropriate management of those risks;
- Outline the appropriate response if an AIS transponder detects a deviation from normal operation;
- Include a structures diagram for the layout and structure, including mooring, of the marine farm moorings. This is to be peer reviewed by an appropriate qualified engineer and must include through life fatigue;
- Include a construction plan to manage the effects of the presence of vessels during construction;
- Detail any initial or ongoing notification to or education of vessel users in relation to the presence of the structures; and
- Record if and when further notice to the Harbour Master and/or Land Information New Zealand is required.
- Require periodic risk reviews and the implementation of any findings.
- Establish an emergency response plan, and require periodic drills.

4.5 Further local maritime context

The intent of this stage of assessment of navigational impacts is to understand the broad as well as specific maritime context. Context is considered as follows:

- Understanding the Base Case local maritime activity, traffic densities and types of traffic.
- Understanding the local traffic routing – small and large vessels.
- Researching and defining future activity, densities and types of traffic.

4.5.1 Analysis of marine traffic and local factors

To understand the base case of local marine activity, traffic density, and vessel type, AIS[18] satellite and terrestrial data for the year 2018[19] was extracted for a defined area[20]. A total of 7,200 records of AIS-Terrestrial vessel positions and 6,800 records of AIS-Satellite vessel positions were returned. These individual data points make up a total of 703 transits of the defined area.

It is acknowledged that relying on the AIS data for the marine traffic has inherent limitations. Whilst it is becoming more common that smaller recreational vessels, in particular sailing vessels, are fitting AIS units, the requirements to be fitted are defined under SOLAS V regulations[21] and Maritime New Zealand Rules[22], Part 40C. These state:

- A ship of 300 gross tonnage or more constructed before 1 January 2017 but on or after 25 May 1980 that proceeds on an international voyage, not later than the first survey on or after 1 January 2017:
- A ship of 300 gross tonnage or more constructed on or after 1 January 2017 that proceeds on an international voyage:
- A ship of 500 gross tonnage or more constructed before 1 January 2017 but on or after 25 May 1980 that proceeds beyond restricted limits, not later than the first survey on or after 1 January 2017:
- A ship of 500 gross tonnage or more constructed on or after 1 January 2017 that proceeds beyond restricted limits

Images of the differing traffic types is given in Appendix A. These show the various traffic categories. The grouping of vessel descriptions used to develop the images is given in Table 4.2.

Table 4.2 – Breakdown of marine traffic grouping

Vessel Category	Type	Vessel Category	Type
Barge	Mussel Barge	Working	Tug
	Barge		Survey
Bulk	Bulk		Harbourmaster
Cargo	Cement Carrier		Fishery Patrol Vessel
	Cargo		Landing Craft
Container	Container		Police
Fishing	Trawler		Navy
	Fishing		Workboat
Passenger	Ferry		Search and Rescue
	Passenger		Patrol
	Cruise		General
Recreational	Sailing Vessel		
	Pleasure Craft		
Tanker	Tanker		Tanker

[18] Source data from Marine Traffic Limited
[19] TIMESTAMP between '2018-01-01 00:00' and '2018-12-31 23:59'
[20] AIS Data area - LAT between 41 S and 40.83 S, LON between 174.14 E and 174.28 E
[21] SOLAS V, Regulation V/19.2.4, Annex 17
[22] Maritime New Zealand – Maritime Rules, Part 40C, Article - 40C.59C - Automatic Identification System

4.5.2 Detailed description of the local navigational features

The local navigation features in this region that impact the natural transit routes for vessels result in a relatively complex navigational context.

Inshore traffic follows the natural transit lines created by the normal coastal environment. Vessels choose to transit across bays and will use prominent headlands as waypoints. Islands also act as waypoints for point to point coastal navigation.

In addition to the island and headlands, the underwater topography influences the route selection for larger vessels or vessels on transit to and from the Cook Strait.

4.5.3 Natural transit routes

There are three natural transit routes in the vicinity of the proposed farm development. These can be separated in to three distinct categories.

- Inshore coastal route – The traffic following the natural transit route created by the dangers extending from Cape Jackson and the entrance to Pelorus Sound.
- Coastal transit route – The traffic following the natural transit route from the North of Stephens Island and the entrance to the Cook Strait, passing to the South of Witts Rock and the North of McManaway Rock.
- Offshore transit route – The traffic following the natural transit route from the North of Stephens Island and the entrance to the Cook Strait, passing to the North of Witts Rock.

It is assessed that the presence of the farm in the proposed location will not have a material impact on the vessels that choose to remain to the North of the unmarked navigational danger associated with Witts Rock.

4.5.4 Current traffic densities and types

In Table 4.3 the traffic has been broken down in to the number of transits that occurred on each route across the specified area in 2018. This is taken from AIS data and so shows all vessel of 500gt or more (300gt for ships operating internationally and all passenger ships)[23] and those smaller vessels that have AIS fitted. Data on other small vessels are therefore not included.

Table 4.3 Traffic breakdown

Transit route	Direction of Travel	Number of transits	Transits per day (both directions)
Coastal transit route	East	185	1.03
	West	191	
Inshore coastal route	East	159	0.88
	West	161	
Offshore transit route	East	36	0.24
	West	52	

23 Regulation 19 of SOLAS Chapter V

What can be seen in the above table is that on average there is about one vessel per day that transits each of the coastal route and the inshore traffic routes. This is an average and there will be occasions where multiple vessels have transited on the same route on the same day and may therefore have some interaction.

This distribution is further broken down by season in Table 4.4, and vessel type in Table 4.5.

Table 4.4 – Traffic breakdown by season

Transit route	Season	Direction of Travel	Number of transits
Coastal transit route	Autumn	East	49
		West	51
	Summer	East	45
		West	57
	Winter	East	47
		West	41
	Spring	East	44
		West	42
Inshore coastal route	Autumn	East	36
		West	37
	Summer	East	74
		West	67
	Winter	East	20
		West	23
	Spring	East	29
		West	34
Offshore transit route	Autumn	East	7
		West	11
	Summer	East	15
		West	19
	Winter	East	4
		West	8
	Spring	East	10
		West	14

Table 4.5 - Traffic breakdown Vessel type

Position relative Farm	Vessel type	Direction of Travel	Number of transits
Coastal transit route	Bulk	East	10
		West	6
	Cargo	East	14
		West	19
	Container	East	49
		West	47
	Fishing	East	88
		West	87
	Passenger	West	5
	Recreational	East	19
		West	22
	Tanker	East	1
	Working	East	4
		West	5
Inshore coastal route	Barge	East	10
		West	13
	Fishing	East	17
		West	19
	Passenger	East	2
		West	2
	Recreational	East	80
		West	74
	Working	East	50
		West	53
Offshore transit route	Barge	East	1
	Fishing	East	8
		West	11
	Recreational	East	22
		West	24
	Working	East	5
		West	17

4.5.5 Predicted future traffic densities

Future demand volumes for container freight have been estimated by Deloitte (Ministry of Transport, 2014). The model took data for 2012 to predict growth rates for trade by region and commodity until 2042 as well as the volume of both imports and exports. The national average growth rates for all products are predicted to increase steadily however these same growth rates vary greatly by region. Similarly, the volumes of container freight are forecast to steadily increase over the same period of time to 23.7 million tonnes. However, it is important to note that the majority of imports arrive to Auckland and Tauranga and the domestic origin of export container freight is driven by the location where the goods are produced.

To accommodate this increase in growth rates and volume, a number of scenarios were considered to predict how this volume of goods would be transported. In the majority of scenarios, the size of vessel used to transport freight increased over time as opposed to the frequency of transits. This increase in vessel size means an increase in draught and hence container freight vessels travelling further away from the shore.

4.5.6 Defined shipping or separation schemes

There are no defined shipping channels or traffic separation schemes in the vicinity of the proposed farm. As a result, except in very poor conditions, vessel routing in the area is invariably determined by shortest route and avoiding hazards.

4.6 The effect of the proposed infrastructure on current traffic densities and types

As explained before, the boundaries of the proposed location have been adjusted to limit the overlap with current traffic routes. The extent of the area boundaries to the North is approximately 1200 metres from the natural large ship transit route and 500 metres from the transiting fishing vessel route, and approximately 1200 metres from the majority of traffic in the coast route to the South. There are some examples of vessels not conforming to the traffic norms and transiting as close as 500 metres to the south of the proposed area. However, after placement of the farms, in similar cases vessels will simply take a slightly different route.

4.6.1 The effect of the proposed farm on future traffic

Any additional traffic levels over current can be expected to follow the same natural transit lines already observed in the area and so there will not be any new impact as a result of the proposed farm being in the location.

4.6.2 Proximity to safe havens, anchorages or mooring areas

There are no recommended anchorages marked in the immediate vicinity of the proposed farm location. Marlborough Sounds offers a number of safe havens, anchorages[24], and moorings for eligible vessels. As a result, the proposed farm would not be expected to have an effect on any vessels intending to anchor.

4.6.3 Access for small craft between and around marine farms

While small vessels would need to remain outside of the buoyed farm structures there is little reason to consider that they would need to be restricted from entering the area inside the development area boundaries. The buoys around each farm would need to be placed to enasure a safe static[25] below surface clearance of 5 metres.

[24] Depending on size and weight of vessels, or if they have a pilot exemption or require a pilot to proceed inside Marlborough Harbour Limits

[25] Sea and swell conditions will create a dynamic relationship between mooring lines and vessel draught. Masters will need to consider this when in the vicinity of the farm.

4.6.4 *Manoeuvring area with special consideration to stopping and turning distances*

The following requirements are extracted from the International Maritime Organisation (IMO) and set the following standards for vessel manoeuvrability:

- Turning ability, the advance should not exceed 4.5 ship lengths, and the tactical diameter[26] should not exceed 5 ship lengths in the turning circle manoeuvre[27].
- Stopping ability, the track reach in the full astern stopping test should not exceed 15 ship lengths.

For analysis, if a 300-metre-long vessel is used the required tactical diameter is 1500 metres or 0.81 NM and the stopping distance is 4500 metres or 2.43NM.

In an emergency situation for large vessels in the transit route to the North of the proposed farm location, there may not be sufficient room for an alteration of course of 180˚ but the available sea room would be sufficient to enable way to be taken off a vessel while on a steady bearing (brought to a stop in a straight line).

4.6.5 *Traffic generated from operations*

It is expected that any additional traffic generated from servicing the farms will form part of the generic traffic flow and not have a significant impact on the non-farm traffic.

[26] The perpendicular distance between a ship's course when the helm is put hard over and its course when she has turned through 180 degrees.
[27] IMO - RESOLUTION MSC.137(76) (adopted on 4 December 2002) STANDARDS FOR SHIP MANOEUVRABILITY

5 Stage 2 – Navigational Risk Assessment

This part of the assessment consists of:

- Hazard identification.
- Risk analysis.
- Risk evaluation against criteria.

5.1 Hazard identification

5.1.1 Hazard identification step

The hazard identification step of the navigation risk assessment methodology developed by Navigatus for open ocean aquaculture considers risk under the following risk groups:

- Collision.
- Allision[28].
- Grounding.

These overarching risk groups are further broken down in to a number of 'Hazards' or 'Causal' factors that are used to analyse the navigational risk associated with the proposed development. In identifying these hazards, the following themes should be considered:

- Technical factors.
- Human factors (perception and error).
- Environmental factors (weather, current, etc).
- Triggers and event chains.

[28] Allision is defined as the striking of a vessel against a fixed object.

5.1.2 Collision

<table>
<tr><th></th><th>Hazard or casual factor</th></tr>
<tr><td rowspan="4">The potential for and consequence of Collision as a result of the factors introduced by the development</td><td>Traffic:
▶ Proximity to traffic routes, density, type and operation
▶ Proximity to navigational danger, chokepoint, port approaches or significant alterations of course
▶ Proximity to port or harbour entrance
▶ Proximity to anchorage areas
▶ Compliance with voluntary code[29] (5nm) for oil laden or hazardous cargo
▶ Potential growth or decline in traffic volumes
▶ Seasonal variation
▶ Special or privileged vessels[30] or operations
▶ Vessel manoeuvrability
▶ Reduction in available sea room</td></tr>
<tr><td>Site factors:
▶ Location of farm area and farm installations (structures and anchoring arrangements)
▶ Alignment and layout of associated installations
▶ Wind weather and sea conditions
▶ Tide and currents
▶ Reduction in water depth
▶ Proximity to other aquaculture or offshore installation(s)</td></tr>
<tr><td>Human Factors:
▶ Lengthened navigation route
▶ Greater complexity
▶ Knowledge of the collision regulations
▶ Keeping of a proper lookout</td></tr>
<tr><td>Other:
▶ Aids to Navigation
▶ Back scatter coastal light
▶ New technology – Unfamiliar restriction</td></tr>
</table>

[29] New Zealand operates a Voluntary Code for Ships Carrying Oil or other Harmful Liquid Substances in Bulk (the Voluntary Code). https://www.maritimenz.govt.nz/commercial/environment/operators/ship-routeing.asp
[30] Privileged vessel defined as a Vessel: Constrained by draught, not under command, or restricted in ability.

5.1.3 Allision (including potential for Foundering)

	Hazard or casual factor
The potential for and consequence of Allision and Foundering as a result of the factors introduced by the development	Traffic: ▶ Proximity to traffic routes, density, type and operation ▶ Proximity to navigational danger, chokepoint, port approaches or significant alterations of course ▶ Proximity to port or harbour entrance ▶ Proximity to anchorage areas ▶ Proximity to voluntary code (5nm) for oil laden or hazardous cargo ▶ Potential growth or decline in traffic ▶ Seasonal variation ▶ Special or privileged vessels or operations ▶ Vessel manoeuvrability ▶ Reduction in available sea room ▶ Recreational traffic ▶ Proximity to wharves, dwellings
	Site factors: ▶ Location of farm area and associated installations ▶ Alignment and layout of farm and associated installations ▶ Wind weather and sea conditions ▶ Tide and currents ▶ Reduction in water depth ▶ Extent of mooring installations ▶ Depth and extent of submerged structure ▶ Sea room between farms for vessel navigation ▶ Proximity to other aquaculture or offshore installation ▶ Proximity to existing underwater insulation(s)

5.1.4 Grounding

	Hazard or casual factor
The potential for and consequence of grounding as a result of the factors introduced by the development	Traffic: ▶ Proximity to navigational danger, chokepoint, port approaches or significant alterations of course ▶ Draught in relation to available depth and width of navigable water ▶ Special or privileged vessels or operations ▶ Vessel manoeuvrability ▶ Reduction in available sea room ▶ Requirement to deviate from traditional route ▶ Funnelling towards navigational danger
	Site factors: ▶ Location of farm installations ▶ Alignment and layout of farm installations ▶ Wind weather and sea conditions ▶ Tide and currents ▶ Reduction in water depth ▶ Proximity to other aquaculture or offshore installation (s)
	Human Factors: ▶ Greater complexity ▶ Reduction in sea room for emergencies ▶ Comprehension of Aids to Navigation ▶ Keeping of a proper lookout ▶ Time pressure
	Other: ▶ Aids to Navigation ▶ Back scatter coastal light ▶ Partly or fully submerged

5.2 Generic site assessment

5.2.1 Context Benchmarking

The first stage of the risk assessment was to undertake an assessment of the area and a farming development in general terms.

In light of the global industry trend towards open water fin fish farm developments, a generic navigational risk methodology for off shore farm developments was firstly developed by Navigatus. This identified a set of 8 criterion to form the basis for a provisional assessment of any identified open water locations by New Zealand King Salmon farm developments. The criteria are described below.

Table 5.1: Assessment criteria

A	Interference with current or established routing
B	Interference with navigational constraints – Anchorages, port approaches, chokepoints, channels
C	Increase in navigational complexity
D	Suitability for AtoN placement
E	Exposure to weather and sea conditions
F	Distance from servicing or support locations
G	Interference of fishing vessels[31] and operations
H	Proximity to other infrastructure

The generic methodology requires that the navigational complexity of each site of interest is provisionally assessed against each criterion using an interval-type scoring system with each step representing an approximate doubling in complexity relative to a generic 'benchmark' site. While not a direct relationship, the nature of mitigation is likely to be driven by the level of complexity.

Table 5.2: Complexity risk scale

Scale	Description of complexity	Probable nature of mitigation
1	No material complexity	No additional mitigations
2	Some complexity	Routine management procedures will suffice
4	Complex factors	Risk would need to be managed with specific procedures and communication
8	Notable level of complexity	Full detailed risk assessment and implementation of specifically developed controls
16	Very high complexity	Requires full detailed risk assessment and development of proven mitigations

[31] Due to limited information available a more detailed local analysis for each location is required

5.2.2 Proposed site navigational complexity assessment

Historic vessel tracks (taken from the vessel AIS records) was overlaid on to the proposed location of the farm development to enable the preparation of provisional navigational complexity / risk scores to, in turn, inform this development specific risk assessment. The scores for the benchmark site and that for North Marlborough is given at Table 5.3 below. The total score is an indicative level of navigational complexity of the location expressed in semi-quantitative terms.

Table 5.3: Site complexity

Site	Criterion								Indicative level of risk
	A	B	C	D	E	F	G	H	
North Marlborough	8	2	3	2	2	2	2	3	24
Benchmark	**1**	**1**	**2**	**1**	**2**	**-**	**2**	**1**	10*

* Does not include potential interaction with fishing vessels.

The above results show that the proposed location has an inherently higher level of risk than the benchmark site and so will demand a greater level of mitigation than for a generic farm development. This conclusion underpinned the risk assessment of the proposed farm development.

5.3 Development site risk identification

An event register was developed to identify the navigational risk associated with the proposed farm development at the identified location. As with the previously discussed benchmarking process, the risk methodology is that to be applied to all future NZKS proposed farm developments. This will ensure a consistent assessment system and hence ability to compare differing sites and development proposals.

As outlined before, risk is assessed under three risk event groups:

- Collision.
- Allision.
- Grounding.

These overarching groups were explored under 7 risk-event headings, each describing a type of event and assessed in turn. The process of assessing these events involved considering a total of 52 causal factors or triggers. Where the event and causal factor were applicable to the proposed farm the overall likelihood and impact of that event was considered and assessed.

The assessed pre-mitigation risk for the proposed farm location is as per Table 5.4 over:

Table 5.4: Risk rating identification table

Risk Event	Likelihood	Consequence	Raw Risk Rating (pre-mitigation)
Vessel collision near proposed farm	Unlikely	Serious	High
Small vessel collision whilst transiting the farm	Unlikely	Serious	High
Vessel under control contacts farm	Unlikely	Serious	High
Operational or maintenance vessel makes contact with a farm	Possible	Serious	Very High
Vessel not under control contacts farm	Rare	Serious	High
Vessel under control grounds	Improbable	Major	Medium
Vessel not under control grounds (effect on farm)	Highly Improbable	Major	Medium

The detail underlying the above is given at Enclosure 1 (Risk Register).

5.4 NRA – Risk Analysis

As explained before, the purpose of risk analysis is to comprehend the nature of risk and its characteristics prior to then evaluating the risk and considering mitigations. It involves detailed consideration of sources, consequences, events, scenarios, and existing controls and their effectiveness. The analysis considers:

- Likelihood of events and associated consequences.
- The nature and magnitude of consequences.
- Added complexity and or connectivity.
- Any time related factors.
- Existing controls and their effectiveness.

5.5 NRA – Risk Evaluation

The purpose of risk evaluation is to determine if individual risks are, and the overall risk is, acceptable or to determine if, given further controls, that risk can be made acceptable. This leads to a decision to:

- Do nothing further as the risk is acceptable – implement the identified controls.
- Understand the risk in more detail – this is done to address uncertainty and develop further knowledge.
- Consider further mitigation options – further identification and analysis of controls and evaluation of the resulting risk.
- Reconsider the overall approach – in particular seek alternative opportunities or benchmark methods that will enable risk to be adequately managed.

The response to the above determine the mitigation of the risks.

6 Stage 3 – Risk Mitigation

6.1 Stage 4 - Risk mitigation

The purpose of this stage was to select and implement options for reducing the overall level of risk or identify controls for addressing individual risks.

As each risk mitigation was developed and or selected, its effectiveness was assessed. A decision was then made if that residual risk is acceptable or if additional controls were required.

6.1.1 *Risk controls - generic*

The NZKS open water farm assessment methodology described before also sets out the mitigations and controls to reduce the risk to As Low As Reasonably Practicable (ALARP)[32].

These are in effect risk control criteria that may be applied when acting to minimise the risk to the lowest level practicable and ideally to a level comparable to the existing levels associated with current normal vessel operations in the area.

The ability to meet these criteria as well as the complexity/risk score derived from the risk assessment were considered when assessing the site. The standard criteria within the methodology are:

- No closer than two nautical miles from established large ship navigation routes, unmarked dangers, chokepoints, significant alterations of course, or existing underwater hazards[33].
- No closer than one nautical mile from natural[34] recreational transit routes.
- No closer than four nautical miles from ports or harbour entrances.
- Boundaries of farm are a diamond shape with north up orientation. Surface structures inside the boundaries aligned parallel to the general direction of traffic flow.
- Suitably marked with Aids to Navigation that meet MNZ endorsed IALA regulations. To include location and extent of danger to surface navigation transmitted on AIS. Position of Aids to Navigation remotely monitored.
- Extent of moorings dangerous to surface to navigation marked.
- Reduce so far as practical the physical footprint inside the consent boundaries. If planned to move location of structures during the consent period maintain consistency of the farm configuration.
- Presence of farm is promulgated to recreational, fishing, commercial vessels and port authorities.

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[32] ALARP is a long established and well accepted risk acceptance criterion that has been tested in the courts and forms the basis of some safety legislation.
[33] Under water hazard in this instance could be considered as wrecks, pipelines, or undersea cables
[34] Natural transit route – the natural route that recreation or small vessels would take. Takes in to account shortest route, point to point navigation, transit across bays, use of headlands and waypoints,

- Location of aquaculture site promulgated through navigation charting, Notice to Mariners, and navigation warnings.
- Structure designed to withstand extreme weather and associated sea conditions based on 50-year return period.
- Structure located to allow safe operations and maintenance to occur not less than 30% of the time based on 10-year return period.

6.1.2 Development of North Marlborough risk options and controls

A number of aspects of the proposed farm development were found not to meet the NZKS open ocean methodology criteria. These are summarised below and are noted in the risk register.

Proximity to transit lanes:

- The boundaries of the proposed location were adjusted from the original design proposal to limit the overlap with current traffic routes. The extent of the area boundaries to the North is approximately 1200 metres from the natural large ship transit route, 500 metres from the transiting fishing vessel route and approximately 1200 metres from the majority of traffic in the coast route to the South. There are some examples of vessels not conforming to the traffic norms and transiting as close as 500 metres to the South of the proposed area. However, after placement and marking of the farms, vessels not on the common routes will simply be able to take a slightly different route.
- The traffic routes are assessed as being of a low volume with only on average one vessel per day transiting each of the coastal and inshore transit routes adjacent to the farm.
- The extent of the farm area will be marked with suitable AtoN to the satisfaction of the Harbourmaster. This will need to include AIS of the proposed farm infrastructure.
- The traffic route currently follows a line that passes to the North of McManaway Rock. This will not be adversely altered. Witts Rock and McManaway Rock will need to be marked with a Virtual AIS to aid in situational awareness.

6.2 Residual risk levels

The levels of risk given implementation of the mitigations was reassessed. The results are in Table 6.1 below.

Table 6.1: Comparison of risk ratings and their respective residual risk rating post mitigations

Risk Event	Overall Raw Risk Rating (pre-mitigation)	Overall Residual Risk Rating (post mitigation)
Vessel collision near proposed farm	High	High
Small vessel collision whilst transiting the farm	High	Medium
Vessel under control contacts farm	High	Medium
Operational or maintenance vessel makes contact with the farm	Very High	High
Vessel not under control contacts farm	High	Medium
Vessel under control grounds	Medium	Medium*
Vessel not under control grounds	Medium	Medium*

7 Risk Assessment Summary Including Key Risks

After mitigations have been applied to the identified risks, there are five medium and two high residual risks associated with the proposal. The key risks are discussed in more detail below. The "*" shown against two medium risks indicate that serendipitous benefits act to lower these risks further – possibly to the extent that these may be considered 'low'.

7.1.1 *Vessel collision near proposed farm*

This risk is assessed as being reduced to a level that is ALARP and is comparable to the risk that is associated pre proposal.

7.1.2 *Operational or maintenance vessel makes contact with the farm*

Due to the nature of operations and requirement to interact in close proximity with the infrastructure during normal operating and maintenance activities there is a higher likelihood of this event occurring. As the exact farm and mooring design is not available at this stage further operational mitigations will be required at a later date. These may include relative movement limits between vessels and structure, maximum weather and sea conditions, technology solution to enable standing off at a greater distance. These operating limitations should be developed and incorporated into NZKS standard operating procedures in order to reduce the risk to ALARP.

7.1.3 *Vessel under control grounds & Vessel not under control grounds*

The addition of virtual AIS on Witts Rock and McManaway Rock will improve situational awareness of their location for vessels transiting the area. This improvement in situational awareness of these dangers means that the risk is assessed to be lower than the risk pre-proposal. Putting aside the serendipitous benefits, these risks are assessed as being reduced to a level that is ALARP.

8 Stage 4 – Final risk evaluation

8.1 Assessment conclusion

Having carried out an assessment of the hazards presented in locating a fin-fish farm at the proposed site, the mitigated risk profile is assessed as being comparable to the benchmark off-shore farm.

Given the application of all practicable mitigations including the refinement of the development boundaries, it is considered the residual level of risk meets the ALARP criterion. Given this, the risk is considered to be acceptable within the context of normal maritime risks.

It is concluded that the risks that have been identified can be adequately managed. It was also identified that positioning a farm as proposed will provide a number of benefits to mariners in the surrounding area – most notably that if the site is appropriately marked, it will become an aid to navigation.

The overall risk is assessed as shown in Table 8.1 below.

Table 8.1: Comparison of risk ratings and their respective residual risk rating post mitigations

Risk Event	Overall Raw Risk Rating (pre-mitigation)	Overall Residual Risk Rating (post mitigation)
Vessel collision near proposed farm	High	High
Small vessel collision whilst transiting the farm	High	Medium
Vessel under control contacts farm	High	Medium
Operational or maintenance vessel makes contact with the farm	Very High	High
Vessel not under control contacts farm	High	Medium
Vessel under control grounds	Medium	Medium*
Vessel not under control	Medium	Medium*

The improvement in situational awareness that results from placing virtual AIS on Witts Rock and McManaway Rock means that the risk is assessed to be lower that the than the risk pre-proposal. Putting aside any serendipitous benefits, these risks are assessed as being reduced to a level that is ALARP.

8.2 Proposed through life navigational risk management provisions

While the proposed mitigations are, together, assessed as being able to achieve the ALARP criterion, it will be important that the effectiveness of the identified controls and mitigations are maintained through life.

The need to maintain navigational safety to a level that is ALARP is that navigational safety means that the effectiveness has to be managed through the life – this is the case for any offshore installation.

Through life navigational safety management will need to include:

- Maintenance of the development and infrastructure, including structure mooring arrangements and marks and lights, in good working and condition.
- Keeping the marine navigational risk assessment up to date in light of any changed traffic and navigational factors or environmental conditions.
- Updating risk mitigations and controls in light of changed practices and technologies.
- Having a commitment to install features designed to comply with latest guidance.
- Meeting and maintaining lighting and marks in accordance with any updated MNZ guidance.
- Keeping the safety and operations plan current.
- Having an emergency plan and keeping it relevant.
- Seek for continuous improvement and identification of human factors by maintaining a “Just culture”[35] in relation to maritime safety.

[35] Under “Just Culture” conditions, individuals are not blamed for 'honest errors', but are held accountable for wilful violations and gross negligence. People are less willing to inform the organisation about their own errors and other safety problems or hazards if they are afraid of being punished or prosecuted

9 Report Summary and Conclusion

The proposed development area is intended to enable the positioning of a number of farms in an offshore maritime environment – a physical environment that differs from the current operation and positioning of salmon farms employed in New Zealand. The key in the design requirements of the farm structures and the whole development is driven by the fact that the farms must operate in the more energetic and demanding coastal conditions versus the more traditional farm locations within sheltered inlets, bays, or sounds. This requires that the farms are able to be secured in deep water and able to withstand higher sea states than has been the norm to date. It also results in the farms being located nearer to large vessel routes and activity.

The work has been undertaken to ensure the assessment of the viability of the proposed area from a maritime navigational risk perspective remains sound.

This report considers the general navigational aspects of a salmon farming development in the proposed area. The work assumes that the farm technology, design and construction are sound. This assumption was necessary to ensure that NZKS can make best use of the rapidly developing technology in the global off shore aquaculture industry. Design options must remain available so that detailed design, final layout, or number of structures located inside the proposed area can be finalised.

Having carried out an assessment of the hazards presented in locating a fin-fish farm at the proposed site, it was concluded that the risks that have been identified may be adequately managed. Given that, the level of risk is considered to meet the ALARP criterion.

9.1 Serendipitous benefits

It is concluded that, although not a defined aim of the development, that there could be clear benefits to mariners of the proposed farm development. Given the area and the farms will be at a known location, and that they will be marked, they will in effect become and AtN.

The addition of virtual AIS marks on the navigation dangers associated with Witts Rock and McManaway Rock as proposed by the risk assessment, will enhance situational awareness.

A further potential benefit of the proposed location will be that the farm could be fitted with an automatic radio weather reporting station and thus give significantly improved real-time navigational information to all mariners – in particular for local fishing and commercial vessels, as well as recreational traffic.

9.2 Overall conclusions

Although somewhat navigationally complex, the proposed development is in an area that has generally low levels of small and medium-sized marine craft traffic. It is however in an area that currently has a compression of traffic flow between two rocks that can be considered dangerous to navigation to deeper draught vessels.

As the development is in an area that is more environmentally challenging than what is found in the areas currently farmed, it will be essential that the design undergoes a detailed engineering risk assessment as part of the design process.

Having carried out the assessment of the navigational hazards of the proposed farm development area, it is concluded that given suitable practical mitigations, the risk associated with the proposed development location can be adequately managed. The resulting risk will not be significantly different than the existing situation created by the natural features. In some respect it is assessed that the presence of these mitigations can actually improve on the current level of navigational risk.

Appendix A: Vessel Traffic Summary - Proposed Farm Development Location

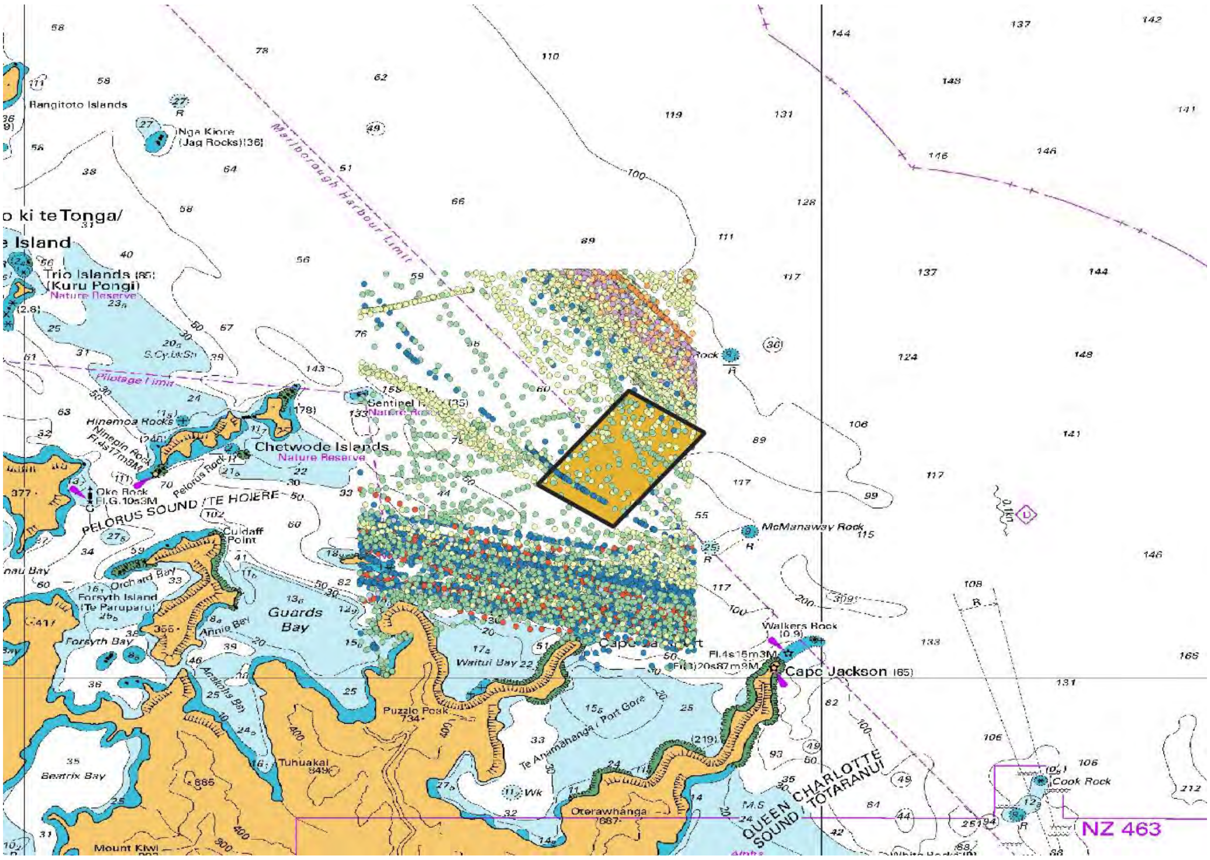

Figure A.1 Traffic surrounding original farm location – all vessel types

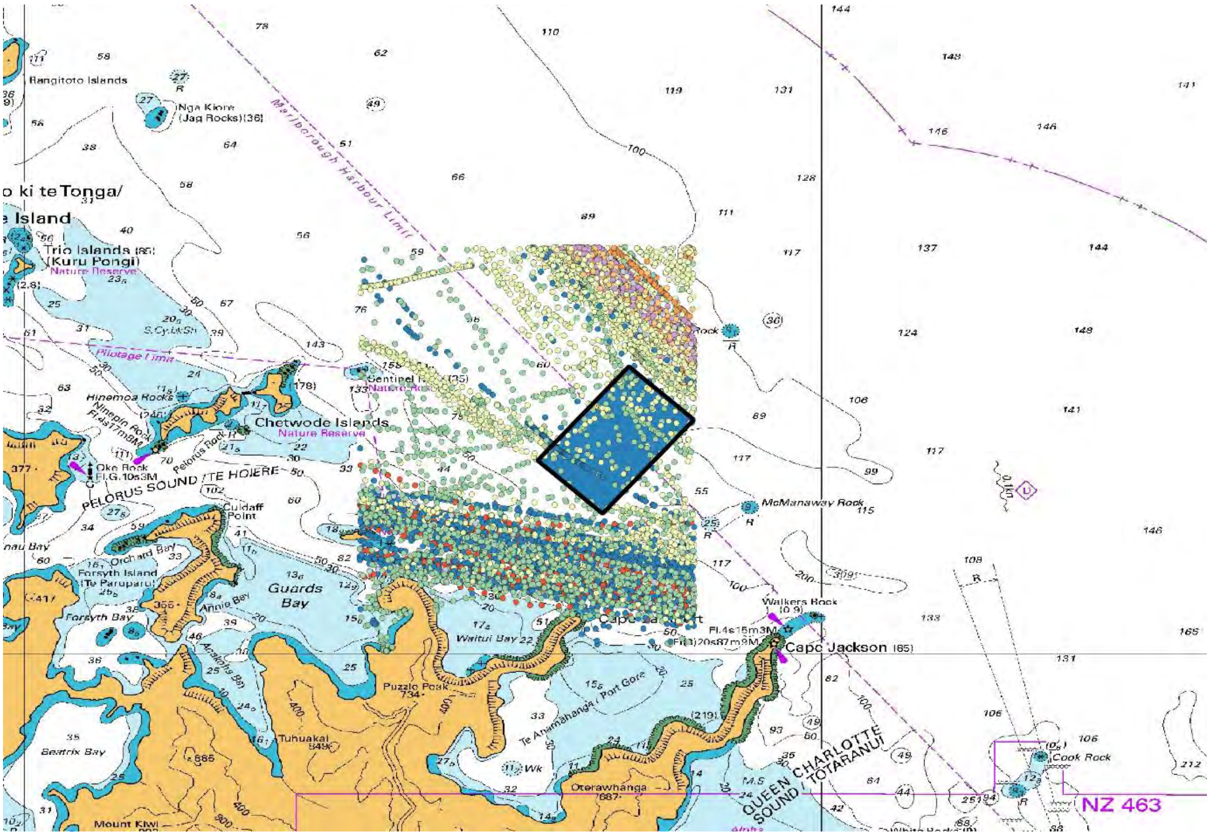

Figure A.2 Traffic surrounding proposed farm location – all vessel types

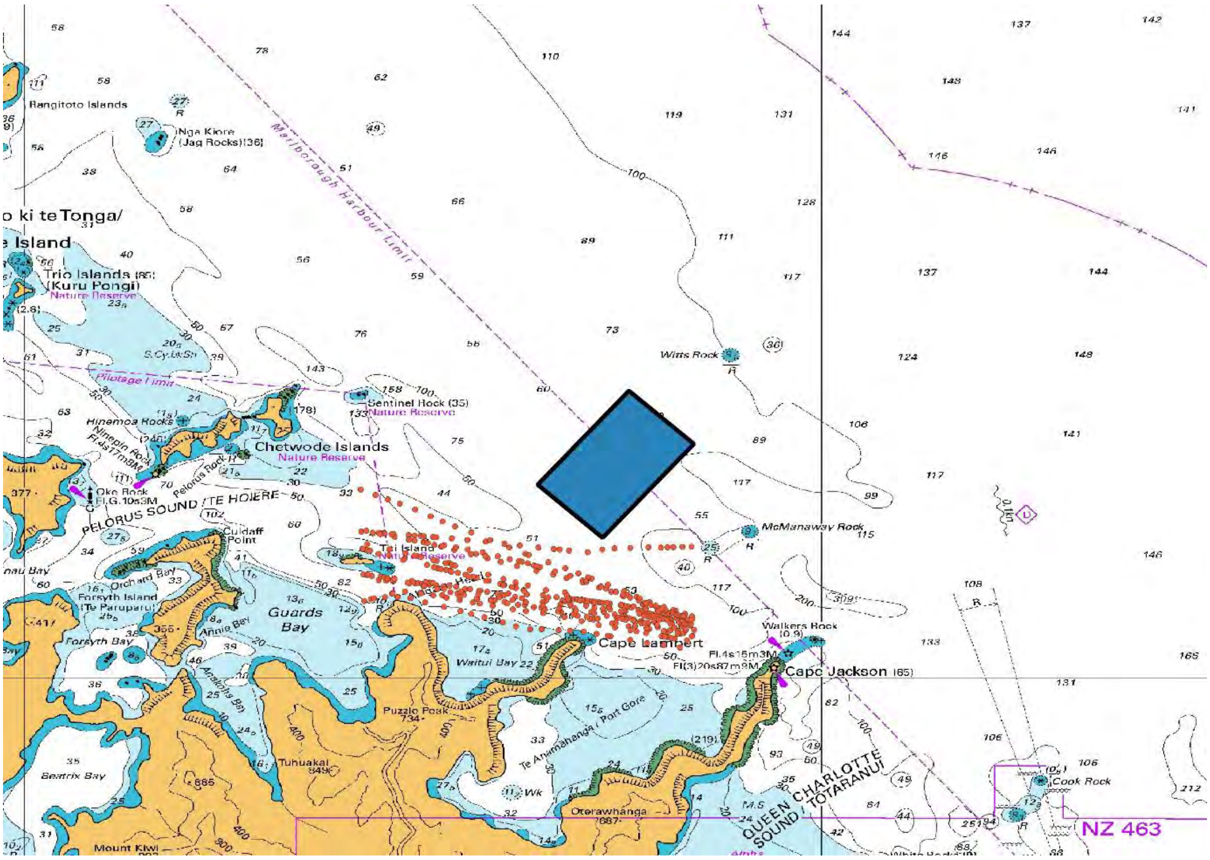

Figure A.3 Traffic surrounding proposed farm location - Barges

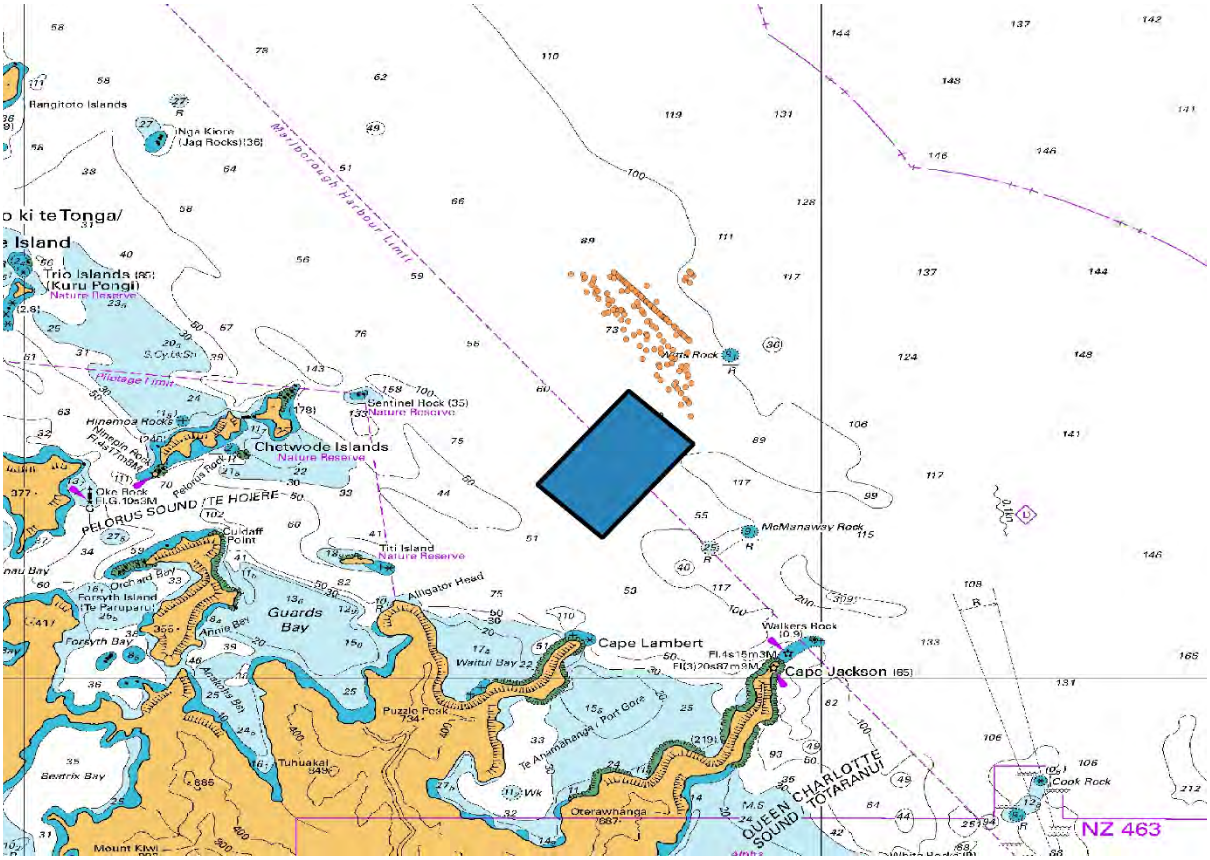

Figure A.4 Traffic surrounding proposed farm location – Bulk Carriers

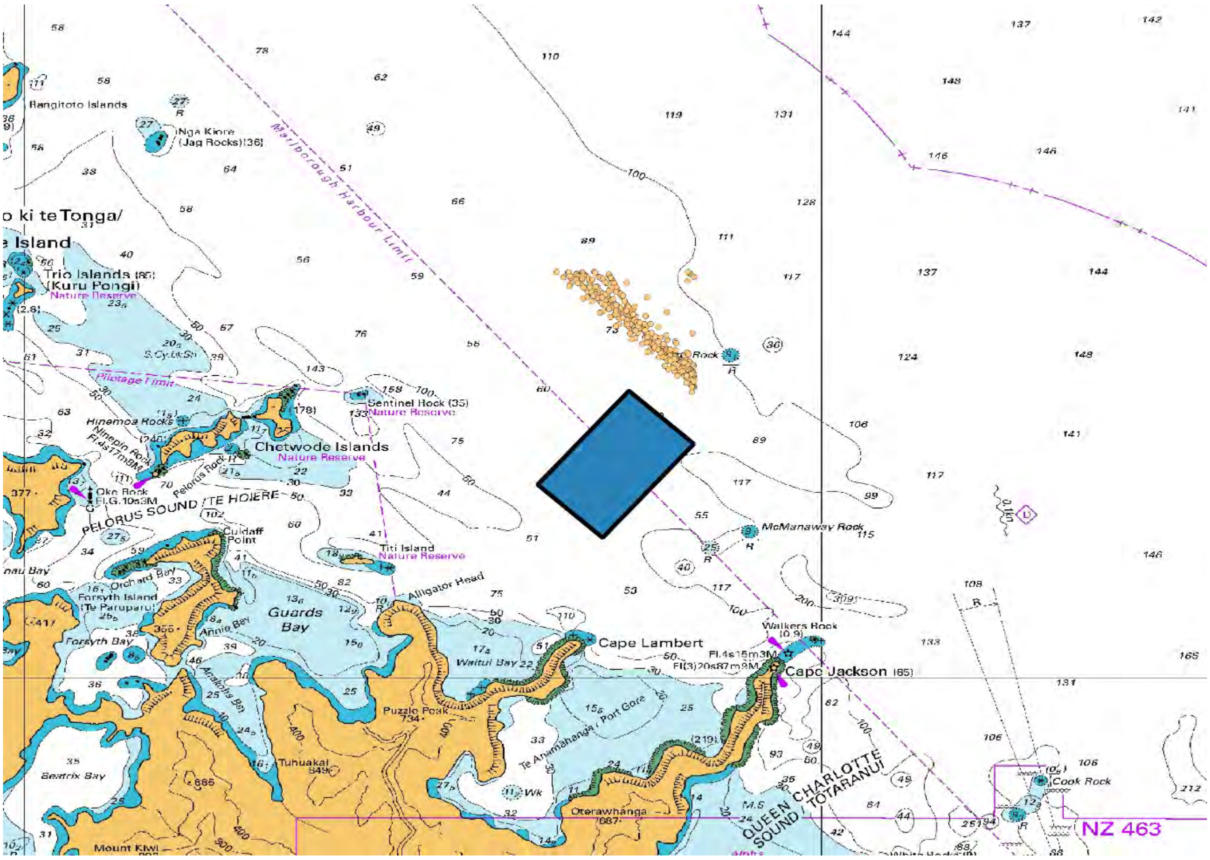

Figure A.5 Traffic surrounding proposed farm location – Cargo

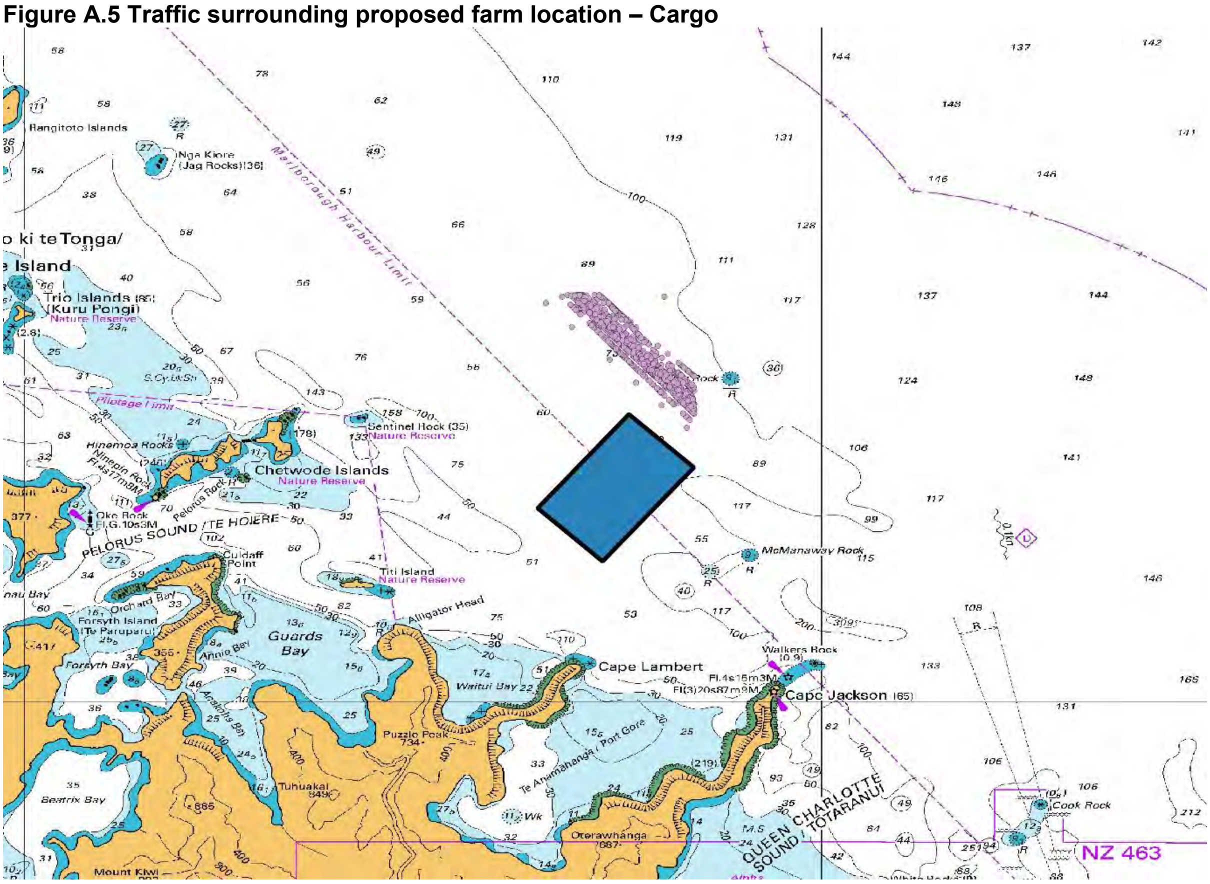

Figure A.6 Traffic surrounding proposed farm location – Container Ships

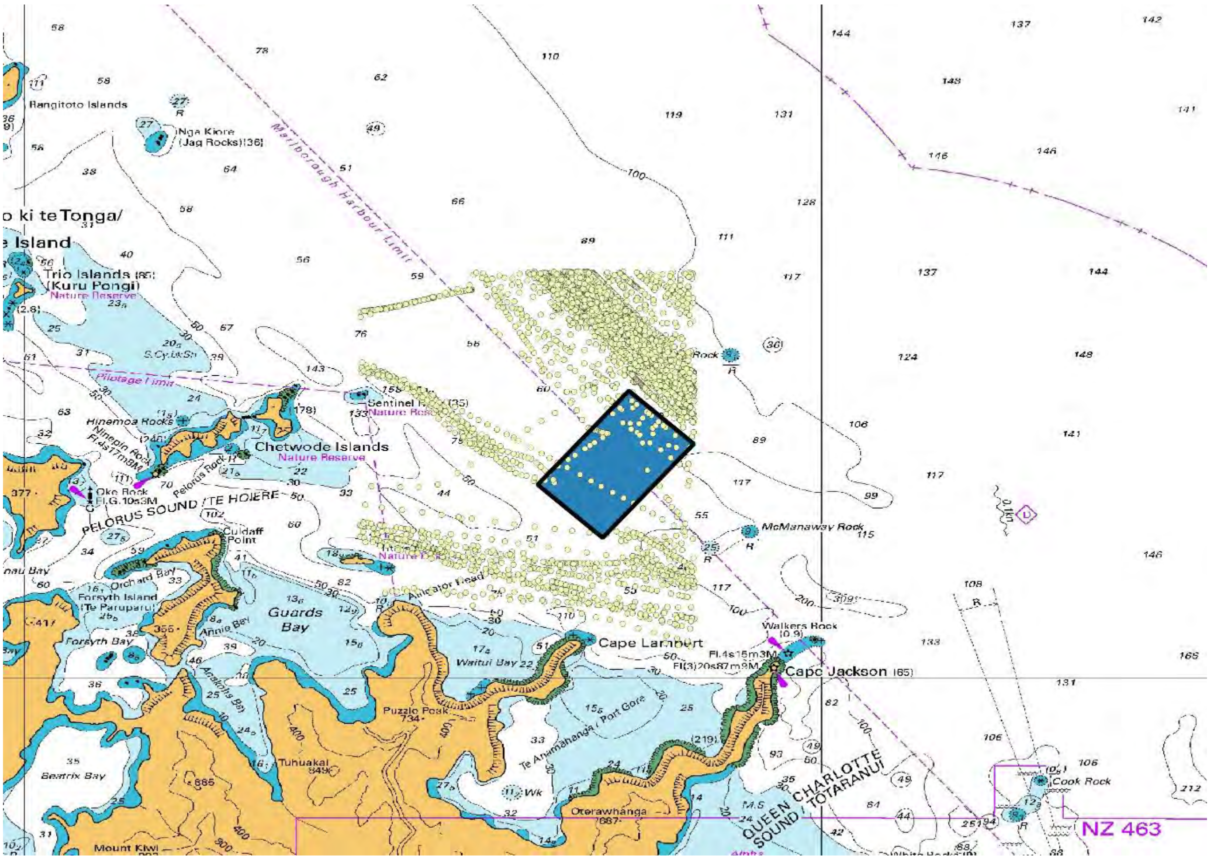

Figure A.7 Traffic surrounding proposed farm location – Fishing Vessels

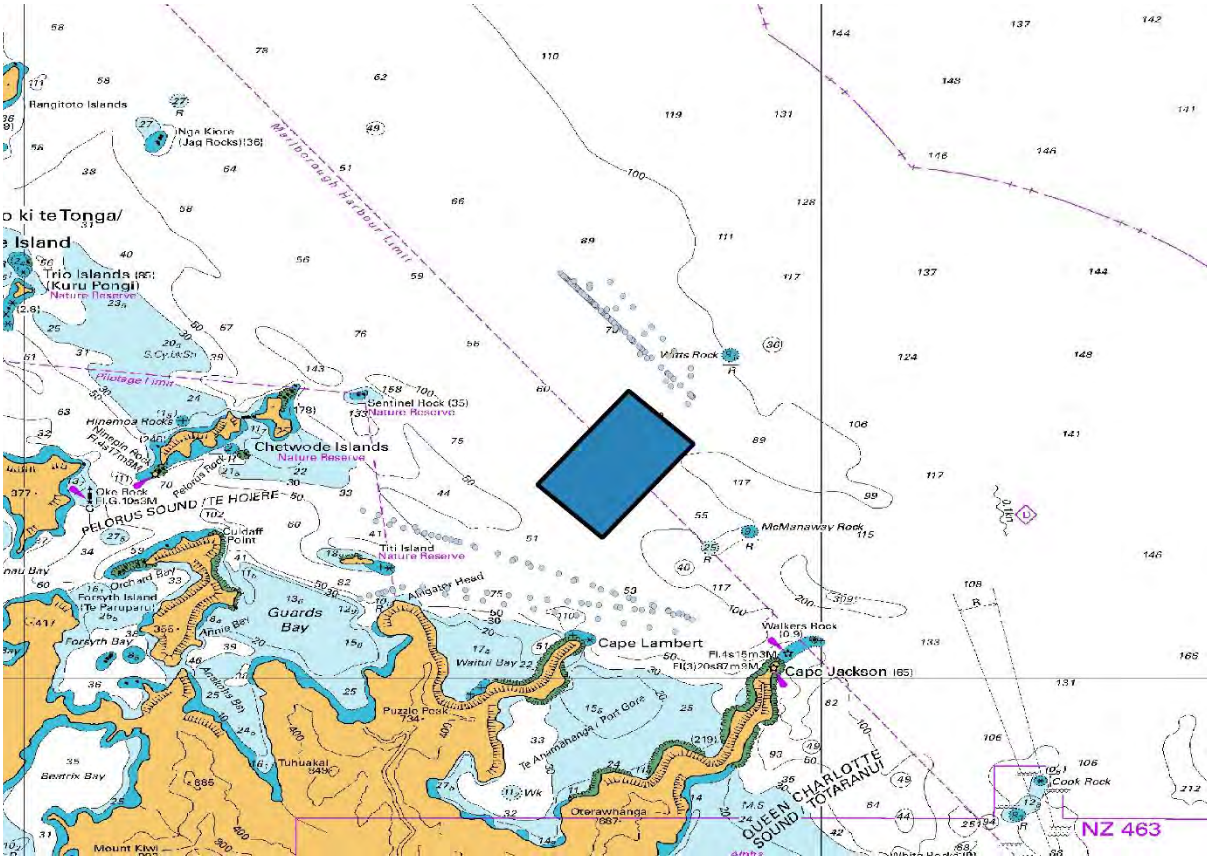

Figure A.8 Traffic surrounding proposed farm location – Passenger Vessels

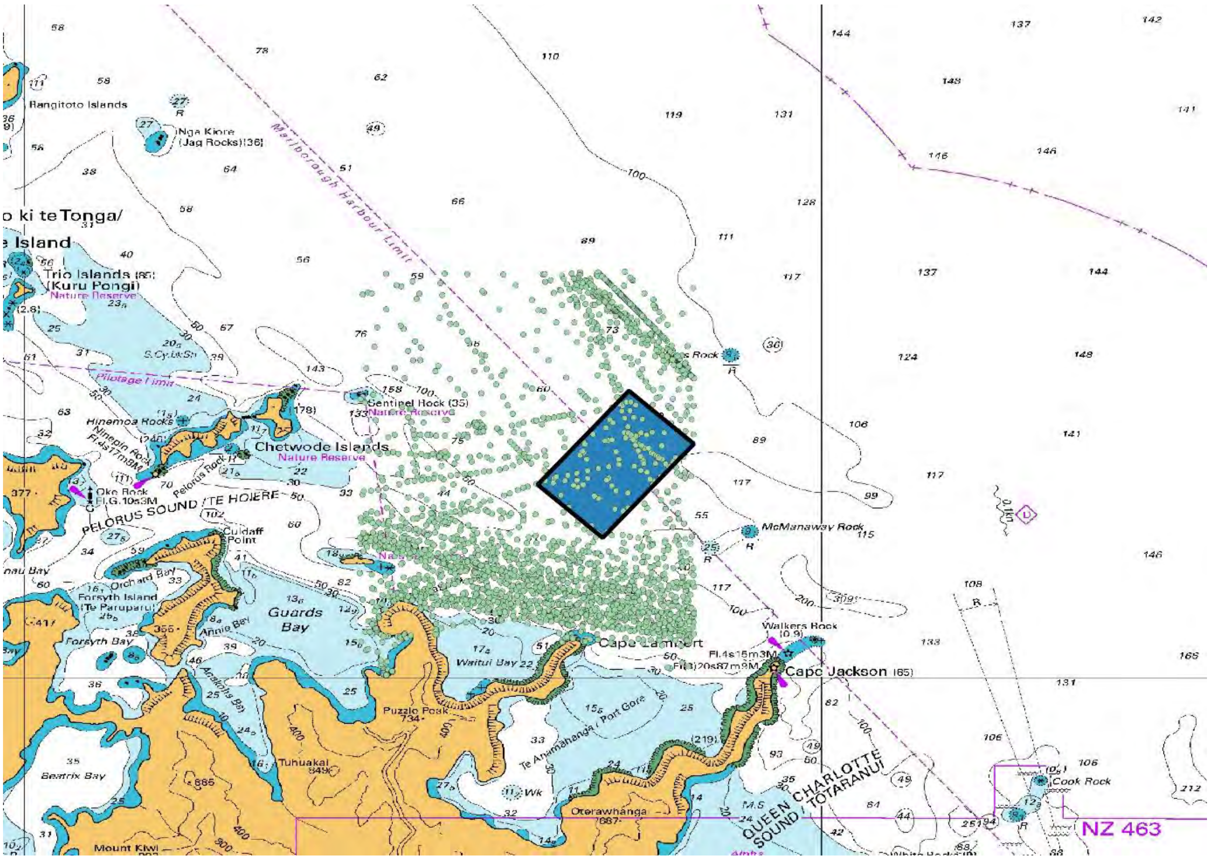

Figure A.9 Traffic surrounding proposed farm location – Recreational Vessels

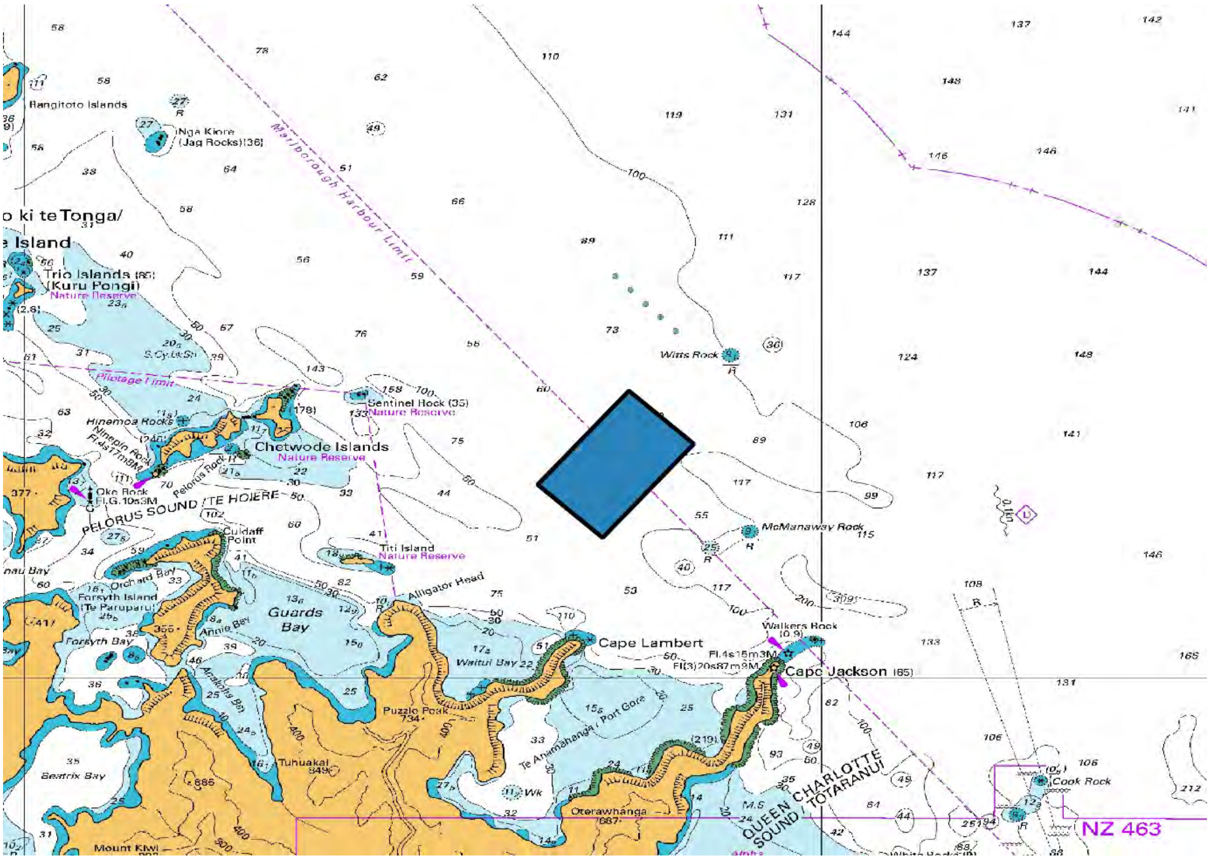

Figure A.10 Traffic surrounding proposed farm location - Tankers

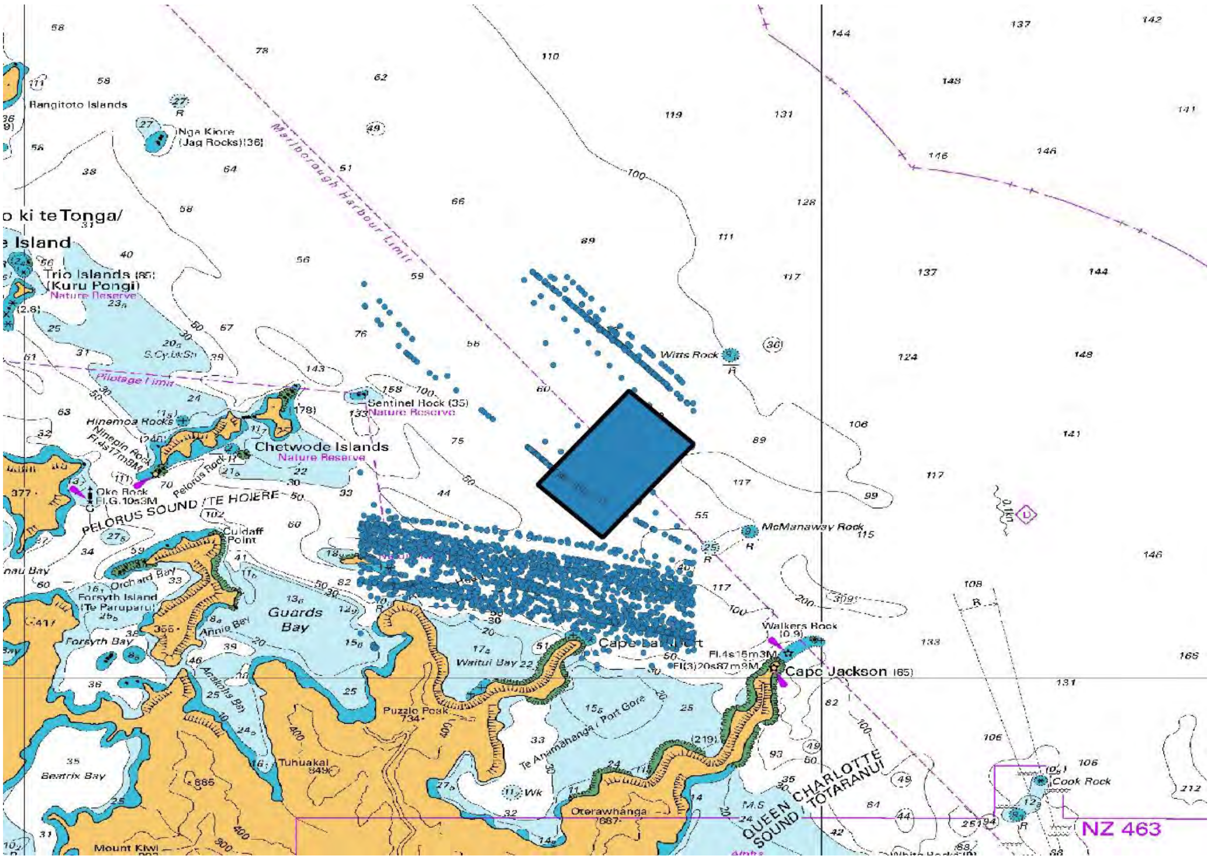

Figure A.11 Traffic surrounding proposed farm location – Working Vessels

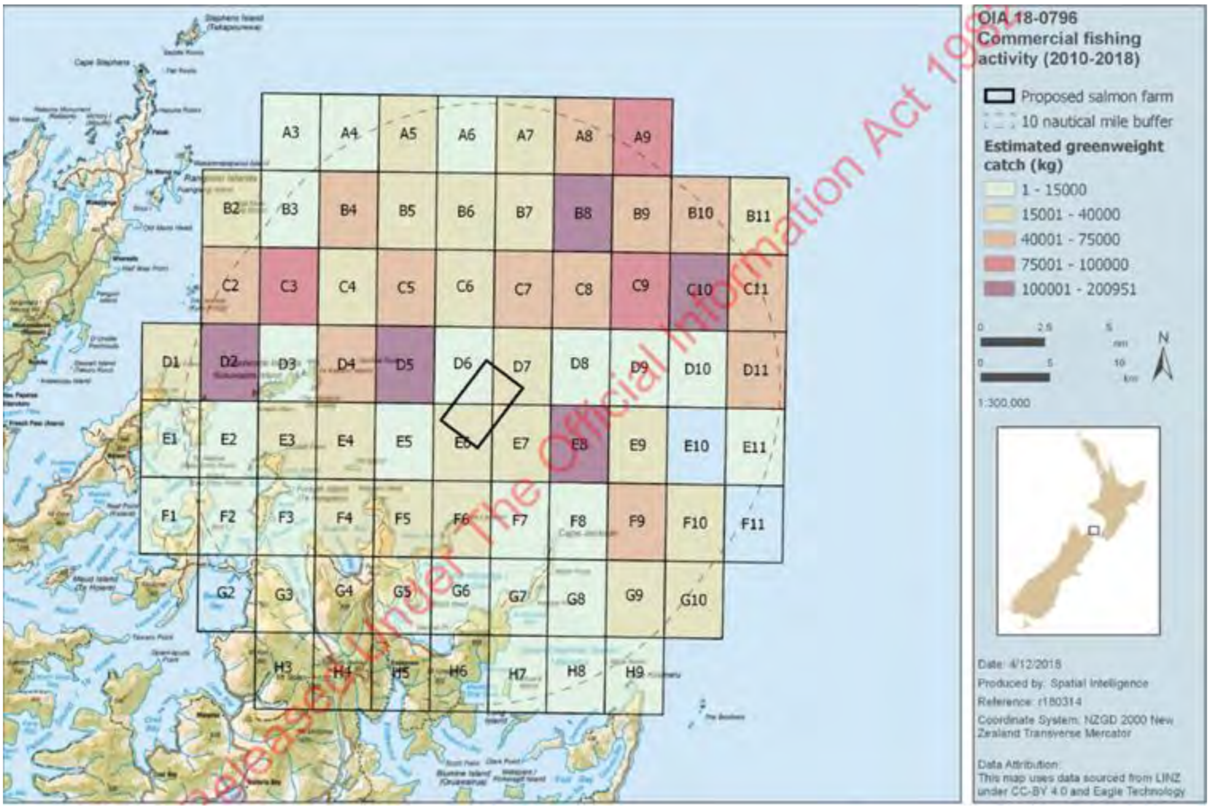

Figure A.12 Part copy of image of commercial fishing activity in the area surrounding the proposed farm location (Taylor & Dempster, 2018)

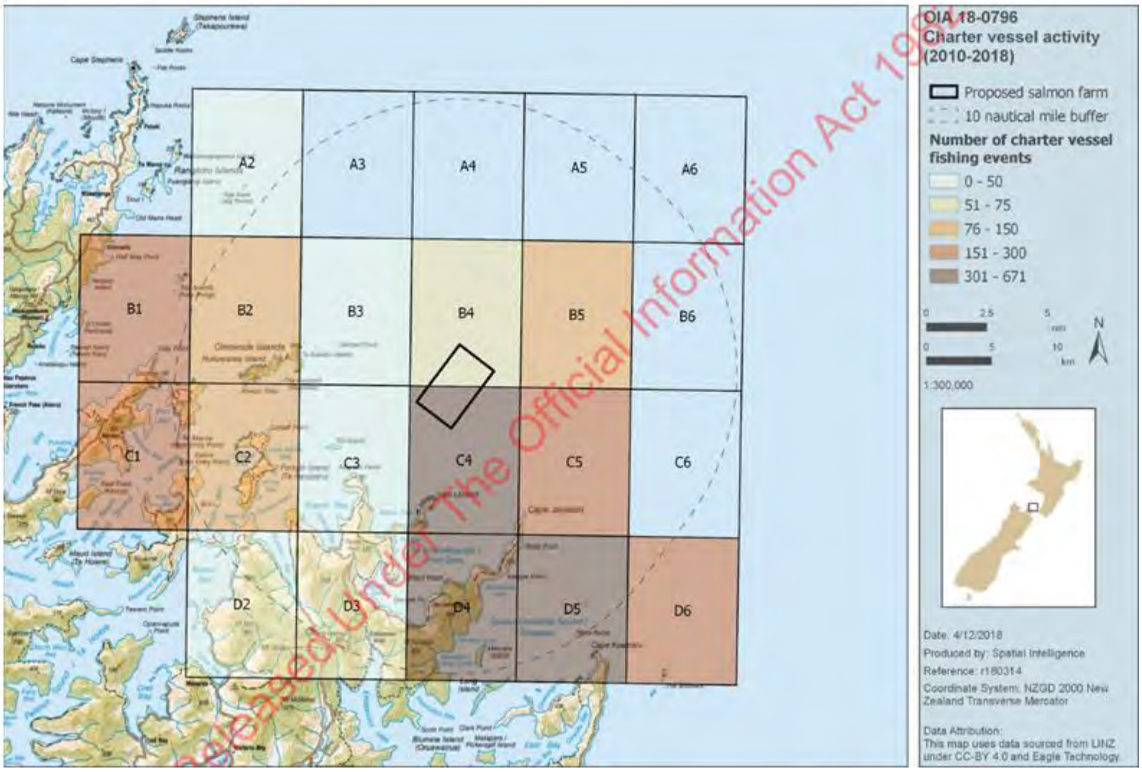

Figure A.13 Part copy of image of charter vessel activity in the area surrounding the proposed farm location (Taylor & Dempster, 2018)

Appendix B: Risk Assessment Tables

Consequence Descriptions (Human)

Descriptor	Expected Outcome	Potential Worst Case
Catastrophic	Incident causing fatalities	
Major	Incident that results in permanent significant injury (people in the water / impact injuries)	Exposure to Catastrophic outcome
Serious	Incident that results in injury (first aid)	Exposure to Major outcome
Moderate	Response required. Fright / concern	Exposure to Serious outcome
Minor	Safety criteria compromised / not met	Exposure to Moderate outcome
Negligible	Sub-optimal process	Process not followed

Consequence Descriptions (Material)

Descriptor	Expected Outcome	Potential Worst Case
Severe	Loss of a farm / farms. Large vessel disabled / lost	
Major	Farm out of commission for an extended period Vessel damaged	Exposure to Catastrophic outcome
Serious	Extended disruption to own ops or third parties	Exposure to Major outcome
Moderate	Disruption to own or third part operations / costs.	Exposure to Serious outcome
Minor	Inefficiencies	Exposure to Moderate outcome
Negligible	Incidental	Process not followed

Consequence Descriptions (Management)

Descriptor	Expected Outcome	Potential Worst Case
Severe	Use of farm area permanently prevented by regulatory action	
Major	Long term restrictions / partial restrictions to operations due regulatory action or management decision	Exposure to Catastrophic outcome
Serious	Short term / partial restrictions to operations due regulatory action or management decision	Exposure to Major outcome
Moderate	External reviews / incident investigations / enhanced oversight / restricted practice	Exposure to Serious outcome
Minor	Internal reviews / incident investigations / restricted practice	Exposure to Moderate outcome
Negligible	Sub-optimal process	Process not followed

Probability Descriptions

Likelihood Table			
	Likelihood of occurrence		
Likelihood descriptor	Indicative frequency	Indicative probability (Expected events per year)	Indicative frequency (Years between events)
Weekly	Approaching each week	30	0.033
Monthly	Several times a year	12	0.083
Probably	Once a year	1	1
Possible	May occur in a year	0.5	2
Unlikely	Not expected to occur that often	0.2	5
Rare	Unlikely to occur	0.1	10
Improbable	Highly unlikely to occur	0.03	33
Highly improbable	Is conceivable	0.01	100
Barely credible	Never heard of	0.002	500

Risk Matrix

Descriptors	N/A	Negligible	Minor	Moderate	Serious	Major	Catastrophic
Weekly	Low	Low	Very High	Very High	Extreme	Extreme	Extreme
Monthly	Very Low	Low	High	High	Very High	Extreme	Extreme
Probable	Very Low	Very Low	Medium	High	Very High	Extreme	Extreme
Possible	Very Low	Very Low	Medium	High	Very High	Very High	Extreme
Unlikely	Very Low	Very Low	Low	Medium	High	High	Extreme
Rare	Very Low	Very Low	Low	Medium	High	High	Extreme
Improbable	Very Low	Very Low	Low	Low	Medium	Medium	Very High
Highly improbable	Very Low	Very Low	Very Low	Low	Low	Medium	High
Barely Credible	Very Low	Very Low	Very Low	Very Low	Low	Low	Medium

Enclosure 1: Risk Register

New Zealand King Salmon Off-shore Farms - North Marlborough Risk Register

Risk	Event	Factors	Context and Detailed Description of farm	Current Assessed Risk: Problem – Likelihood	Current Assessed Risk: Problem – Consequence Rating	Current Assessed Risk: Risk Rating – Problem	Mitigations and Factors	Mitigated Risk: Problem (Mitigated) – Likelihood (Mitigated)	Mitigated Risk: Problem (Mitigated) – Consequence Rating (Mitigated)	Mitigated Risk: Risk Rating – Problem (Mitigated)
	Vessel on Vessel collision near the farm	Proximity of farm boundaries to inshore costal traffic routes used by smaller commercial and recreational traffic	Northern boundaries adjacent to traffic route, Southern boundaries 1200m clear of inshore route				Boundaries clearly marked with AtoN			
	Vessel on Vessel collision near the farm	Proximity to navigational dangers (not otherwise listed)	All hazards otherwise listed				Nil			
	Vessel on Vessel collision near the farm	The increase or decreases Seasonal variation of traffic density	Increased small vessel and recreational vessels during summer period				Farm clearly marked with approved AtoN			
	Vessel on Vessel collision near the farm	Alignment and layout of installation in relation to traffic flow	Farm boundary parallel to general direction of traffic flow, farms parallel to boundaries				AtN aid general navigation			
	Vessel on Vessel collision near the farm	Predicted future vessel traffic - Increased capacity achieved through operational improvements and increase of vessel size and draught	No significant increase, large vessels transit to north of Witts rock				Already parallel to traffic flow			
	Vessel on Vessel collision near the farm	Impact from wind weather and sea conditions on vessel	No change from current situations				NZKS on water crew may be able to assist			
	Vessel on Vessel collision near the farm	Effect of tide and current on vessels	No change from current situations, farm aligned parallel to current/tidal flow				Individual farm parallel to traffic flow - Does not add risk. However AtN aids SA			
	Vessel on Vessel collision near the farm	Greater navigational complexity in the wider area as a result of reduction in waterspace due to farm	Farm location reduces navigable water near traffic route, in addition to traffic compression through the proximity of rocks				Farm clearly marked with approved AtoN			
	Vessel on Vessel collision near the farm	Varying level of knowledge of the collision regulations (COLREGS)	Inherent level of knowldege of mariners				All vessels have duty tp prevent collison			
	Vessel on Vessel collision near the farm	Failure to keep a proper lookout	Inherent behaviour of mariners				AIS and radar reflectors to be used			
	Vessel on Vessel collision near the farm	Type, Size, visibility of Aids to Navigation\	Marks not fit for purpose				Approval process			
	Vessel on Vessel collision near the farm	Proximity of farm boundaries to natural transit routes created by point to point navigation techniques	Placement of farm boundaries parallel to natural navigation routes				Suitable AtoN on farm, Virtual AIS on rocks will improve situational awareness			
	Vessel on Vessel collision near the farm	Proximity of farm boundaries to existing vessel transit route	Northern boundaries adjacent to traffic route				Parallel to traffic flow, pens parallel to boundaries			
	Vessel on Vessel collision near the farm	Draught in relation to available depth and width of Navigable water	Limitations on sea room				Virtual AIS placed over the two rocks			
	Vessel on Vessel collision near the farm	Reduction in sea room to take action to avoid collision in accordance with collision regulations COLGEGS	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Minimal traffic, limited COLREG situations. Marked on navigation charts, AIS and radar			
	Vessel on Vessel collision near the farm	Reduction in sea room when responding to internal vessel defects or emergencies	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Sufficient sea room between pens for manoeuvring in an emergencies			
	Vessel on Vessel collision near the farm	Vessel manoeuvrability	Narrowing sea room requires vessel to manuver	Unlikely	Serious	High	Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness	Rare	Serious	High
	Vessel on Vessel collision near the farm	Reduction in available sea room due to farm presence	Not sufficient room for 180˚turn for large vessels, majority of large vessels remain to north of Witts rock. Sufficient sea room to stop whilst maintain course				Minimal traffic, limited COLREG situations. Marked on navigation charts, AIS and radar			
	Vessel on Vessel collision near the farm	Proximity to dwellings and small wharves	No change, no dwellings or wharves in vicinity				Nil			
	Vessel on Vessel collision near the farm	Vessel route selection	No change from current situations				Outside natural transit and already established routeing			
	Vessel on Vessel collision near the farm	Vessel speed	No change from current situations				Greater situational awareness through AtoN			
ment	Vessel on Vessel collision near the farm	Requirement for vessels to deviate from their established route	No change from current situations				Outside natural transit and already established routeing			

The potential for and consequence of **Collision** as a result of the factors introduced by the developn

Vessel on Vessel collision near the farm	Proximity to other aquaculture or offshore installation	Nil adjacent installations	Nil
Vessel on Vessel collision near the farm	Proximity to existing underwater installations	Nil adjacent installations	Nil
Vessel on Vessel collision near the farm	Unmarked dangers to navigation	Two rocks (9.1m) in close proximity	Virtual AIS to increase situational awareness of location
Vessel on Vessel collision near the farm	Farm causing funnelling of vessel	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation - however heightened risk	Outside natural transit and already established routeing caused by two offshore rocks . AtN counter effect
Vessel on Vessel collision near the farm	Comprehension of Aids to Navigation	Suitable marks approved by Harbourmaster	Approved by harbourmaster and in accordance with IALA
Vessel on Vessel collision near the farm	Traffic density	Average of 1 transit per day passing in the traffic lane to the north	Suitable AtoN to aid situational awareness
Vessel on Vessel collision near the farm	Time pressure	No change from current situations	Greater situational awareness provided by use of AtoN
Vessel on Vessel collision near the farm	Vessels joining transit routes	No significant change from current situation	Greater Situational awareness provided by use of AtoN, Limited vessels joining in the vicinity of the farm
Vessel on Vessel collision near the farm	Vessels crossing traffic route	Vessels not following traffic route required to manoeuvre, limited evidence of crossing vessels	Greater Situational awareness provided by use of AtoN, Will provide more controlled conditions for crossing vessels
Vessel on Vessel collision near the farm	Vessel size	No change from current situations, majority of large vessels remain outside of Witts Rock	Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness
Vessel on Vessel collision near the farm	Type of farm structure	Exact details TBC. Likely to be low-profile or semi-submerged	Suitable AtoN on farm to show extend of dangers and improve situational awareness
Vessel on Vessel collision transiting through the farm (small/recreational)	Proximity to navigational dangers (not otherwise listed)	All hazards otherwise listed	Nil
Vessel on Vessel collision transiting through the farm (small/recreational)	Proximity of proposed farm to a port or harbour entrance	Clear of all major port and harbour entrances	Nil
Vessel on Vessel collision transiting through the farm (small/recreational)	Predicted future vessel traffic - Increased capacity achieved through operational improvements and increase of vessel size and draught	No significant increase, large vessels transit to north of Witts rock	Already parallel to traffic flow
Vessel on Vessel collision transiting through the farm (small/recreational)	The increase or decreases Seasonal variation of traffic density	Increased small vessel and recreational vessels during summer period	Farm clearly marked with approved AtoN
Vessel on Vessel collision transiting through the farm (small/recreational)	Impact from wind weather and sea conditions on vessel	No change from current situations	NZKS on water crew may be able to assist
Vessel on Vessel collision transiting through the farm (small/recreational)	Effect of tide and current on vessels	No change from current situations, farm aligned parallel to current/tidal flow	Individual farm parallel to traffic flow - Does not add risk. However AtN aids SA
Vessel on Vessel collision transiting through the farm (small/recreational)	Greater navigational complexity in the wider area as a result of reduction in waterspace due to farm	Farm location reduces navigable water near traffic route, in addition to traffic compression through the proximity of rocks	Farm clearly marked with approved AtoN
Vessel on Vessel collision transiting through the farm (small/recreational)	Varying level of knowledge of the collision regulations (COLREGS)	Inherent level of knowldege of mariners	All vessels have duty tp prevent collison
Vessel on Vessel collision transiting through the farm (small/recreational)	Failure to keep a proper lookout	Inherent behaviour of mariners	AIS and radar reflectors to be used
Vessel on Vessel collision transiting through the farm (small/recreational)	Type, Size, visibility of Aids to Navigation\	Marks not fit for purpose	Approval process
Vessel on Vessel collision transiting through the farm (small/recreational)	Proximity of farm boundaries to natural transit routes created by point to point navigation techniques	Placement of farm boundaries parallel to natural navigation routes	Suitable AtoN on farm, Virtual AIS on rocks will improve situational awareness
Vessel on Vessel collision transiting through the farm (small/recreational)	Proximity of farm boundaries to existing vessel transit route	Northern boundaries adjacent to traffic route	Parallel to traffic flow, pens parallel to boundaries
Vessel on Vessel collision transiting through the farm (small/recreational)	Draught in relation to available depth and width of Navigable water	Limitations on sea room	Virtual AIS placed over the two rocks

Vessel on Vessel collision transiting through the farm (small/recreational)	Vessel route selection	No change from current situations	Unlikely	Serious	High	Outside natural transit and already established routeing	Unlikely	Moderate	Medium
Vessel on Vessel collision transiting through the farm (small/recreational)	Reduction in sea room when responding to internal vessel defects or emergencies	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Sufficient sea room between pens for manoeuvring in an emergencies			
Vessel on Vessel collision transiting through the farm (small/recreational)	Proximity of farm boundaries to inshore costal traffic routes used by smaller commercial and recreational traffic	Northern boundaries adjacent to traffic route, Southern boundaries 1200m clear of inshore route				Boundaries clearly marked with AtoN			
Vessel on Vessel collision transiting through the farm (small/recreational)	Presence of special or privileged vessels	Some restricted in ability to manoeuvre activity in close proximity to pens				Company SOPS and seamanship training			
Vessel on Vessel collision transiting through the farm (small/recreational)	Vessel manoeuvrability	Narrowing sea room requires vessel to manuver				Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness			
Vessel on Vessel collision transiting through the farm (small/recreational)	Requirement for vessels to deviate from their established route	No change from current situations				Outside natural transit and already established routeing			
Vessel on Vessel collision transiting through the farm (small/recreational)	Proximity to other aquaculture or offshore installation	Nil adjacent installations				Nil			
Vessel on Vessel collision transiting through the farm (small/recreational)	Recreational traffic transit routes	Route 1200m South, sufficient navigable water available				AtoN			
Vessel on Vessel collision transiting through the farm (small/recreational)	Compression of traffic flow	Two rocks (9.1m) in close proximity already compress traffic no significant change to current situation				Virtual AIS placed over the two rocks			
Vessel on Vessel collision transiting through the farm (small/recreational)	Proximity to existing underwater installations	Nil adjacent installations				Nil			
Vessel on Vessel collision transiting through the farm (small/recreational)	Unmarked dangers to navigation	Two rocks (9.1m) in close proximity				Virtual AIS to increase situational awareness of location			
Vessel on Vessel collision transiting through the farm (small/recreational)	Farm causing funnelling of vessel	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation - however heightened risk				Nil			
Vessel on Vessel collision transiting through the farm (small/recreational)	Traffic density	No significant change from current situation				Suitable AtoN to aid situational awareness			
Vessel on Vessel collision transiting through the farm (small/recreational)	Time pressure	No change from current situations				Greater situational awareness provided by use of AtoN			
Vessel under control makes contact with the farm	Proximity of farm boundaries to inshore costal traffic routes used by smaller commercial and recreational traffic	Northern boundaries adjacent to traffic route, Southern boundaries 1200m clear of inshore route				Boundaries clearly marked with AtoN			
Vessel under control makes contact with the farm	Proximity to navigational dangers (not otherwise listed)	All hazards otherwise listed				Nil			
Vessel under control makes contact with the farm	Proximity of proposed farm to a port or harbour entrance	Clear of all major port and harbour entrances				Nil			
Vessel under control makes contact with the farm	Predicted future vessel traffic - Increased capacity achieved through operational improvements and increase of vessel size and draught	No significant increase, large vessels transit to north of Witts rock				Already parallel to traffic flow			
Vessel under control makes contact with the farm	The increase or decreases Seasonal variation of traffic density	Increased small vessel and recreational vessels during summer period				Farm clearly marked with approved AtoN			
Vessel under control makes contact with the farm	Presence of vessels restricted in their ability to manoeuvre	No change from current situations, majority of restricted in ability vessels expected to remain outside of Witts Rock				AtoN allow sufficient warning for vessels restricted in ability to manoeuvre.			
Vessel under control makes contact with the farm	Alignment and layout of installation in relation to traffic flow	Farm boundary parallel to general direction of traffic flow, farms parallel to boundaries				AtN aid general navigation			
Vessel under control makes contact with the farm	Impact from wind weather and sea conditions on vessel	No change from current situations				NZKS on water crew may be able to assist			
Vessel under control makes contact with the farm	Effect of tide and current on vessels	No change from current situations, farm aligned parallel to current/tidal flow				Individual farm parallel to traffic flow - Does not add risk. However AtN aids SA			
Vessel under control makes contact with the farm	Greater navigational complexity in the wider area as a result of reduction in waterspace due to farm	Farm location reduces navigable water near traffic route, in addition to traffic compression through the proximity of rocks				Farm clearly marked with approved AtoN			

he factors introduced by the development

Vessel under control makes contact with the farm	Failure to keep a proper lookout	Inherent behaviour of mariners	Unlikely	Serious	High	AIS and radar reflectors to be used	Unlikely	Moderate	Medium
Vessel under control makes contact with the farm	Type, Size, visibility of Aids to Navigation\	Marks not fit for purpose				Approval process			
Vessel under control makes contact with the farm	Proximity of farm boundaries to natural transit routes created by point to point navigation techniques	Placement of farm boundaries parallel to natural navigation routes				Suitable AtoN on farm, Virtual AIS on rocks will improve situational awareness			
Vessel under control makes contact with the farm	Proximity of farm boundaries to existing vessel transit route	Northern boundaries adjacent to traffic route				Parallel to traffic flow, pens parallel to boundaries			
Vessel under control makes contact with the farm	Draught in relation to available depth and width of Navigable water	Limitations on sea room				Virtual AIS placed over the two rocks			
Vessel under control makes contact with the farm	Reduction in sea room to take action to avoid collision in accordance with collision regulations COLGEGS	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Minimal traffic, limited COLREG situations. Marked on navigation charts, AIS and radar			
Vessel under control makes contact with the farm	Reduction in sea room when responding to internal vessel defects or emergencies	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Sufficient sea room between pens for manoeuvring in an emergencies			
Vessel under control makes contact with the farm	Presence of special or privileged vessels	Some restricted in ability to manoeuvre activity in close proximity to pens				Company SOPS and seamanship training			
Vessel under control makes contact with the farm	Vessel manoeuvrability	Narrowing sea room requires vessel to manuver				Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness			
Vessel under control makes contact with the farm	Recreational traffic transit routes	Route 1200m South, sufficient navigable water available				AtoN			
Vessel under control makes contact with the farm	Proximity to dwellings and small wharves	No change, no dwellings or wharves in vicinity				Nil			
Vessel under control makes contact with the farm	Compression of traffic flow	Two rocks (9.1m) in close proximity already compress traffic no significant change to current situation				Virtual AIS placed over the two rocks			
Vessel under control makes contact with the farm	Vessel route selection	No change from current situations				Outside natural transit and already established routeing			
Vessel under control makes contact with the farm	Vessel speed	No change from current situations				Greater situational awareness through AtoN			
Vessel under control makes contact with the farm	Depth and extent of submerged structure (including moorings) in relation to under keel clearance	Sufficient under keel clearance provided for in design				Mooring design provides static UKC of 5m at edge of pens, 10m at 100m and 20m at 200m from the buoys			
Vessel under control makes contact with the farm	Unmarked dangers to navigation	Two rocks (9.1m) in close proximity				Virtual AIS to increase situational awareness of location			
Vessel under control makes contact with the farm	Farm causing funnelling of vessel	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation - however heightened risk				Outside natural transit and already established routeing caused by two offshore rocks . AtN counter effect			
Vessel under control makes contact with the farm	Farm causing funnelling of vessel towards navigational danger	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation				Outside natural transit and already established routing caused by two offshore rocks. AtN aid SA			
Vessel under control makes contact with the farm	Proximity to chokepoint	No change from current situations				No impact from chokepoint			
Vessel under control makes contact with the farm	Stationary vessels	No change from current situations				No indication of stationary or drifting vessels in data			
Vessel under control makes contact with the farm	Vessels joining transit routes	No significant change from current situation				Greater Situational awareness provided by use of AtoN, Limited vessels joining in the vicinity of the farm			
Vessel under control makes contact with the farm	Vessels crossing traffic route	Vessels not following traffic route required to manoeuvre, limited evidence of crossing vessels				Greater Situational awareness provided by use of AtoN, Will provide more controlled conditions for crossing vessels			
Operational/maintenance vessel makes contact with the farm	Impact from wind weather and sea conditions on vessel	No change from current situations				NZKS on water crew may be able to assist			
Operational/maintenance vessel makes contact with the farm	Effect of tide and current on vessels	No change from current situations, farm aligned parallel to current/tidal flow				Individual farm parallel to traffic flow - Does not add risk. However AtN aids SA			

The potential for and consequence of **Allision** as a result of t

Operational/maintenance vessel makes contact with the farm	Failure to keep a proper lookout	Inherent behaviour of mariners	Possible	Serious	Very High	AIS and radar reflectors to be used	Unlikely	Serious	High
Operational/maintenance vessel makes contact with the farm	Type, Size, visibility of Aids to Navigation\	Marks not fit for purpose				Approval process			
Operational/maintenance vessel makes contact with the farm	Proximity of vessel during operation or maintenance of pens	Operational SOP to be developed to include controls for wind, weather, sea conditions limits				SOPs and maintenance procedures to be developed with detailed design, limitations on vessel movement to be in place			
Operational/maintenance vessel makes contact with the farm	Draught in relation to available depth and width of Navigable water	Limitations on sea room				Virtual AIS placed over the two rocks			
Operational/maintenance vessel makes contact with the farm	Reduction in sea room when responding to internal vessel defects or emergencies	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Sufficient sea room between pens for manoeuvring in an emergencies			
Operational/maintenance vessel makes contact with the farm	Vessel manoeuvrability	Narrowing sea room requires vessel to manuver				Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness			
Operational/maintenance vessel makes contact with the farm	Vessel speed	No change from current situations				Greater situational awareness through AtoN			
Operational/maintenance vessel makes contact with the farm	Depth and extent of submerged structure (including moorings) in relation to under keel clearance	Sufficient under keel clearance provided for in design				Mooring design provides static UKC of 5m at edge of pens, 10m at 100m and 20m at 200m from the buoys			
Operational/maintenance vessel makes contact with the farm	Available sea room between farms for vessel navigation	Sufficient under keel clearance provided for in design				Sufficient sea room between pens for manoeuvring in an emergencies			
Operational/maintenance vessel makes contact with the farm	Unmarked dangers to navigation	Two rocks (9.1m) in close proximity				Virtual AIS to increase situational awareness of location			
Operational/maintenance vessel makes contact with the farm	Time pressure	No change from current situations				Greater situational awareness provided by use of AtoN			
Operational/maintenance vessel makes contact with the farm	Vessel size	No change from current situations, majority of large vessels remain outside of Witts Rock				Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness			
Operational/maintenance vessel makes contact with the farm	Visibility of structure	Stucture will have little if any freebaord and parts or whole submerged				All dangers to navigation marked by AtoN, approved by harbourmaster and in accordance with IALA			
Operational/maintenance vessel makes contact with the farm	Type of farm structure	Exact details TBC. Likely to be low-profile or semi-submerged				Suitable AtoN on farm to show extend of dangers and improve situational awareness			
Vessel not under control makes contact with the farm	Proximity of farm boundaries to inshore costal traffic routes used by smaller commercial and recreational traffic	Northern boundaries adjacent to traffic route, Southern boundaries 1200m clear of inshore route				Boundaries clearly marked with AtoN			
Vessel not under control makes contact with the farm	Proximity to navigational dangers (not otherwise listed)	All hazards otherwise listed				Nil			
Vessel not under control makes contact with the farm	Proximity of proposed farm to a port or harbour entrance	Clear of all major port and harbour entrances				Nil			
Vessel not under control makes contact with the farm	Predicted future vessel traffic - Increased capacity achieved through operational improvements and increase of vessel size and draught	No significant increase, large vessels transit to north of Witts rock				Already parallel to traffic flow			
Vessel not under control makes contact with the farm	The increase or decreases Seasonal variation of traffic density	Increased small vessel and recreational vessels during summer period				Farm clearly marked with approved AtoN			
Vessel not under control makes contact with the farm	Presence of vessels restricted in their ability to manoeuvre	No change from current situations, majority of restricted in ability vessels expected to remain outside of Witts Rock				AtoN allow sufficient warning for vessels restricted in ability to manoeuvre.			
Vessel not under control makes contact with the farm	Alignment and layout of installation in relation to traffic flow	Farm boundary parallel to general direction of traffic flow, farms parallel to boundaries				AtN aid general navigation			
Vessel not under control makes contact with the farm	Impact from wind weather and sea conditions on vessel	No change from current situations				NZKS on water crew may be able to assist			
Vessel not under control makes contact with the farm	Effect of tide and current on vessels	No change from current situations, farm aligned parallel to current/tidal flow				Individual farm parallel to traffic flow - Does not add risk. However AtN aids SA			
Vessel not under control makes contact with the farm	Proximity of farm boundaries to natural transit routes created by point to point navigation techniques	Placement of farm boundaries parallel to natural navigation routes				Suitable AtoN on farm, Virtual AIS on rocks will improve situational awareness			

	Vessel not under control makes contact with the farm	Proximity of farm boundaries to existing vessel transit route	Northern boundaries adjacent to traffic route				Parallel to traffic flow, pens parallel to boundaries			
	Vessel not under control makes contact with the farm	Draught in relation to available depth and width of Navigable water	Limitations on sea room	Rare	Serious	High	Virtual AIS placed over the two rocks	Improbable	Serious	Medium
	Vessel not under control makes contact with the farm	Reduction in sea room when responding to internal vessel defects or emergencies	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Sufficient sea room between pens for manoeuvring in an emergencies			
	Vessel not under control makes contact with the farm	Vessel manoeuvrability	Narrowing sea room requires vessel to manuver				Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness			
	Vessel not under control makes contact with the farm	Compression of traffic flow	Two rocks (9.1m) in close proximity already compress traffic no significant change to current situation				Virtual AIS placed over the two rocks			
	Vessel not under control makes contact with the farm	Vessel route selection	No change from current situations				Outside natural transit and already established routeing			
	Vessel not under control makes contact with the farm	Vessel speed	No change from current situations				Greater situational awareness through AtoN			
	Vessel not under control makes contact with the farm	Depth and extent of submerged structure (including moorings) in relation to under keel clearance	Sufficient under keel clearance provided for in design				Mooring design provides static UKC of 5m at edge of pens, 10m at 100m and 20m at 200m from the buoys			
	Vessel not under control makes contact with the farm	Available sea room between farms for vessel navigation	Sufficient under keel clearance provided for in design				Sufficient sea room between pens for manoeuvring in an emergencies			
	Vessel not under control makes contact with the farm	Unmarked dangers to navigation	Two rocks (9.1m) in close proximity				Virtual AIS to increase situational awareness of location			
	Vessel not under control makes contact with the farm	Farm causing funnelling of vessel	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation - however heightened risk				Outside natural transit and already established routeing caused by two offshore rocks . AtN counter effect			
	Vessel not under control makes contact with the farm	Farm causing funnelling of vessel towards navigational danger	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation				Outside natural transit and already established routing caused by two offshore rocks. AtN aid SA			
	Vessel not under control makes contact with the farm	Time pressure	No change from current situations				Greater situational awareness provided by use of AtoN			
	Vessel under control grounds	Proximity of farm boundaries to inshore costal traffic routes used by smaller commercial and recreational traffic	Northern boundaries adjacent to traffic route, Southern boundaries 1200m clear of inshore route				AtN aid general navigation			
	Vessel under control grounds	Proximity to navigational dangers (not otherwise listed)	All hazards otherwise listed				Nil			
	Vessel under control grounds	Predicted future vessel traffic - Increased capacity achieved through operational improvements and increase of vessel size and draught	No significant increase, large vessels transit to north of Witts rock				Already parallel to traffic flow			
	Vessel under control grounds	Presence of vessels restricted in their ability to manoeuvre	No change from current situations, majority of restricted in ability vessels expected to remain outside of Witts Rock				AtoN allow sufficient warning for vessels restricted in ability to manoeuvre.			
	Vessel under control grounds	Alignment and layout of installation in relation to traffic flow	Farm boundary parallel to general direction of traffic flow, farms parallel to boundaries				AtN aid general navigation			
	Vessel under control grounds	Impact from wind weather and sea conditions on vessel	No change from current situations				NZKS on water crew may be able to assist			
	Vessel under control grounds	Effect of tide and current on vessels	No change from current situations, farm aligned parallel to current/tidal flow				Individual farm parallel to traffic flow - Does not add risk. However AtN aids SA			
	Vessel under control grounds	Greater navigational complexity in the wider area as a result of reduction in waterspace due to farm	Farm location reduces navigable water near traffic route, in addition to traffic compression through the proximity of rocks				Farm clearly marked with approved AtoN			
	Vessel under control grounds	Failure to keep a proper lookout	Inherent behaviour of mariners				AIS and radar reflectors to be used			
	Vessel under control grounds	Type, Size, visibility of Aids to Navigation\	Marks not fit for purpose				Approval process			
	Vessel under control grounds	Proximity of farm boundaries to natural transit routes created by point to point navigation techniques	Placement of farm boundaries parallel to natural navigation routes				Suitable AtoN on farm, Virtual AIS on rocks will improve situational awareness			

The potential for and consequence of **Grounding** as a result of the factors introduced by the development

Vessel under control grounds	Proximity of farm boundaries to existing vessel transit route	Northern boundaries adjacent to traffic route				Parallel to traffic flow, pens parallel to boundaries			
Vessel under control grounds	Draught in relation to available depth and width of Navigable water	Limitations on sea room	Improbable	Major	Medium	Virtual AIS placed over the two rocks	Highly improbable	Major	Medium
Vessel under control grounds	Reduction in sea room when responding to internal vessel defects or emergencies	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Sufficient sea room between pens for manoeuvring in an emergencies			
Vessel under control grounds	Presence of special or privileged vessels	Some restricted in ability to manoeuvre activity in close proximity to pens				Company SOPS and seamanship training			
Vessel under control grounds	Vessel manoeuvrability	Narrowing sea room requires vessel to manuver				Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness			
Vessel under control grounds	Compression of traffic flow	Two rocks (9.1m) in close proximity already compress traffic no significant change to current situation				Virtual AIS placed over the two rocks			
Vessel under control grounds	Vessel route selection	No change from current situations				Outside natural transit and already established routeing			
Vessel under control grounds	Vessel speed	No change from current situations				Greater situational awareness through AtoN			
Vessel under control grounds	Proximity to existing underwater installations	Nil adjacent installations				Nil			
Vessel under control grounds	Unmarked dangers to navigation	Two rocks (9.1m) in close proximity				Virtual AIS to increase situational awareness of location			
Vessel under control grounds	Farm causing funnelling of vessel	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation - however heightened risk				Outside natural transit and already established routeing caused by two offshore rocks . AtN counter effect			
Vessel under control grounds	Farm causing funnelling of vessel towards navigational danger	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation				Outside natural transit and already established routing caused by two offshore rocks. AtN aid SA			
Vessel under control grounds	Comprehension of Aids to Navigation	Suitable marks approved by Harbourmaster				Approved by harbourmaster and in accordance with IALA			
Vessel under control grounds	Traffic density	No significant change from current situation				Suitable AtoN to aid situational awareness			
Vessel under control grounds	Time pressure	No change from current situations				Greater situational awareness provided by use of AtoN			
Vessel not under control grounds - Farm only causes effect on farm related	Proximity to navigational dangers (not otherwise listed)	All hazards otherwise listed				Nil			
Vessel not under control grounds - Farm only causes effect on farm related	Predicted future vessel traffic - Increased capacity achieved through operational improvements and increase of vessel size and draught	No significant increase, large vessels transit to north of Witts rock				Already parallel to traffic flow			
Vessel not under control grounds - Farm only causes effect on farm related	Presence of vessels restricted in their ability to manoeuvre	No change from current situations, majority of restricted in ability vessels expected to remain outside of Witts Rock				AtoN allow sufficient warning for vessels restricted in ability to manoeuvre.			
Vessel not under control grounds - Farm only causes effect on farm related	Alignment and layout of installation in relation to traffic flow	Farm boundary parallel to general direction of traffic flow, farms parallel to boundaries				AtN aid general navigation			
Vessel not under control grounds - Farm only causes effect on farm related	Impact from wind weather and sea conditions on vessel	No change from current situations				NZKS on water crew may be able to assist			
Vessel not under control grounds - Farm only causes effect on farm related	Effect of tide and current on vessels	No change from current situations, farm aligned parallel to current/tidal flow				Individual farm parallel to traffic flow - Does not add risk. However AtN aids SA			
Vessel not under control grounds - Farm only causes effect on farm related	Greater navigational complexity in the wider area as a result of reduction in waterspace due to farm	Farm location reduces navigable water near traffic route, in addition to traffic compression through the proximity of rocks				Farm clearly marked with approved AtoN			
Vessel not under control grounds - Farm only causes effect on farm related	Failure to keep a proper lookout	Inherent behaviour of mariners				AIS and radar reflectors to be used			
Vessel not under control grounds - Farm only causes effect on farm related	Proximity of farm boundaries to natural transit routes created by point to point navigation techniques	Placement of farm boundaries parallel to natural navigation routes	Highly improbable	Major	Medium	Suitable AtoN on farm, Virtual AIS on rocks will improve situational awareness	Highly improbable	Major	Medium

	Vessel not under control grounds - Farm only causes effect on farm related	Proximity of farm boundaries to existing vessel transit route	Northern boundaries adjacent to traffic route	Highly improbable	Major	Medium	Parallel to traffic flow, pens parallel to boundaries	Highly improbable	Major	Medium
	Vessel not under control grounds - Farm only causes effect on farm related	Reduction in sea room when responding to internal vessel defects or emergencies	Individual farm size dependant however likely sufficient sea room for emergency manoeuvre will be available				Sufficient sea room between pens for manoeuvring in an emergencies			
	Vessel not under control grounds - Farm only causes effect on farm related	Vessel manoeuvrability	Narrowing sea room requires vessel to manuver				Larger vessels already predominantly remain outside Witts rock, Dangers marked with AtoN to improve situational awareness			
	Vessel not under control grounds - Farm only causes effect on farm related	Proximity to existing underwater installations	Nil adjacent installations				Nil			
	Vessel not under control grounds - Farm only causes effect on farm related	Unmarked dangers to navigation	Two rocks (9.1m) in close proximity				Virtual AIS to increase situational awareness of location			
	Vessel not under control grounds - Farm only causes effect on farm related	Farm causing funnelling of vessel	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation - however heightened risk				Outside natural transit and already established routeing caused by two offshore rocks . AtN counter effect			
	Vessel not under control grounds - Farm only causes effect on farm related	Farm causing funnelling of vessel towards navigational danger	Two rocks (9.1m) in close proximity already funnel traffic no significant change to current situation				Outside natural transit and already established routing caused by two offshore rocks. AtN aid SA			
	Vessel not under control grounds - Farm only causes effect on farm related	Traffic density	No significant change from current situation				Suitable AtoN to aid situational awareness			
	Vessel not under control grounds - Farm only causes effect on farm related	Time pressure	No change from current situations				Greater situational awareness provided by use of AtoN			