Aquatic
Environmental
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Assessment of ecological effects of Project South, an open ocean salmon farm proposed for eastern Foveaux Strait

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Executive summary

Introduction

Sanford Ltd (Sanford) is preparing a consent application to develop an offshore salmon farm in eastern Foveaux Strait, to the south-east of Ruapuke Island, comprising five separate farming areas, each with 26 ha containing the pens and barge and 157 ha including anchors. The application is for larger farming area for each of the areas to allow for final changes in siting after consultation. The proposed area will likely serve as grower farms operating initially in conjunction with existing smolt and broodstock salmon farms in Big Glory Bay and later from land hatcheries.

The nearest farming area of pens would be approximately 10 km from the nearest point on Ruapuke Island and the farming areas will be in water depths of between 52 and 80 m. The Foveaux Strait area is a high energy environment with currents up to 1.2 m s^{-1} and wave heights of up to 10 m having been recorded.

The farming areas will likely be developed in four stages with full development being a grid of 2x5 polar circle pens producing an estimated 5,400 t per year per farming area at full development.

Field surveys of the benthic habitat, currents and water quality, and a desktop study using existing information were used to describe the aquatic ecology of Foveaux Strait and the Ruapuke Area in the vicinity of the proposed farm. Individual reports will be attached to the application. The main purpose of this report is to provide a summary describing the existing environment and an overall assessment of potential effects of the proposed new salmon farm.

Assessment of effects

The effects of marine farming in New Zealand are generally well understood for inshore coastal areas and embayments and have been extensively documented in recent years. At present there are no offshore farms operating but applications have been made for a New Zealand King application off the north-east of the South Island and Ngai Tahu have made an application for a farm off northern Stewart island. Offshore farms will potentially cause the same types of effects as inshore farms but dispersion of material will be greater and more rapidly diluted, increases in nutrients and reductions in dissolved oxygen are likely to be less and cumulative effects from anthropogenic activities are reduced compared with inshore farms. On the other hand, potential effects on marine mammals and seabirds may be greater.

The key considerations for the water column are from increased nitrogen inputs and changes in dissolved oxygen, which can affect farmed salmon and naturally occurring biota. In terms of the benthic environment, the main considerations are deposition of excess feed and faecal material which can result in changes to organic matter, dissolved oxygen, biochemical reactions including release of hydrogen sulphide, and changes to algal and faunal communities. Other considerations are biosecurity and the effects on wild fisheries, mammals and birds.

Water column

Potential hydrodynamic considerations include changes to current speed and direction, stratification and wave characteristics. The assessment concluded that any changes in currents will be localised around farms and will not affect overall circulation patterns.

Water quality data is very limited for Foveaux Strait but preliminary results from a monthly monitoring programme set up in the third quarter of 2019 by Sanford indicates low total ammonia nitrogen (TAN) concentrations (<10 mg/m^3), moderate nitrate-N concentrations of 45-70 mg/m^3, except in late January 2020 when it had dropped to 4 mg/m^3, and relatively low dissolved reactive phosphorus (DRP) and total phosphorus (TP) concentrations. Chlorophyll *a* concentrations (chl-*a*, indicator of phytoplankton biomass) were 0.2 to 1.8 mg/m^3 over the late spring 2019,/summer 2020. The relatively high nitrate-N concentrations are likely due to upwelled water entrained into Foveaux Strait and the higher chl-*a* concentrations in early November may be due to a spring peak. Chl-*a* concentrations are likely to be higher in late winter/spring and lower in summer and late autumn/early winter, based on data from outer Paterson Inlet. The reverse would occur for dissolved inorganic nitrogen (DIN - TAN, nitrate- and nitrite-N), with levels increasing at the end of summer then decreasing in late winter/spring largely in response to phytoplankton growth.

Modelling of nutrient releases and associated potential increases in phytoplankton biomass was carried out by ADS and predicts that:

- Increases in TAN could extend some distance from the proposed farming areas (Farming Areas A-E) but at very low concentrations (average increases 2-3 mg/m^3). Concentrations could exceed 4 mg/m^3 within the pen areas and a plume of increased TAN could extend up to 8-9 km in the worst case from the pens which is for the blocks in the north. Most of increases would be within the farming areas. Occasional very short increases could be up to 10-12 mg/m^3 but these would be of very short duration (10 mins), within the pen areas, and would be rapidly dispersed and mixed;

- Potential chl-*a* increases followed a similar pattern to TAN. The average increases in chl-*a* concentration are predicted to be less than 0.3 mg/m^3 outside the pen areas. Increases up to 0.2 to 0.6 mg/m^3 could occur with a maximum of 1.4 mg/m^3. The higher increases, if they did occur would be very short-lived and restricted to close to the pen areas. Occasional very short increases were predicted to be up to 1.2 to 1.4 mg/m^3 but again these would be of very short duration (10 mins) and unlikely to occur because of the response time for phytoplankton;
- The predicted increases in TAN concentrations and the corresponding potential increases in chl-*a* are small when compared to those predicted at other farming sites both within New Zealand and Australia. The small increases are to be expected, due to the stronger flows found at this site that act to dilute and rapidly mix TAN released into the water column; and
- Modelling of changes to dissolved oxygen (DO) showed the reduction would be less than <0.1 mg/L. Any reductions would be insignificant, would not be ecologically meaningful or result in any effects on the farmed fish or natural biota.

To put these results into context there are two considerations. Firstly, phytoplankton will use DIN in the form of TAN and nitrate-nitrite-N for growth. The increase in TAN only averages 2-3 mg/m^3 while there is 57-70 mg/m^3 of nitrate-N available. Thus, the increase in available DIN, due to release of TAN is small and is unlikely to be detectable or ecologically meaningful in terms of increased phytoplankton biomass or risk of phytoplankton blooms. Secondly the release of nitrogen as TAN from a fully developed farm is estimated to be 2,150 tonnes/yr which is only 0.5% of the estimated total nitrogen passing through Foveaux Strait each year.

Benthic environment

Surveys of the application site showed the environment was well scoured with a substrate dominated by coarse and fine sand, occasionally mixed with mud or shell hash. No acute changes in topography, biogenic reefs or patches were observed in the proposed farm area. The benthic environment has a sparse epifauna and infauna with low diversity.

Benthic effects around salmon farms will depend on the characteristics of the benthic environment and the extent and intensity of the farming activity. Existing information for inshore farms shows that effects on grain size, organic content and copper and zinc levels are restricted to within 50-100 m beyond the farm boundaries and are generally within the range at control sites.

The deposition modelling by ADS showed that:

- Faecal material and residual feed from the proposed farming areas will generally be deposited in the direction of the predominant residual current. The current fields at each site do differ, though most have a predominately WSW and NNE flow direction;
- At some sites (Farming Areas A, B, and D) the depositional footprint is predicted to be up to at least 2 km from the pen sets. However, because the discharged material is scattered at such distances, the concentrations of deposited material accumulating at any one given location are relatively low; and
- Thresholds that would be expected to result in ecologically significant effects on the benthic environment (defined here as carbon and solids thresholds of 0.73 kg m^{-2} yr^{-1} and 5.2kg m^{-2} yr^{-1} respectively) are predicted to only occur within the pen areas and small patches up to a few hundred meters outside the pen areas.

The absence of sensitive biogenic reef communities around the farm sites and within the overall application site, generally low abundance and richness of infauna, the small area actually occupied, the disturbance from strong currents and previous dredging and fishing, distance from any reefs or biogenic communities, and localised nature of deposition mean that the effects will not be ecologically significant. This also means any effects on the benthic community would not have any measurable effect on higher levels in the food web such as birds and fish or inshore areas.

Biosecurity - pests

The potential adverse effects associated with biosecurity and effects on wild fisheries, are considered to be low in inshore areas such as Big Glory Bay. However, the proposed farm is offshore,close to an important oyster fishery and in an area free of invasive pests at present.

The main considerations associated with a finfish farm in the application area are vessel movements and pest transfer via hull biofouling, especially from outside Southland, and installation of new infrastructure. Seven species are listed as marine pests in the Southland, Regional Pest Management Plan (SRPMP). The only pest species listed as being already established in Southland is the Asian kelp *Undaria pinnatifida*, and there are established objectives and associated rules to prevent further Undaria infestations.

The Sanford proposal has the potential to introduce new species into an area that is relatively isolated from current influences. Furthermore, the proposal will create a hub of activity in that location with the potential to contribute to the ongoing regional spread of pests. However, these are all risks that can be effectively managed.

The role of the proposed farming areas as pest habitats and reservoirs for spread will be in part limited by the need to maintain on-farm biofouling to low levels for operational reasons. In addition, pest spread and establishment in the natural environment will be restricted or negated by the relatively isolated location of the farming areas, in a location with inhospitable environmental conditions that will limit pest establishment or proliferation. These conditions include water depths beyond the reported habitat range of most recognised pests, as well as a high energy wave/current environment and a relatively featureless sandy seabed in the farm environs.

Fish and fisheries

The fish community in the region of the proposed farming areas consists of a range of pelagic and demersal species, including spiny dogfish, barracouta, red gurnard, blue cod, red cod, terakihi, elephant fish, hapuka, ling and witch. The Foveaux Strait region and the area of the proposed farm supports commercial inshore fisheries for cod potting; bottom trawling for barracouta, flatfish and several other species; set-netting for spiny dogfish, school shark and rig; a nationally important oyster fishery; and paua and lobster fisheries. There is a relatively low level of recreational fishing compared with other parts of New Zealand.

Fish farm structures and faecal material and residual feed may attract wild fish species, and wild fish can aggregate around structures and food sources. The consequences of attraction on wild fish could be positive through the creation of habitat and increased food availability, but could also potentially affect their food resources, displace regional fish populations from other habitats, make fish more vulnerable to recreational harvest, and predation through attraction of seals, dolphins or sharks, and farmed fish could transfer pathogens.

The effects on the benthic community and food resources from the proposed farm will be very localised and not expected to be significant away from the farming areas. Thus flow-on effects on wild fish populations are not expected. The location in deep water and away from shallow water reefs and habitats will reduce the risk of fish aggregations compared with inshore farms but there is likely to be attraction of larger predatory pelagic fish around the farms.

The risk of escapees and passing on pathogens is considered low in New Zealand because of the small size of the industry, the limited overlap of farmed and wild salmon populations, the limited salmon numbers in the wild populations and the fact that the wild populations are non-indigenous. This is likely to be even more applicable to offshore farms, such as the proposed application site.

There is likely to be some overlap of the farming areas with commercial fisheries. The nationally important oyster fishery is based 20-25 km away and to the west of Ruapuke Island but the application site and depths occupied by farming areas do overlap with areas for flatfish, gurnard, red cod, stargazer and warehou that are primarily caught by local set net fishers and smaller trawlers.

Mammals

The Foveaux Strait region is considered an important area for a large number of New Zealand's cetacean and pinniped species. At least seven marine mammal species are considered year-round residents and / or seasonal visitors of these waters, with several baleen whale species migrating to and through Foveaux Strait each winter/spring, and more offshore species wandering into shallow regions over warmer months.

The species that need to be considered are New Zealand fur seals, New Zealand sea lions, bottlenose dolphins, southern right and humpback whales, and orca. While the proposed farming areas represent similar habitats to those available across the wider Foveaux Strait region, it also potentially constitutes important winter mating habitat for southern right whales and forms part of humpback whales' northern migration corridor. Southland and Stewart Island waters also support sub-populations of nationally endangered bottlenose and Hector's dolphins, as well as a new breeding colony of nationally vulnerable sea lions, all of which need to be considered.

The main effects of the proposal are possible habitat displacement or avoidance and entanglement risk. Other matters considered include underwater noise, artificial submerged lighting and trophic flow-on effects. Although the overall likelihood of these effects is considered low to moderate, with appropriate management these effects are predicted to be negligible to minor. However, the consequences of a rare event, such as the death of endangered species, warrants appropriate management actions. To ensure that the most appropriate protective measures are in place, a Marine Mammal Management Plan (MMMP) will be developed prior to commencing operations.

Seabirds

The area around the proposed salmon farm, Ruapuke and nearby islands provide foraging grounds and support breeding populations of yellow-eyed penguins, Foveaux shags, blue penguins, Fiordland crested penguin pied shags, spotted shags, little shags, southern black-backed gulls, red-billed gulls and white-fronted terns and foraging grounds for a range of other species. Other foraging groups include various petrels, shearwaters, mollymawks and albatross. A significant proportion of the New Zealand yellow-eyed penguin population along with the majority of the Foveaux shag (Threatened-Nationally Vulnerable) supported in the wider Foveaux Strait region.

The main considerations are exclusion, changes to food resources and entanglement, particularly for Foveaux shag and yellow-eyed penguin because of their threat ranking and the importance of this area to those species. The foraging distributions of the above species may overlap with the proposed location of the salmon farm but all have wide foraging ranges compared with the very small area occupied by the pens, or feed at different depths to that of the farm.

Changes and reductions in the benthic biota are not expected to be significant thus will not have a significant effect on the bird populations. Entanglement is the greatest concern because of the attraction to wild fish aggregations, attraction to lighting and roosting opportunities. The main species of concern are Foveaux shag and other diving species such as blue penguins and diving petrels. The species at greatest risk because of its threat ranking and the importance of this area for the New Zealand population is the Foveaux shag. Surface feeding birds may also get entangled in surface nets. Management options will be implemented to reduce the chance of entanglement including staged development of the farms, with associated monitoring and adaptive management, use of pens that can be submerged, application of best practice with respect to surface nets, and not installing predator nets or using new tougher mesh instead of predator nets. Monitoring of any mortalities during the staging will be critical to confirm the effects are as predicted.

A comprehensive monitoring and management plan along with a Biosecurity Management Plan and Marine Mammal Management Plan will be developed. A summary of the monitoring and management recommended is provided in the **Table 12** at the end of this report.

Glossary of terms used:

AEE	Assessment of ecological effects
BGB	Big Glory Bay
BMP	Biosecurity Management Plan
Chl-*a*	Chlorophyll *a*
DIN	Dissolved inorganic nitrogen
DO	Dissolved oxygen
DRP	Dissolved reactive phosphorus
EMP	Environmental Monitoring Plan
FCR	Food conversion ratio
MMMP	Marine Mammal Management Plan
RPD	Redox potential discontinuity depth
TAN	Total ammonia nitrogen
TOC	Total organic carbon
TOM	Total organic matter
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids

CONTENTS

1 BACKGROUND

Sanford has been farming salmon in Big Glory Bay (BGB), Stewart Island, for more than 40 years. Salmon production in BGB has increased steadily from 186 tonnes (t) in 1987, to 515 t in 1990, 1400 t in 2000 and approximately 3,500 t currently. The biggest impairment to growth is the lack of suitable high-flow sites for further development of the industry. As a result, Sanford has been scoping the potential for a new, open water ‘salmon’ farm.

Sanford Ltd (**Sanford**) are now preparing a consent application for installing a salmon farm in an area in Foveaux Strait close to its present operations.

1.1 Site Selection

An initial, comprehensive site selection exercise was undertaken to identify an area suitable for the project. The site selection phase included an initial constraints mapping exercise which was carried out by the Danish Hydrological Institute (DHI) that was then cross-checked against farming requirements such as depth.

The area identified as most suitable was to the south-east of Ruapuke Island, at the eastern end of Foveaux Strait. Based on this information a further refinement was made based on available benthic environmental data, the need to avoid areas of potential high diversity, culture importance and to provide a buffer between the farming areas and Ruapuke Island which is highly valued for its titi population and owned by whanau of Ngai Tahu.

The resulting area was identified as most suitable for the activity is shown in **Figure 1**.

1.2 The Project

The proposed development will consist of five 26 ha for pens and barge. The area for each area, including anchors will be 157 ha. To allow for some re-siting of farming areas, if necessary, a larger area of some 1,050 ha has been identified for each farming area. For biosecurity reasons the farming areas are separated by at least 8 km. The application is to install pens in the five farming areas shown in **Figure 1**. The pens chosen are Akva “Atlantis” pens with a diameter of 38 m, circumference of 120 m and which can be submerged, if necessary, in severe weather events.

For the purposes of this report the application site is the area occupied by the five farming areas.

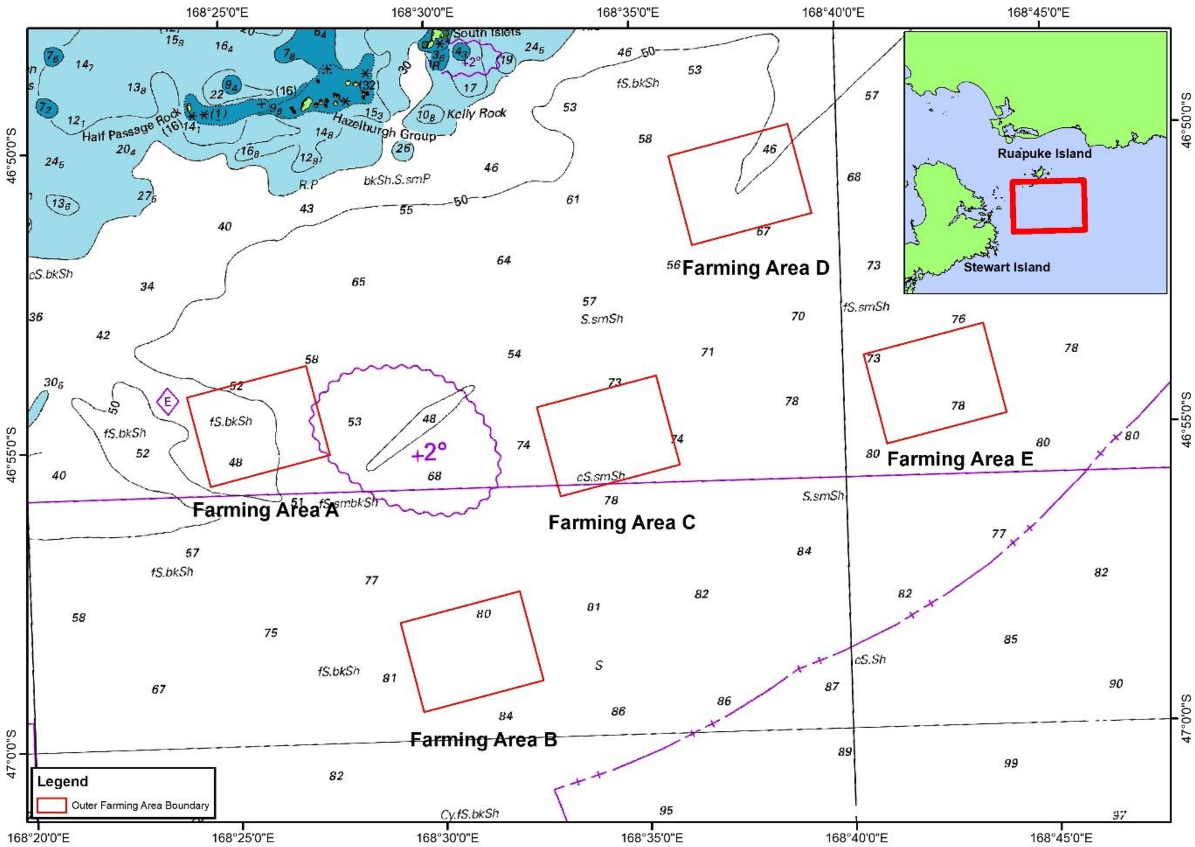


Figure 1. Map showing the individual Farming Areas A-E and wider areas for which consent is being sought to farm salmon.

1.3 Environmental Assessments undertaken

In preparation for a consent application a number of workstreams have been undertaken including:

- Hydrodynamics to describe the currents and tidal flows, and to provide the basis for modelling of nitrogen inputs and deposition from the salmon farm;
- Water quality to describe the existing state of water quality, chemical features and phytoplankton biomass in the application site. A monthly sampling programme has been initiated in the application site;
- Benthic habitat survey and description of the benthic environment including seabed and faunal characteristics. This will update and confirm the habitat in the application site and specific farming areas based on earlier work;
- Modelling of deposition and nutrient-phytoplankton processes and potential effects of the proposed farm;
- Risks associated with biosecurity (pests and disease).

- Description of fish resources and commercial fisheries in the region and potential effects of the proposal; and
- Description of mammal and bird use of the application site and more importantly the farming areas, and potential effects of the development.

2 DESCRIPTION OF ENVIRONMENT AND VALUES

2.1 General

Foveaux Strait is located between the bottom of the South Island and Stewart Island. The Strait is mainly flat bottomed with water depths generally 20 - 35 m deep, sloping away to the east and west where the substrate becomes predominantly fine sand. It should be noted that the application site, which is located to the south-east of Ruapuke Island in 52-80 m of water, is on the eastern edge of Foveaux Strait and better described as in the Ruapuke Basin. The application site.

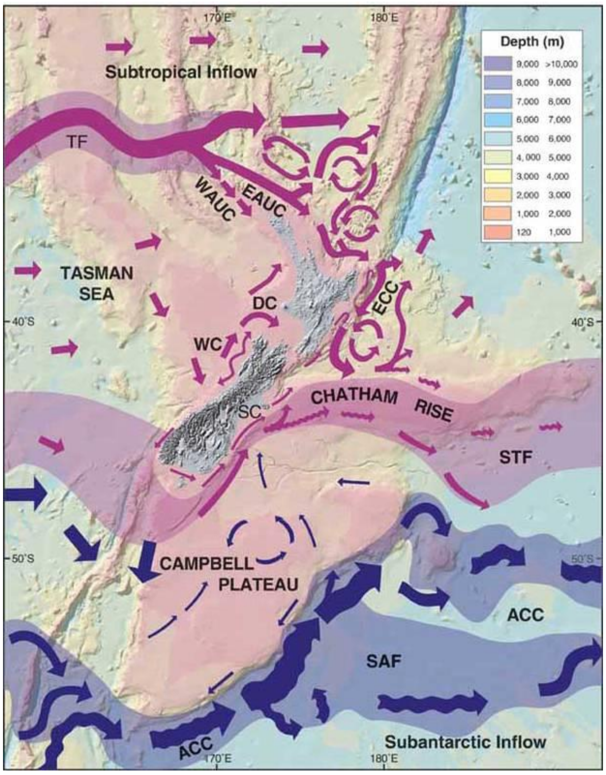


Figure 2. The Subtropical Front is shown here, running along the bottom of the South Island. Others shown are the East Cape Current (ECC), Tropical Front (TF), Antarctic Circumpolar Current (ACC), Subantarctic Front (SAF), East and West Auckland Currents (EAUC and WAUC), D'Urville Current (DC), Westland Current (WC) and Southland Current (SC). Image / Niwa

The main part of Foveaux Strait experiences moderate to strong wind and tidally-driven currents with flow direction predominantly west to east and dominated by the Southland Current (Stevens *et al*. 2019, Heath 1972, **Figure 2**). The prevailing wind is from the west.

Ruapuke Island is the largest island between the South Island and Stewart Island and highly valued by iwi, including for the mutton bird or titi.

2.2 Protected areas

There are three protected areas near the application site and proposed farming areas (**Figure 3**), Dog Island Lighthouse Government Purpose Reserve, Bench Island Nature Reserve and the Catlins Coast Marine Mammal Sanctuary Reserve.

Bench Island Nature Reserve sits approximately 2.5 km northeast of Stewart Island, 20 km south-west of Ruapuke Island, and at least 10km away from the nearest farming area. It was the subject of a terrestrial ecological survey of forest composition and was characterised as having a more pristine native forest cover compared to neighbouring Stewart Island. Its status as a nature reserve is unlikely to be adversely affected by marine farming activities.

The most notably important marine reserve is the Catlins Coast Marine Mammal Sanctuary located north of the application site. The sanctuary is approximately 66,000 hectares covering nearly 161km of coastline (Department of Conservation). The area was classified a reserve under the Marine Mammals Protection Act to protect populations of Hector's Dolphins that are found along Southland coast.

The constraints mapping undertaken as part of the initial site selection exercise ensured that the proposed farming areas are well away from these protected areas and will not be affected.

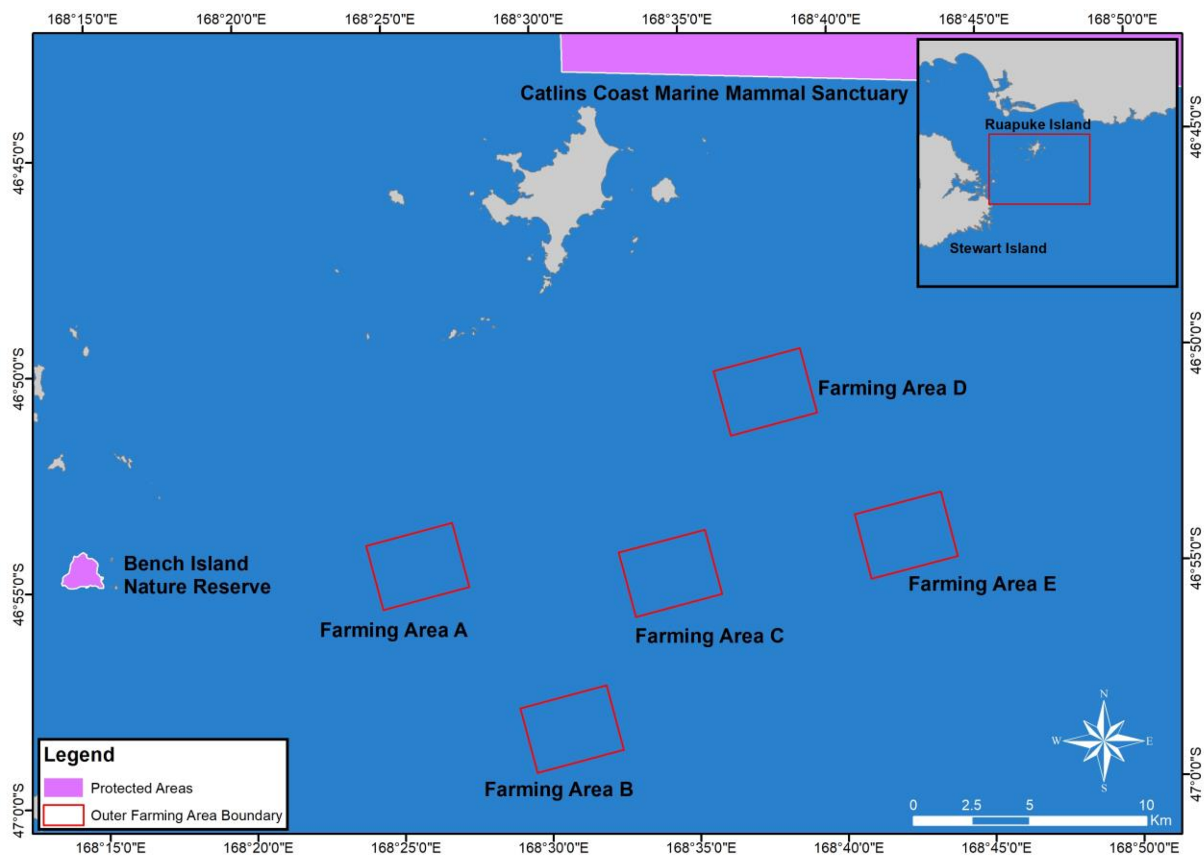


Figure 3. Protected areas in the vicinity of the application site and farming areas.

2.3 Hydrodynamics and physical features

Hydrodynamics conditions influence the dispersal of fish farm waste (dissolved and solid), influence oxygen availability within the pens, and the spatial extent and magnitude of the environmental effects as well as animal welfare on the farm. Hydrodynamics typically refers to the physical attributes of the water including currents, waves and stratification (Plew, 2013).

There are only a few current measurements available for Foveaux Strait and the Ruapuke Basin and most of the information available is based on a mixture of drogue measurements and numerical modelling but with little in-situ data for validation. This is particularly true for the application site.

This section describes currents, waves and stratification of the water column in Foveaux Strait and the application site.

2.3.1 Currents

The hydrodynamics of Foveaux Strait and environs have been described in a number of reports including Cullen, 1967, Cranfield 1968, Heath (1972), Pickrill & Mitchell (1979), Vincent *et al.* (1991), Chiswell (1996), Gorman *et al.* (2003), Russell & Vennell (2017) and Stevens *et al.* (2019). Cullen (1967) and Cranfield (1968) report that currents can reach speeds of 1.2 m s^{-1} though generally at sites west of the proposed farming areas; with currents travelling in the constricted areas between islands in Foveaux Strait potentially reaching greater speeds *e.g.* between Ruapuke and Green Islands. Cullen (1967) describes tidal flow as “the rising tide sets eastward through the Strait, direction being reversed with the fall of the tide”. Cranfield (1968) makes the observation that “[t]he tidal streams of Foveaux Strait run eastward on the rising tide and westward on the falling tide. Cullen’s (1967) reported mean current flows and directions are corroborated by ADS’s hydrodynamic model outputs during the ebb and flood tide (see ADS 2019b). Cranfield (1968) also provides some surface current data, but these describe an area between Ruapuke and Green Islands situated well north of the proposed farming areas and situated between two closely spaced islands.

Many of these observations describe water currents on the more constricted areas of the Foveaux Strait, and few describe the actual conditions at the proposed site itself, which is situated in deeper waters, some farming areas are in the lee of Ruapuke Island, and are in the Ruapuke Basin. For this reason, a hydrodynamic model was used to simulate water movement at the proposed location.

As input to this application, data from three acoustic doppler current profiler (ADCP) deployments in and around the study area, including one carried out specifically for this project, were used and the information is presented in ADS (2019b). The deployments were in:

1) Big Glory Bay
2) Port Adventure
3) Between Ruapuke Island and the application area

As part of the assessment for this application an hydrodynamic model was developed by ADS to assess the hydrodynamic regime. The results of these simulations were then used to drive water movement within the water quality module (see Section 3.5).

Hydrodynamics were modelled for a one-year period (2017) using MIKE modelling software. A 3D model was constructed to cover the waters around Stewart Island and between Stewart Island the South Island (ADS 2019b). This model included regional tidal, wind and current information provided by internationally recognised global models. The model consists of 10 vertical layers and has a horizontal resolution of between approximately 80-2000 meters depending on the location.

The three sets of ADCP data combined with four water level stations located at Stewart Island and the lower parts of the South Island (see ADS 2019b) were used to calibrate and validate this model. An example of ADCP collected south-east of Ruapuke Island and several kilomters to the west of the proposed farming areas is presented in **Figure 4**. Results indicate average flows of approximately 40 cm/s and peak flows of 1.2 m/s which are similar to previous observations made by Cranfield (1968) and Stevens *et al*. (2019).

Overall the hydrodynamic model was found to be fit for purpose (see appendix in ADS 2019b) and there is a good match between the model and ADCP current and water level data. This hydrodynamic model was used to drive the water quality and depositional modules (see ADS 2019b and c).

Model results indicate that the main flow directions at the site are to the east, north-east, south-west and west. Flow is generally between 0.2-0.4 m/s at the site with maximums of approximately 0.7 m/s. Much stronger flows were observed to the west particularly near Ruapuke Island and match those observed by previous studies. An example of typical flow directions and current speeds during summer is provided in **Figure 5A** and **Figure 5B.**

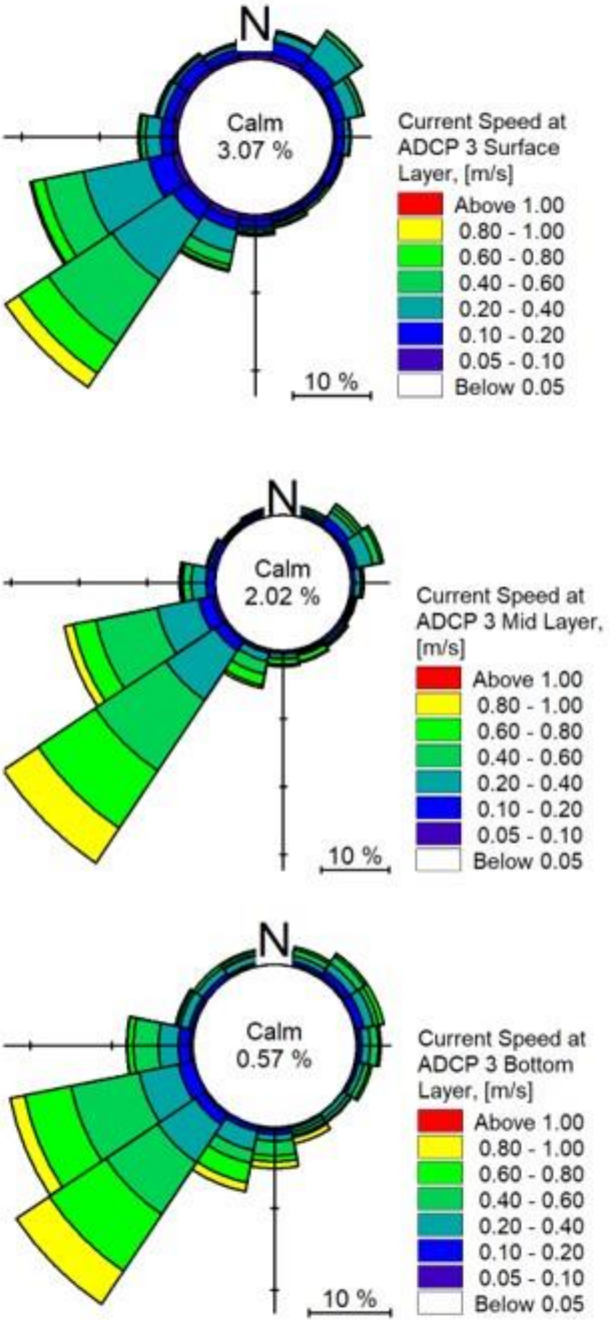


Figure 4. ADCP3 current speed and direction plot from south-east of Ruapuke Island.

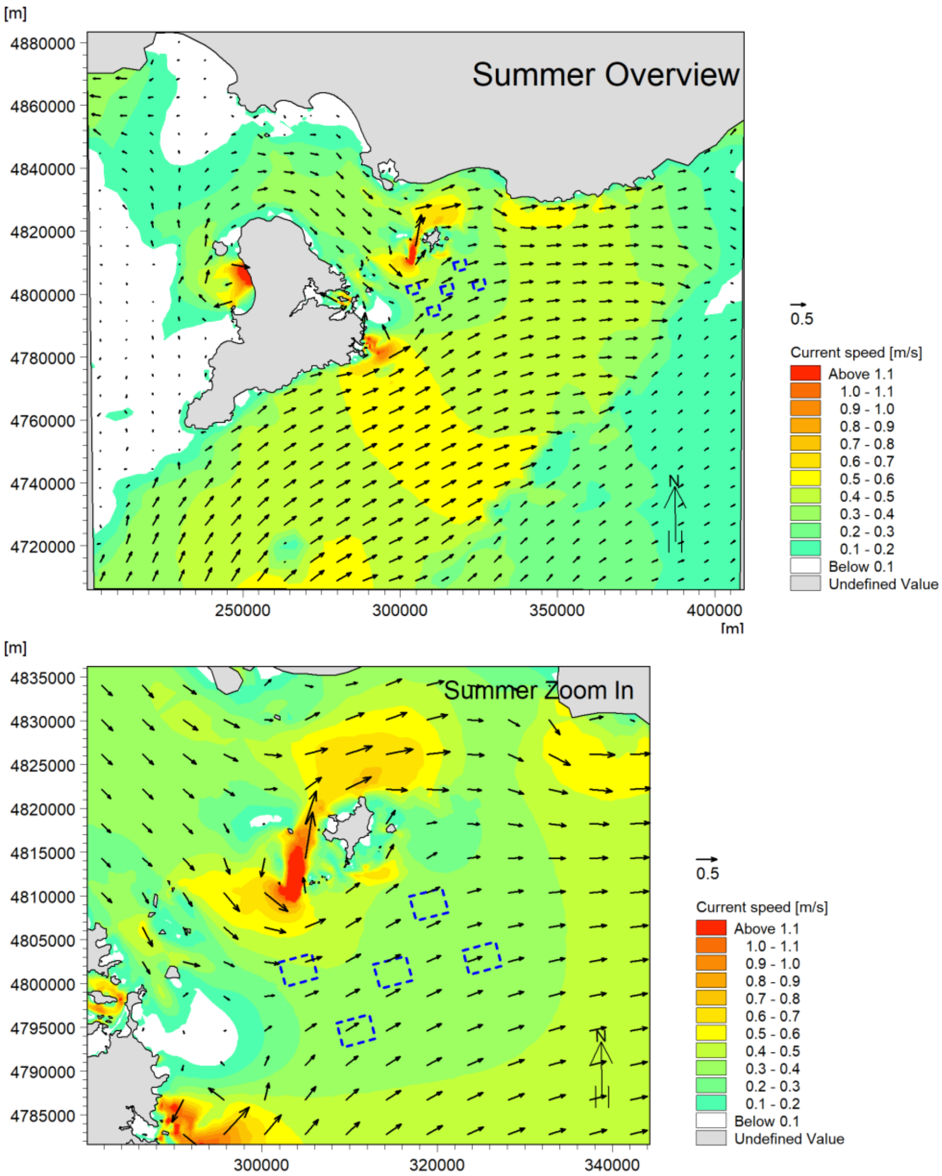


Figure 5A. An example of flood driven flow during summer. Blue blocks show the proposed farming areas.

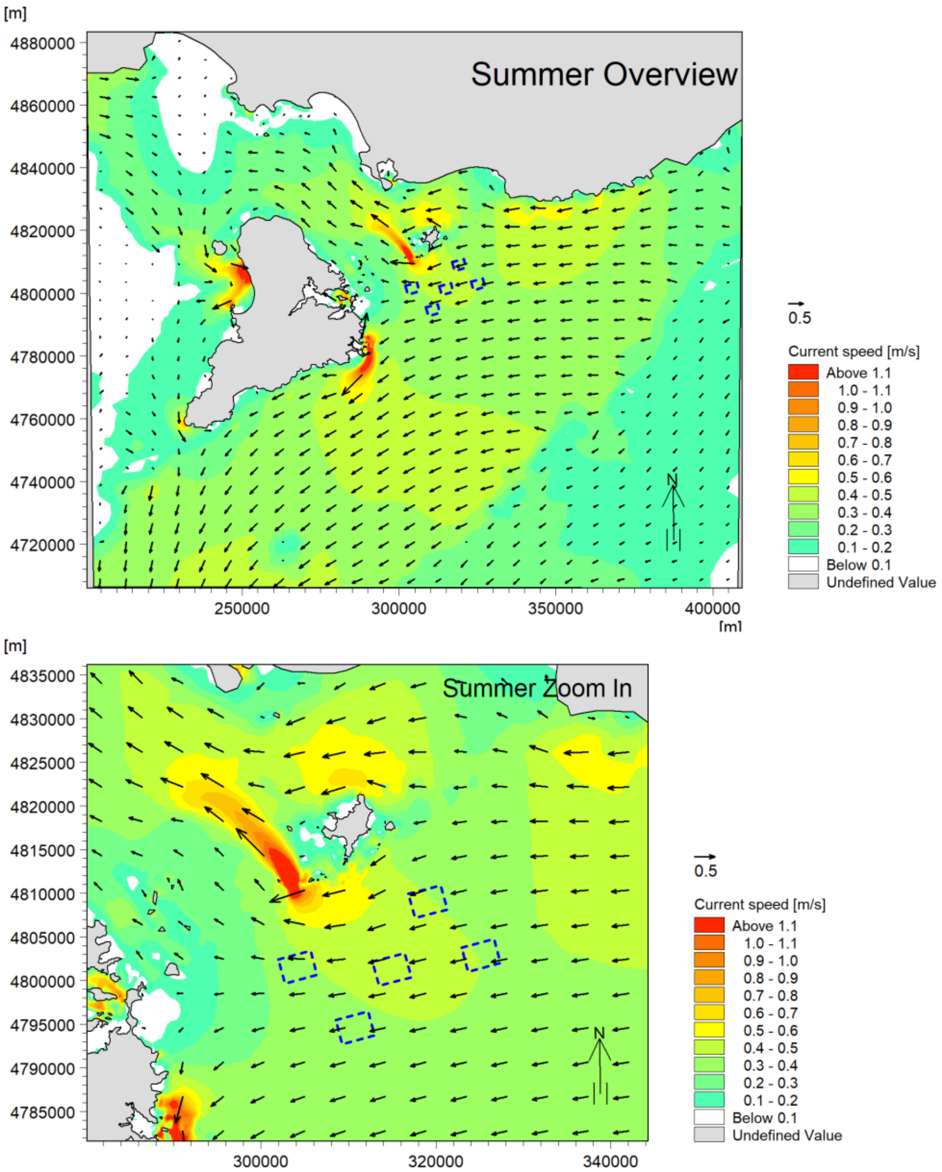


Figure 5B. An example of ebb driven flow during summer. Blue blocks show the proposed farming areas.

2.3.2 Waves

The wave climate in the region of the application site is a major consideration for offshore fish farming and infrastructure. The wave environment in the interior of Foveaux Strait is dynamic and subject to variations in wave energy and direction. Pickrill and Mitchell (1979) reported energetic wave conditions in the Foveaux Strait (northwest of Stewart Island) with a mean significant wave height of 3.7m (>10 sec period) and greater than 10m waves occurring more than 1% of the time (Cranfield *et al.* 2003) (**Figure 6**). Pickrill and Mitchell (1979) report some seasonality to predominant wave height and direction for the stations located in west Foveaux Strait and south of Stewart Island, with larger waves observed to originate more from the west in autumn and winter compared to the smaller summer waves from more varied directions (**Figure 7**).

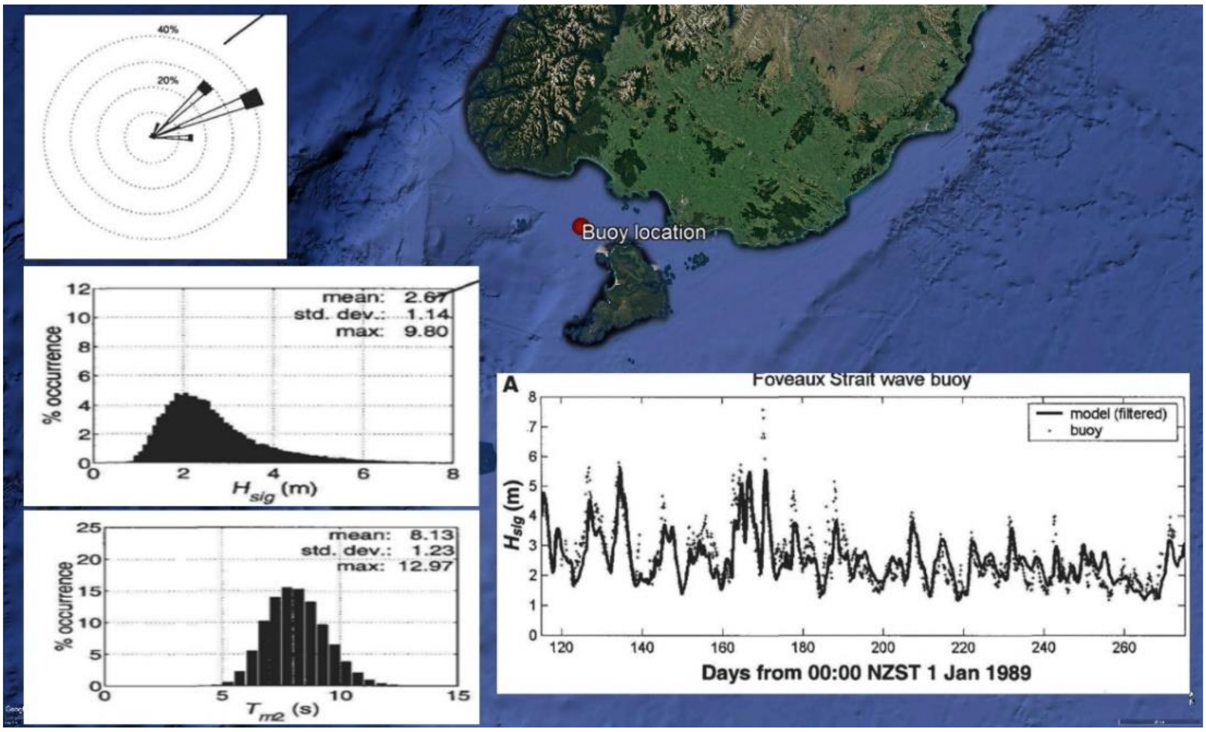


Figure 6. Location of buoy placement, wave rose, distribution of significant wave height, distribution of second-moment mean period and significant wave buoy height from the 20 years hindcast. **Wave rose bars are pointing the direction to which waves travel** and show occurrence of waves in ranges 0-1m, 1-2m, 2-4m, and >4m (outermost).

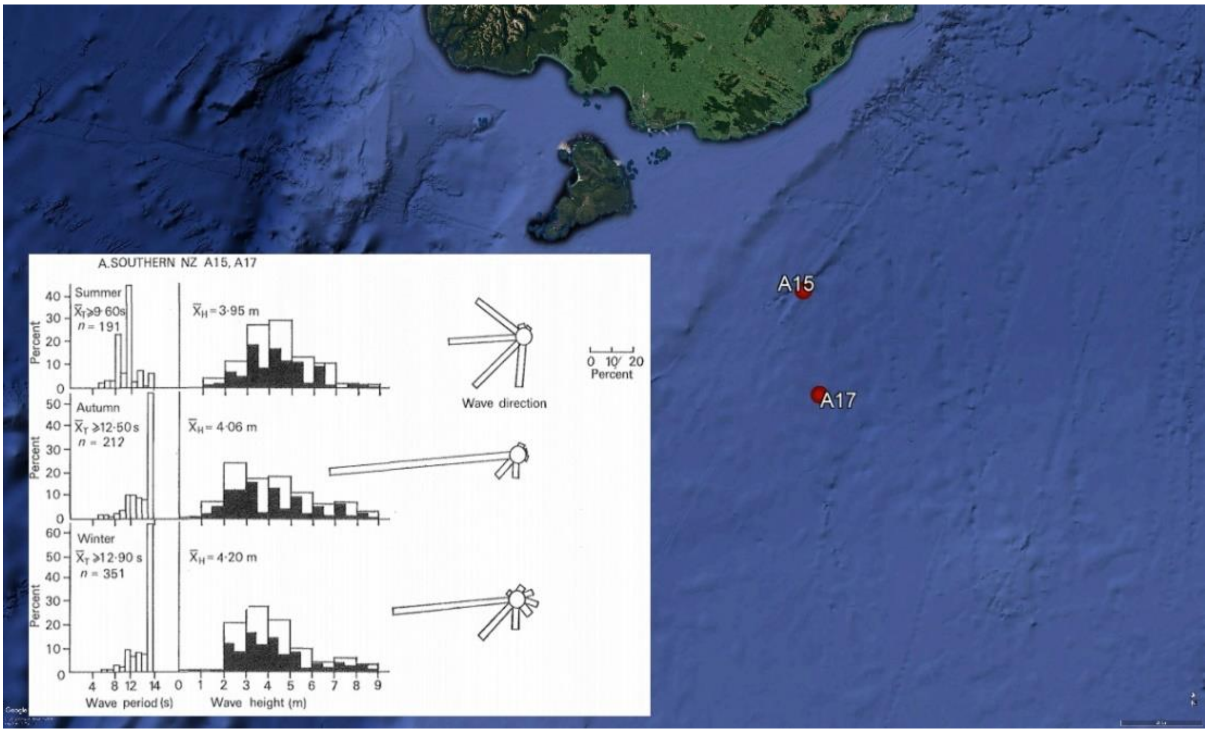


Figure 7. Seasonal breakdown of wave height, period, and direction at station A15 and A17. Seasons defined as: summer-Dec, Jan, Feb; autumn-Mar, April, May; winter- Jun, Jul, August; spring-Sep, Oct, Nov. Wave rose bars show direction of wave origin (convention change occurred after this paper was published).

ADS have also provided a wave model specifically for the south-east waters of Stewart Island whose domain includes BGB, Patterson Inlet and much of the area south-west of the application site (**Table 1** and **Table 2, Figures 8-10**).

Table 1. MetOcean Solutions wave model information

Dataset	New Zealand
Wave Model	MSL SWAN
Wind Model	MSL WRF
The station/node in the MetOcean Solutions wave model	47.1˚S 168.25 ˚E
Grid resolution	0.05˚
Extent of the wave model	165˚ E to 179.95˚ E and 48˚ S to 34˚ S

Six scenarios (with various wave heights, periods, speeds, and direction) were simulated to model the wave conditions in waters south-east of Stewart Island. During the 1/10-year wave simulation waves were observed to be greater than 10 meters close to the application site while even larger waves were predicted during a 1/100-year event.

Table 2. Parameters of wave model in different scenarios

Scenario	Significant Wave Height, Hs (m)	Peak Period, Tp (s)	Direction Nautical (deg)	Speed (m/s)
1st	2	14	180	15
2nd	4	16	135	15
3rd	7	16	135	20
4th	2.5	14	45	15
5th (extreme condition of 10 years return period)	7.9	14	45	27
6th (extreme condition of 100 years return period)	9.5	14	45	30

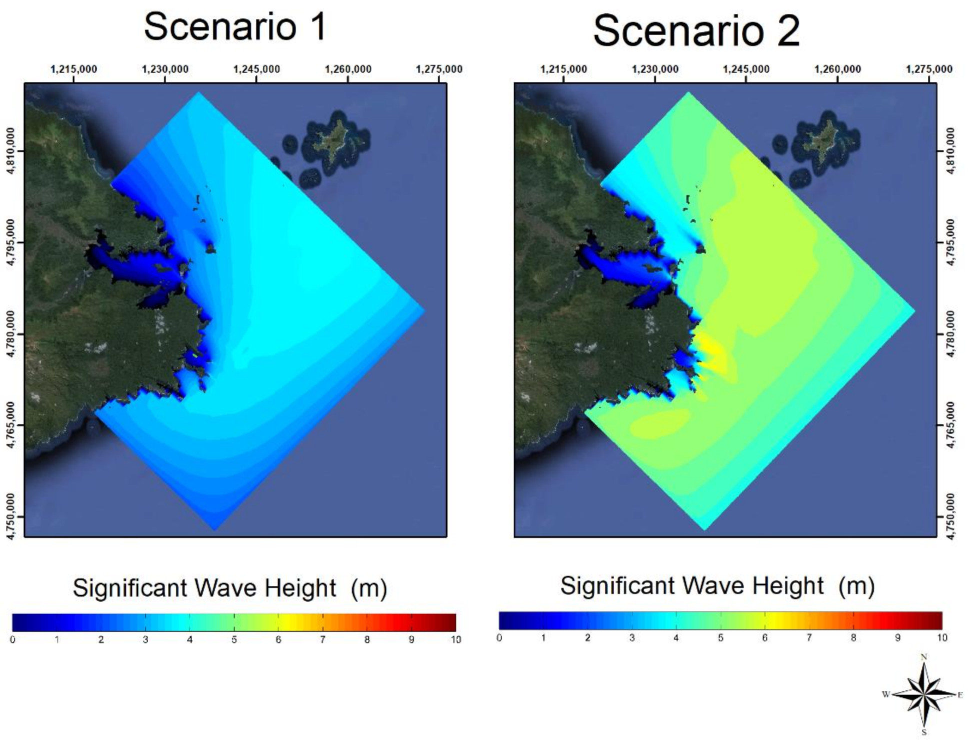


Figure 8. Overview of wave height at the south-east of Stewart Island in Scenario 1 and Scenario 2

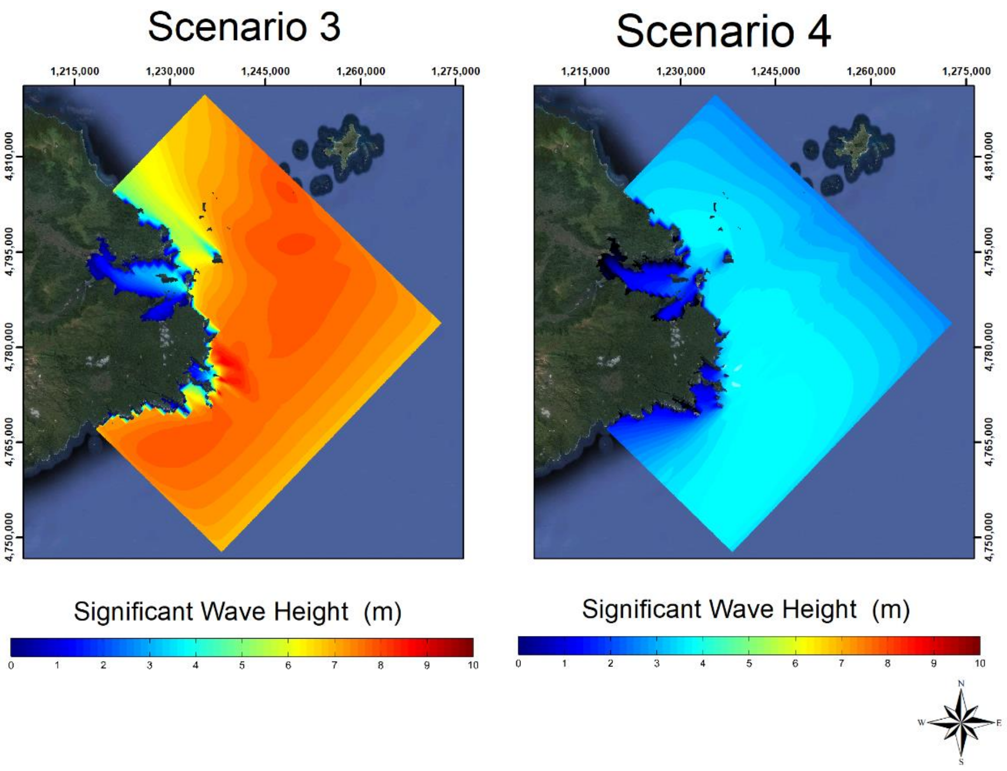


Figure 9. Overview of wave height at the south-east of Stewart Island in Scenario 3 and Scenario 4

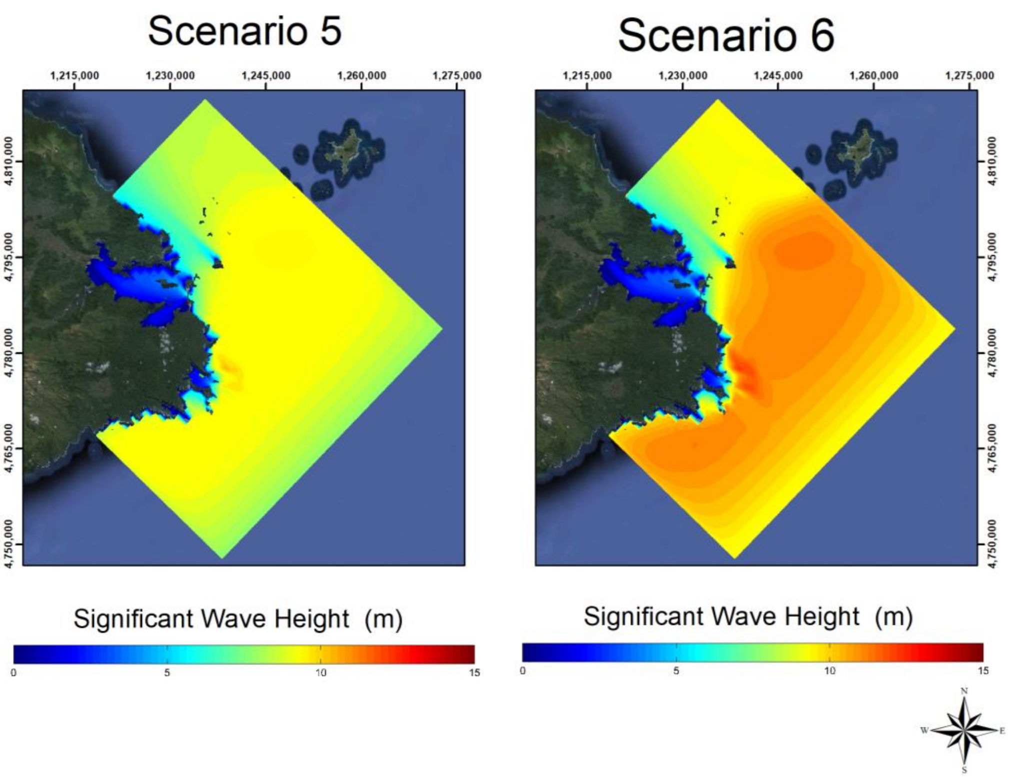


Figure 10. Overview of wave height at the south-east of Stewart Island in Scenario 5 and Scenario 6

2.3.3 Sea surface temperature

Sea surface temperature (SST) is the water temperature close to the ocean's surface. SST is an important parameter for aquaculture because a fish's metabolism is heavily influenced by the temperature of the water. Thus the efficiency at which a given fish can convert food into body mass (*i.e.* Food conversion ratio (FCR)) is also affected by it.

An analysis of 40 years of SST data has shown that NZ waters are warming in general, and more so with proximity to the coasts (Sutton and Bowen 2019). The largest changes in SST have occurred along the eastern edge of the North Island (**Figure 11**) with average increases of 0.34°C per decade. Further south, south of the Otago Peninsula, and towards Stewart Island, the average SST change is more modest (0 to 0.04°C per decade), though the change does seem to increase closer to shore and with proximity to the Foveaux Strait (~0.18°C per decade). Note positive SST anomalies (warming) around Stewart Island are becoming more frequent over the last four decades (**Figure 12**).

Given that SST increases are projected to be less than 1.0 °C in 50 years, warming does not appear to be an immediate threat to salmon aquaculture in this region, especially with modern selective breeding programs in place (as seen with Tassal's Atlantic Salmon stocks seemingly growing successfully in a warming Macquarie Harbour). However, the temperature projections reported here concern mean temperatures and do not account for any increased variation in seasonal SST (higher highs and lower lows) noting that salmon deaths have occurred in recent years in the Marlborough Sounds due to higher temperatures.

Coastal upwelling has important implications for aquaculture development due to sudden temperature shifts (typical summer water is 15°C and Southland Current waters range from 8°C to 10°C (Chiswell 1996)) and the introduction of nutrient-rich waters supplying inorganic nutrients and potentially enhancing algal productivity. Such inputs have been implicated in the algal bloom that resulted in large-scale mortality in BGB in 1989 (Chang *et al.* 1990).

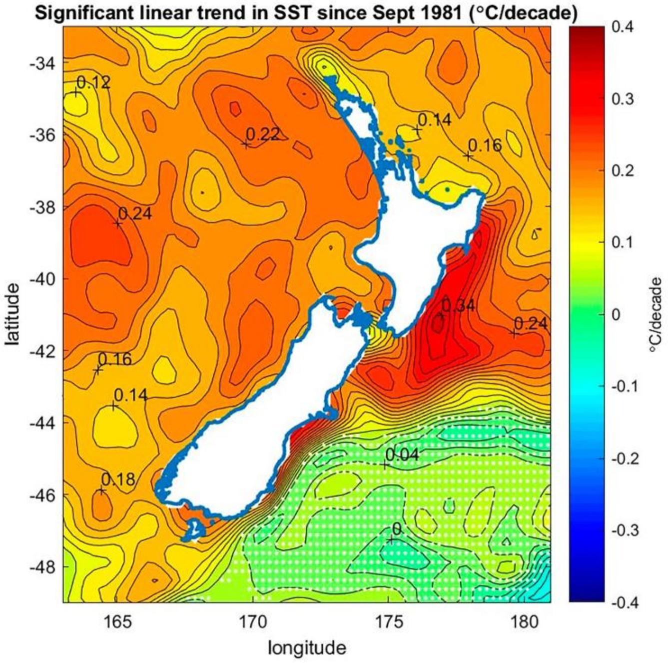


Figure 11. Significant SST trends since 1981. From Sutton and Bowen (2019).

2.3.4 Stratification

Stratification occurs when light, buoyant water overlies heavy dense water and is caused either by temperature differences (warm water is lighter than cold water), or by differences in salinity (freshwater is lighter than seawater).

Measurements of physical properties through Foveaux Strait by Vincent *et al*. (1991) found the water column was well mixed vertically, which means that it is not stratified. Vincent *et al*. (1991) also showed a gradient from warm, saline waters in the west to cooler, less saline waters in the east. There was evidence of freshwater riverine inputs at sites closer to the coast of the South Island, which may induce localised stratification at these locations. Such effects are unlikely to reach the application site.

Preliminary data collected as part of an ongoing survey of water quality at the proposed site also indicates no thermal stratification, at least in the top 20 meters in November and December 2019.

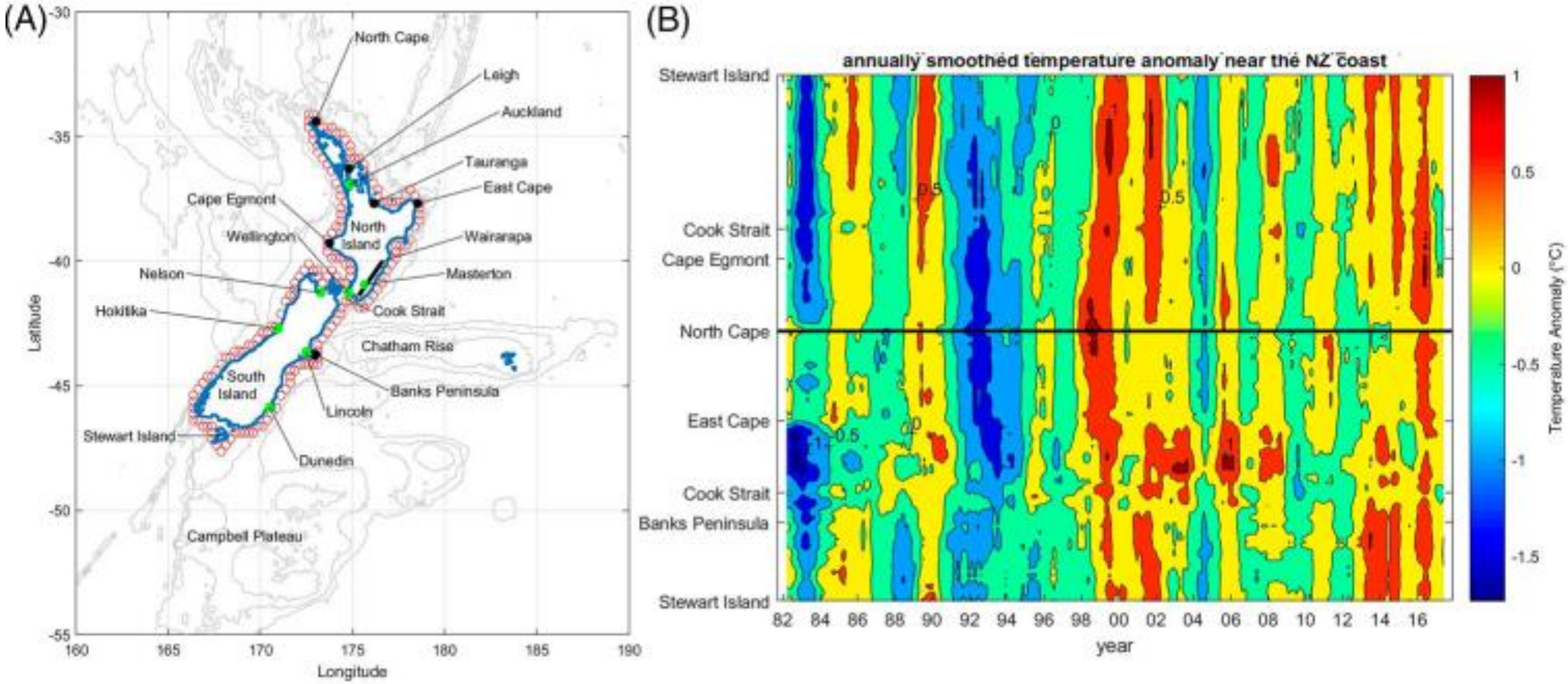


Figure 12. Time Series of SST

2.4 Water quality and plankton

2.4.1 Nutrient Status and chlorophyll a

Water quality data is scarce for Foveaux Strait and even more so for the Ruapuke area with most of the data available from early research voyages in the 1970s and 1990s.

Nutrients

Vincent *et al*. (1991) found low ammonia-N levels in Foveaux Strait but there was a marked increase towards the seabed which was attributed to secondary production in the sediments.

Nitrogen is considered to be the primary limiting nutrient in New Zealand coastal waters (MacKenzie & Gillespie 1986, and Bradford-Grieve *et al.* 1996). Thus primary production in Foveaux Strait is heavily influenced by the source of the water with nutrient deplete sub-tropical waters from the west coast of the South Island resulting in limitation of phytoplankton production and inputs of colder nutrient-rich (nitrate-nitrogen) upwelled water from the sub-Antarctic at times from the west and east (Houtman 1974, Heath 1975, Vincent *et al*. 1991, Chiswell 1996) resulting in enhanced production. Based on results from a number of research voyages in the early 1990s nutrient concentrations, and in particular nitrate-N, increase from west to east (Gillespie *et al.* 2009) and are likely to stimulate phytoplankton production in eastern Foveaux Strait. Gillespie *et al.* (2009) collated data for Foveaux Strait from the research voyages which showed that nitrate-N concentrations ranged from 10-30 µg/L. At the eastern end of the Strait temperature varied from 11.6 – 15.0 ^{o}C in summer (Feb 1977-1980 and May 1989) and nitrate-N from 10-85 µg/L over the same period (Gillespie *et al*. 2009) with highest concentrations when the water was cooler reflecting the input of colder sub-Antarctic water.

A new monitoring programme in the area of the proposed development, and in outer Patterson Inlet as part of compliance monitoring for BGB, was initiated by Sanford in November 2019. Preliminary data is shown in **Table 3.** TAN concentrations were low, nitrate-N concentrations moderate at 45-70 mg/m^3 but with low levels in January 2020 (4 mg/m^3) probably due to uptake by phytoplankton), and dissolved reactive phosphorus (DRP) and total phosphorus (TP) concentrations relatively low. Concentrations are generally in the range recorded for waters offshore of the Marlborough Sounds (Newcombe *et al*. 2018) and BGB/outer Patterson Inlet for this time of year. Chl-*a* concentrations were 0.2 to 1.8 mg/m^3 over the late spring/summer 2019/2020 period. The relatively high nitrate-N concentrations are likely to due to upwelled water entrained into Foveaux Strait. Note that the new monitoring programme started in November 2019 so may have missed the spring peak in chl-*a* but there appeared to be another peak in January 2020.

Table 3. Water quality data for 5 m depth at a site near Farming Area A. ND=no data

Parameter	6/11/2019	27/11/2019	17/12/2019	28/1/2020
Dissolved reactive phosphorus (DRP) (mg/m^3)	11	13	12	4
Ammonia-Nitrogen (mg/m^3)	4	3	8	6
Nitrate-N (mg/m^3)	57	70	45	4
Total N (mg/m^3)	147	145	156	119
Total P	45	14	16	13
Chlorophyll *a* (mg/m^3)	1.5	0.3	0.3	1.8

Plankton

The water column is inhabited by planktonic algae (phytoplankton) and microscopic animals (zooplankton). Phytoplankton, which are the major source of food for filter-feeding bivalves and zooplankton, occur as single planktonic cells, colonies or chains in the water column. When phytoplankton die they sink to the seafloor, thereby contributing to the sedimentation of organic matter, which in turn provides a food source for deposit feeding animals living on or in the sediments. Zooplankton includes microscopic protozoans, copepods, krill and larvae of crustacea. They provide important links in food webs and provide a dispersal mechanism for crustacean and fish larvae.

Plankton communities are highly variable and dynamic in space and time, undergoing relatively predictable seasonal cycles. There is very little reported data on the phytoplankton community composition in Foveaux Strait and none that we are aware of for the Ruapuke area but the area is likely to be highly productive with phytoplankton production supporting commercial fisheries, shellfisheries and bird populations.

Phytoplankton community composition has recently been added to monitoring programmes in outer Patterson Inlet and at a site close to Farming Area A. The first data from December 2019 showed a community dominated by the diatom *Chaetoceros* spp., and other diatoms *Nitzschia* spp. and *Thalassiosira* spp.. *Pseudo-Nitzschia* spp., a diatom which is toxic to shellfish, was recorded as a co-dominant but not at trigger levels for harmful algae.

There are no published data for zooplankton in Foveaux Strait and the Ruapuke area but it is likely to be dominated by neritic copepods at times or open ocean species of copepods and euphausiids, depending on the season and input of subantarctic and subtropical waters (Bradford-Grieve *et al*. 1999)

Harmful algae blooms

Harmful Algal Blooms (HABs) have previously affected marine farms in New Zealand. For instance, *El Niño* climate conditions in the spring of 1992 resulted in cooler sea temperature off the northeast coast and these were linked to major unusual HAB events (Rhodes *et al.* 1993).

HABs can be prompted by several factors including the rapid supply of inorganic nutrients and shifting of the physical conditions in which the algal community lives (*e.g.* light conditions, salinity, temperature, *etc*.). The major sources of nutrient inputs into the coastal ocean would be riverine inputs and coastal upwelling.

There have been several harmful nauturally occuring algal blooms (HABs) reported for the area around Foveaux Strait, namely around Invercargill and in BGB on Stewart Island. Mackenzie (1991) and Chang *et al.* (1990) both reported observed blooms of the algae *Heterosigma akashiwo* and *Chattonella sp.*in BGB. These were the major cause of fish mortality in early 1989 in BGB causing gill and intentine lesions as well as abnormal secrestions of mucous and distruction of gill lamellae. The ichthyotoxic species *Pfesteria shumwayae* was detected in samples collected around Invercargill in the year 2000 (Rhodes *et al*. 2001). Large fish kills in estuaries in the USA have been attributed to this species (Burkholder *et al.* 2001, Vogelbein *et al.* 2002).

2.5 Benthic environment

2.5.1 Benthic environment of Foveaux Strait

The nature of the seabed and benthic communities in Foveaux Strait has been well described as part of studies associated with the oyster fishery. However, as most of the dredging for oysters is to the west of Ruapuke Island, there is limited published benthic data for the application site.

Michael (2010) provides a habitat map of the area around the northern part of Stewart Island and the bottom of the South Island based on earlier sediment surveys and more recent habitat data from video transects in 2006 (**Figure 13**). It shows that particularly the outer parts of the mapped area, including the application site in which the proposed farming areas are located, is dominated by sand ripple habitat. The area between Stewart Island and the South Island (north and northwest of the application site) contains diverse habitats, including:

- Rocky patch reef with epifauna;
- Flat gravels with clean (usually *Ostrea chilensis*, *Pseudoxyperas elongata*, and *Glycymeris modesta*) or encrusted (usually bound by small encrusting bryozoans) shell;
- Flat gravels red algae and kaeos (*Pyura pachydermatina*);
- Gravels waves or lowly undulating gravels with clean shell in the troughs;
- Flat sand and gravel with and without biogenic patches;
- Large sand waves; and
- Biogenic areas (along the coastline of Stewart Island).

The strong currents and nutrient-rich water flowing through Foveaux Strait support diverse benthic habitats.[1] Of the habitats found in this area, biogenic habitats are of particular value. The structural complexity of these habitats generally results in increased biodiversity of the assemblages that occur within them. It is presumed that traditionally, the un-dredged coastal waters of Foveaux Strait would have supported biogenic reefs with a rich associated fauna of oysters, fragile lace corals, sponges and other invertebrates[1] (Morrison *et al.* 2014).

Wood *et al.* (2013) predicted suitable habitat for multiple bryozoan species on the New Zealand continental shelf. The area around Stewart Island and Foveaux Strait and Ruapuke area (including the application site) were found to be a predicted hotspot of habitat-forming bryozoans (**Figure 14**).

Jones *et al.* (2016) collated Local Ecological Knowledge (LEK) from trawl fishers around New Zealand to record their knowledge of biogenic habitat and create maps of potential biogenic

[1] https://www.doc.govt.nz/about-us/our-policies-and-plans/statutory-plans/statutory-plan-publications/conservation-management-strategies/stewart-island-rakiura/section-one/part-one-management-objectives-and-policies/1_3-conservation-of-natural-resources/1_3_5/

habitat. This approach for gathering information is known to be uncertain but is also acknowledged to be a valuable complement to scientific data. Jones *et al*. (2016) describe the caveats of their approach as follows:

> "The maps and site descriptions presented here represent a valuable, but in many places, unverified indication of where biogenic habitats might exist on the New Zealand continental shelf, and are intended only to inform the design of future field sampling".

The map of Foveaux Strait created by Jones *et al.* (2016) is shown in **Figure 15**. While it is difficult to compare this map with the distribution of subjective habitat classes based on sediment composition shown in **Figure 13**, the information near the application site is generally consistent, except for an area labelled "horse mussels" south-east of Rapuke Island shown in **Figure 15**. This and two other areas with this label were described as "shelly seabed, the fishers picking up horse mussels, sponges, and oyster shells".

Maps of bryozoan presence and abundance provided by Anderson *et al*. (2018) demonstrate that Foveaux Strait and the area around and south-west of Stewart Island is an important area for bryozoan species (**Figure 16**). However, **Figure 16** shows that no bryozoan have been observed south-east of Ruapuke Island, including in the application site.

Biogenic habitats susceptible to breakage and dislodgement are adversely affected by fishing activities and the extensive areas of bryozoan thickets in Foveaux Strait are among several biogenic habitats in New Zealand showing signs of damage and loss (Anderson *et al.* 2018). The biogenic reefs in Foveaux Strait have long been under pressure from commercially trawl fishery for oysters that has taken place in the area for over 100 years, focusing primarily on bryozoan biogenic reefs that once covered large areas of the Strait (Anderson *et al.* 2018; Cranfield *et al.* 2003). The resulting changes to the composition of the seabed biota, particularly in regard to the diverse biogenic reef communities, including complexity and distribution of bryozoan reefs are likely to have been substantial (Anderson *et al.* 2018). Effects of dredging on biogenic reefs included damaging the reef structure, removing epifauna and exposing associated sediments, which were then reworked and transported down-current in the strong tidal flow (Cranford *et al.* 2003).

Cranfield *et al.* (2004) investigated the extent to which biogenic habitats have regenerated in Foveaux Strait by surveying five sites along a gradient of habitat complexity **(Figure 17).** They found that biogenic habitat has regenerated in localised patches on the dredge-modified seafloor and that oyster populations have rebuilt on habitat that was not nearly as complex as the original biogenic reefs. An area of high habitat complexity and regenerated oyster populations is located north of Ruapuke Island. Cranfield *et al.* (2004) found that the extent of habitat regeneration appeared to largely depend both on the time since fishing ceased and on the proximity of the sources of re-colonising propagules.

The farming areas are mostly outside the area experiencing historic fishing pressure (**Figure 17**). This, in combination with the habitat characteristics indicated in **Figures 13** and **15** indicates that the application site is likely to be outside the area of (historically) high value and structurally complex biogenic habitats. The area has likely experienced some physical disturbance through trawling and dredging (also see section 2.6.2 'Commercial fisheries') but at a lower intensity compared to the central Foveaux Strait area.

The farming areas have been carefully chosen to avoid sensitive habitats and in particular the biogenic habitats immediately to the south-east of Ruapuke Island and the flat gravels with encrusted shell hash to the north of the area.

2.5.2 Benthic survey of the application site

To provide additional and targeted information about the benthic environment in the application site, a benthic survey was conducted as part of this AEE. The benthic survey results are reported in ADS (2019a) and summarised here.

The survey was conducted in August 2019. A range of methods (side scan sonar, sediment sampling, underwater video, and continuous single bean echo sounder surveys) were utilised to assess seabed habitats and sediment characteristics, including benthic fauna. The survey focussed on the five proposed farming areas but also covered other parts of the wider application site. The 29 sampling station locations for sediment samples, drop camera and video transects at and near each of the five proposed farm sites as well as at four additional locations in vicinity are shown in **Figure 18**.

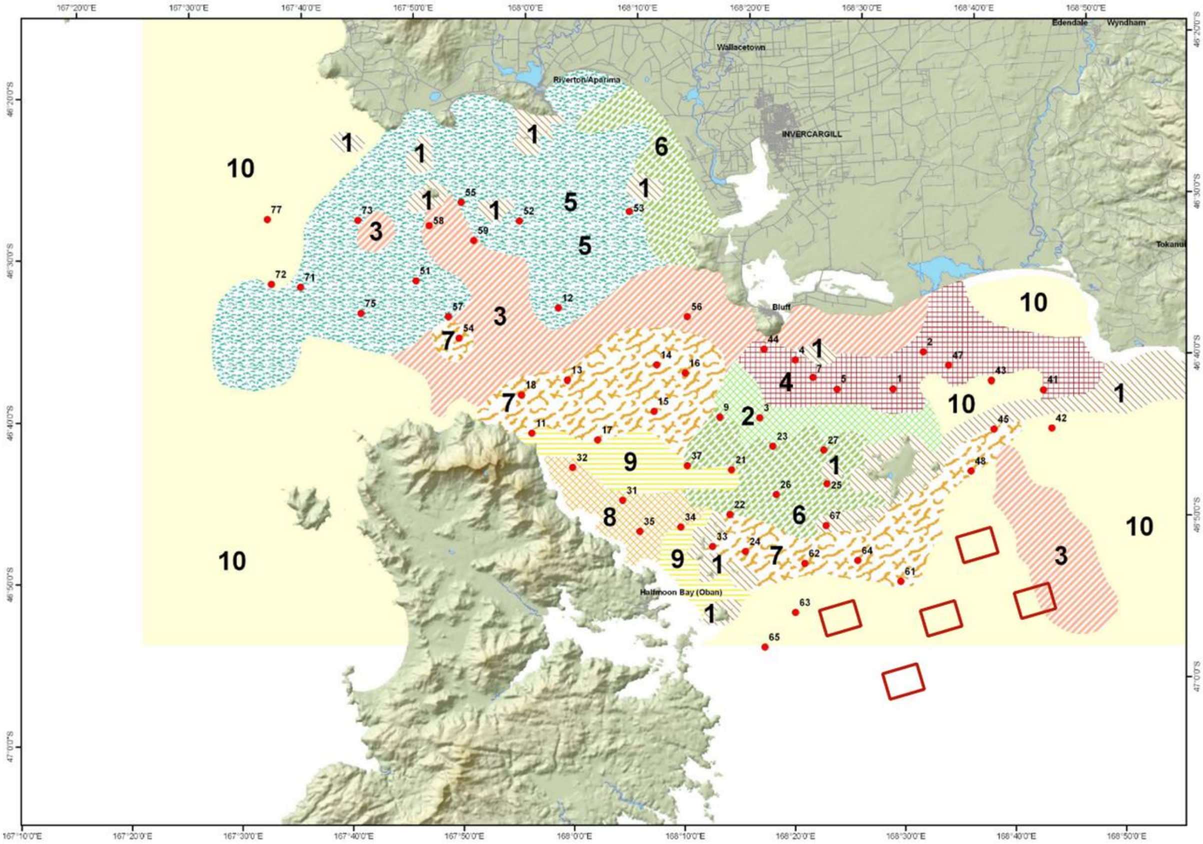


Figure 13. The distribution of subjective habitat classes based on sediment composition, structure and stability from 2006 video transects and the sediment map of Cullen & Gibb (1966). 1, rocky patch reef with epifauna, usually surrounded by sand and fine gravels; 2, flat gravels with clean shell (usually *Ostrea chilensis*, *Pseudoxyperas elongata*, and *Glycimeris modesta*); 3, flat gravels and encrusted shell (usually bound by small encrusting bryozoans (Cranfield *et al.*. 2004 and Dennis Gordon, NIWA, pers. comm.); 4, flat gravels red algae and kaeos (*Pyura pachydermatina*); 5, gravels waves or lowly undulating gravels with clean shell in the troughs; 6, flat sand and gravel; 7, flat sand and gravel with biogenic patches; 8, biogenic areas; 9, large sand waves; and 10, sand ripple. The proposed farming areas are shown as red blocks. Modified from Michael (2010).

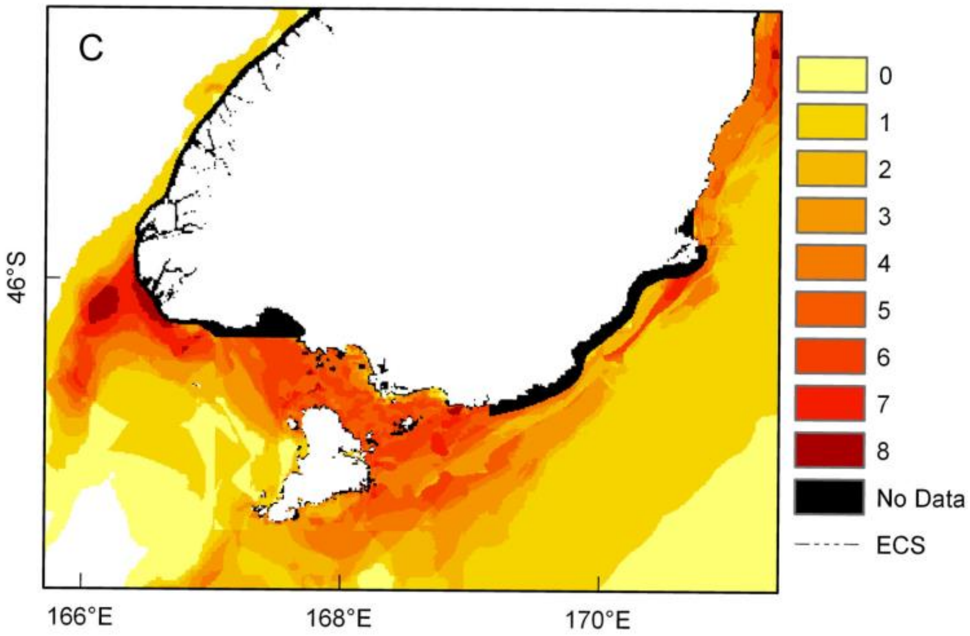


Figure 14. Predicted Bryozoan hotspots by Wood *et al.* (2013). The numbers 0 to 8 indicate the number of species predicted to find suitable habitat.

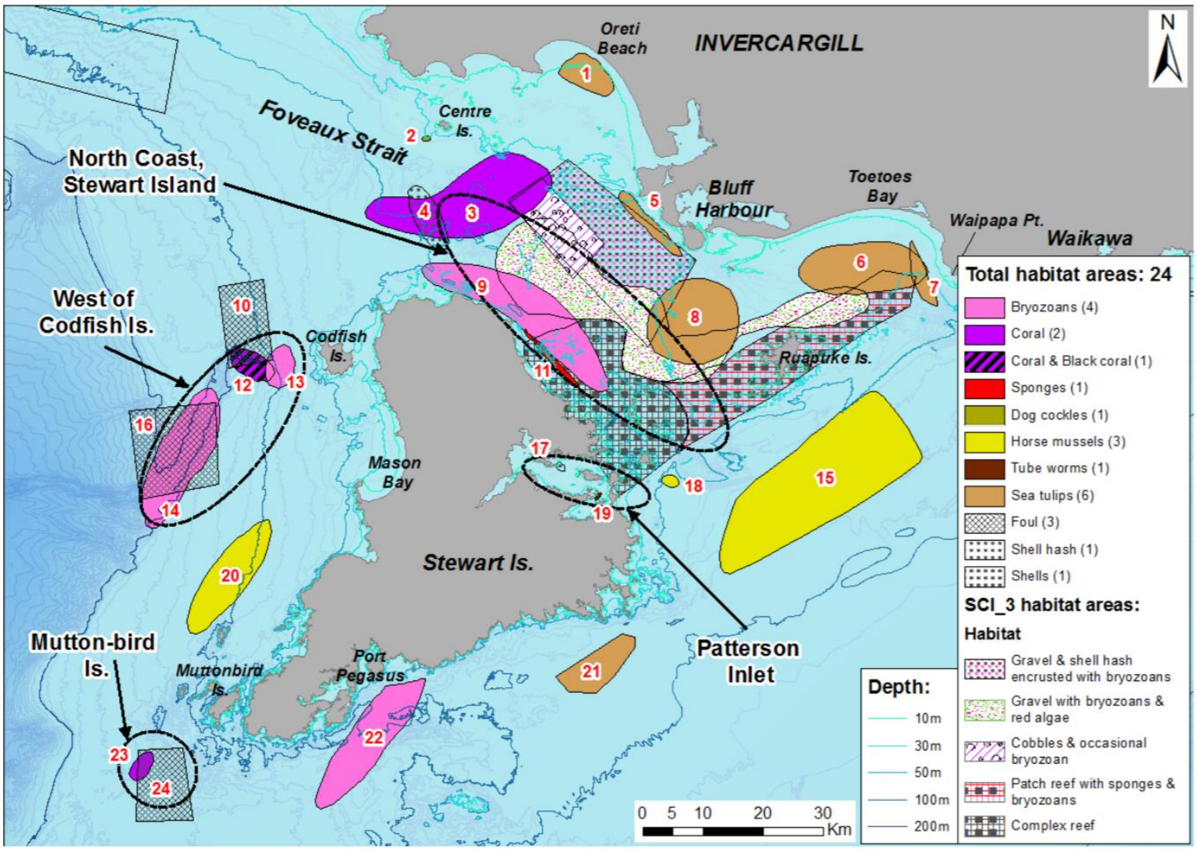


Figure 15. Local Ecological Knowledge (LEK) map for Foveaux Strait and Stewart Island indicating the location of bryozoan (and 'coral') fields - depicted by pink (and purple and purple striped) polygons. Each fisher-drawn area has been assigned a unique number, specific to this regional section (red). Source: Jones *et al.* (2016).

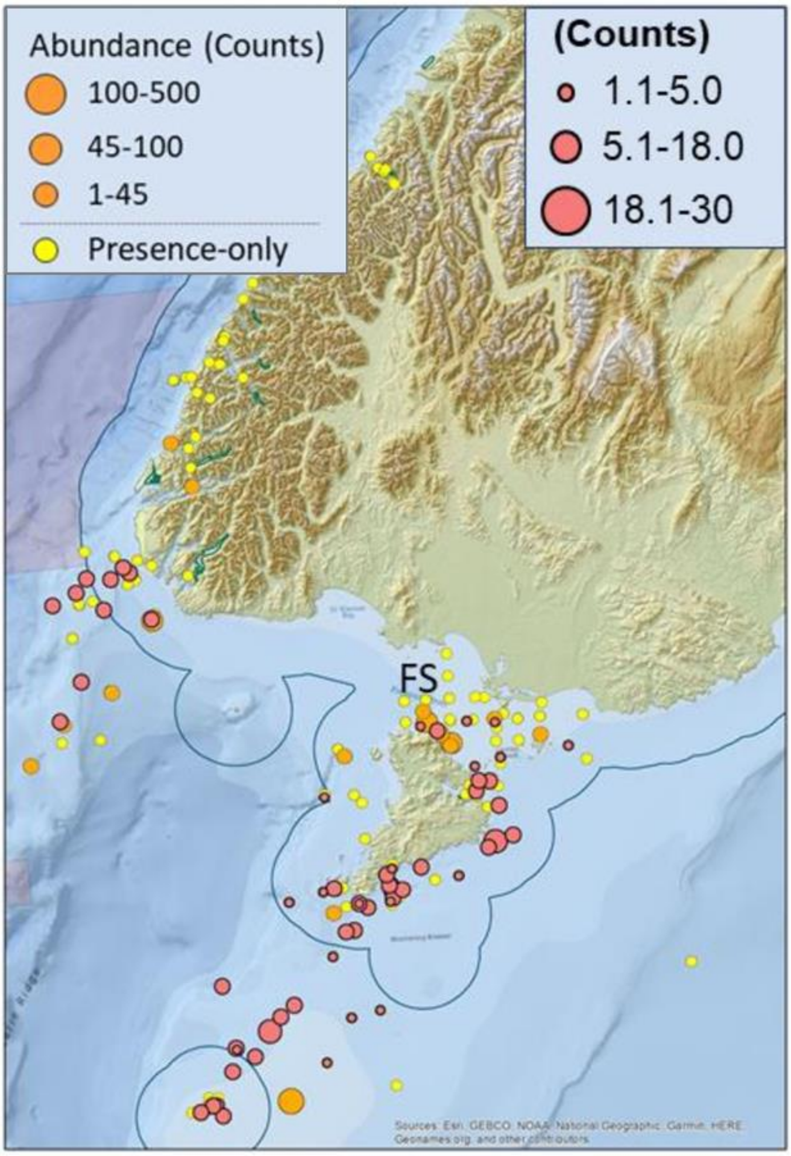


Figure 16. Bryozoan abundance in the southern New Zealand region. Total abundance (orange bubble plots) of the eight-key reef-building species (combined) from NIWA's Specify data, and their presence (yellow circles) from all available datasets (OBIS-NZ, TePapa, and University datasets). pink circles represent bryozoan counts from university surveys (A. Smith, Otago University). Source: Anderson *et al.* (2018).

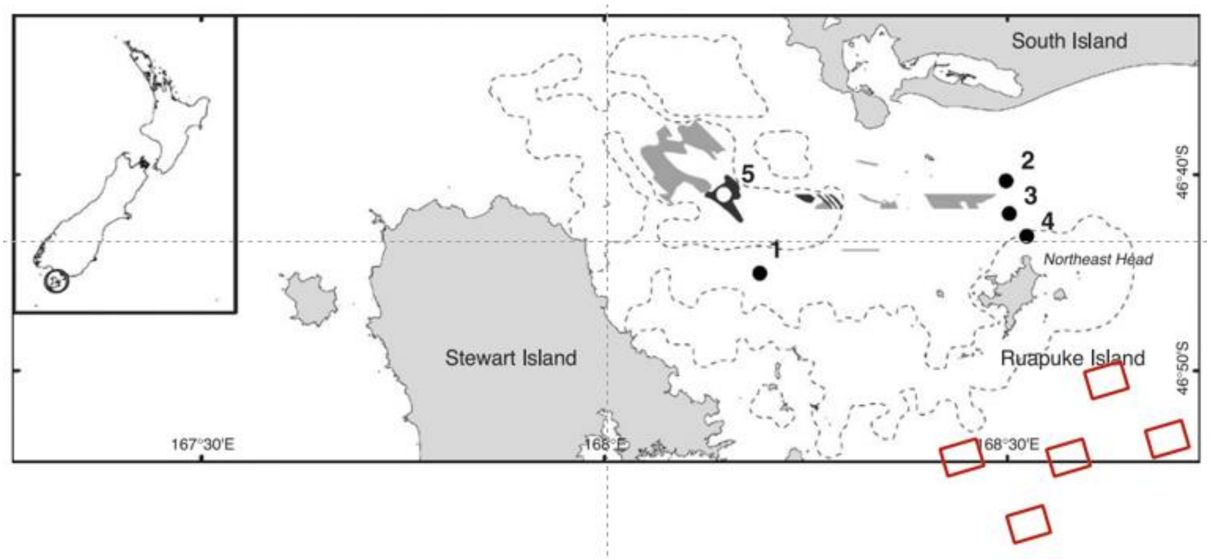


Figure 17. Study sites from Cranfield *et al.* (2004) numbered according to rank habitat complexity. The dotted outline within this figure indicates areas with historic fishing pressure. The proposed farming areas are shown as red blocks.

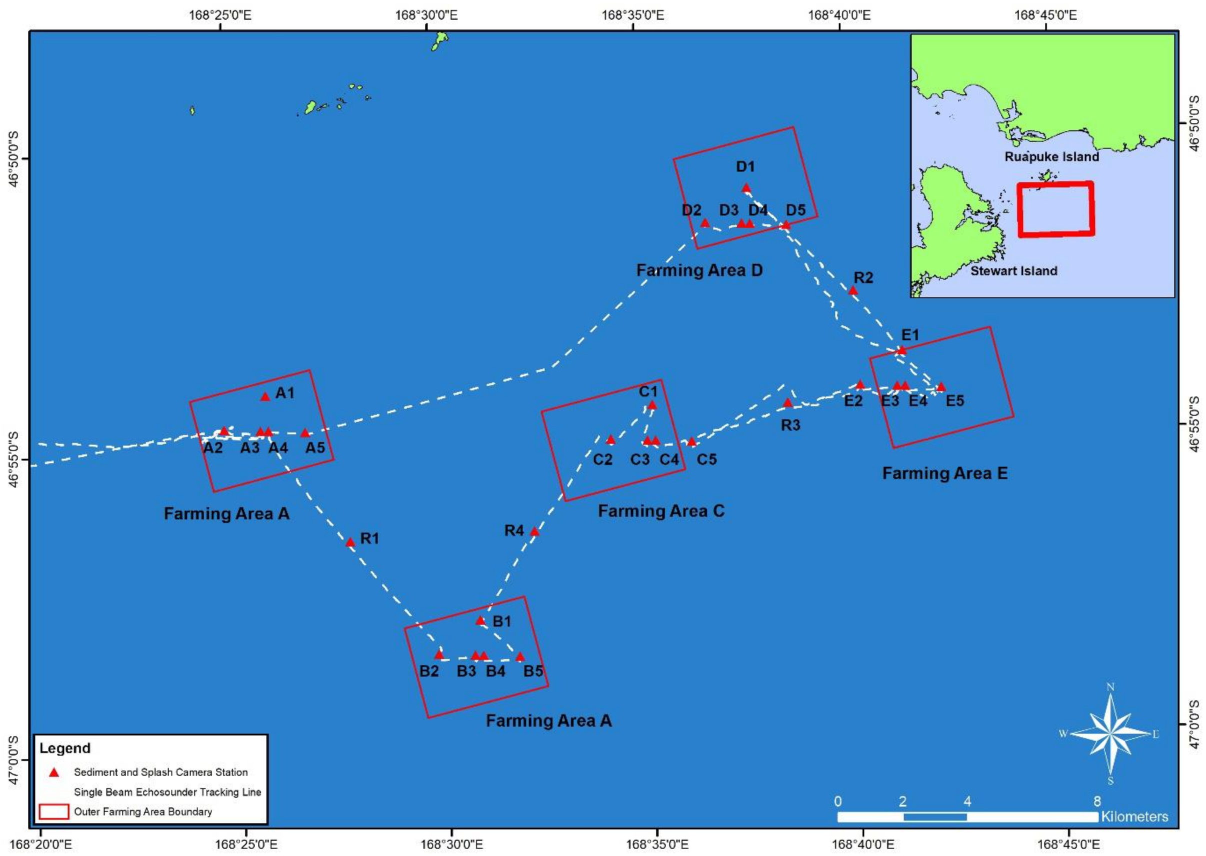


Figure 18. Sampling station locations for sediment samples, drop camera and video transects at and near each of the five proposed farm sites as well as four additional sampling stations. The white dashed line represents the path of the Single Beam Echo Sounder survey. Source: ADS (2019a).

The findings from the recent survey can be summarised as follows:

- The Single Beam Echo Sounder survey demonstrated that the seabed surface morphology is low relief (a few cm) sand waves with mud or shell hash deposits in the troughs. No abrupt changes in the seabed bathymetry were observed;

- Qualitative sediment assessments indicate that sediments in the area and in the farming areas comprise mostly sand, occasionally mixed with mud or shell hash. Grain size analysis of a sample collected under proposed Farming Area A confirmed that the sediment at this location was predominantly coarse (44.9%) and very coarse (24.3%) sand, with the remaining fractions being medium sand (13.0%), particles larger than 2 mm (11%) and only small proportions of fine grained sediment fractions (0.2% fine sand and 6.6% mud);

- Drop camera and video footage collected from the 29 sampling stations demonstrated:

    - Sparse epifauna comprising:

        - A few *Ophiopsammus maculate* (brittle star) and other sea stars on the seabed around the west and northern part of the application site;

        - Oysters and other bivalves in the eastern part of the application site;

        - Crinoids in the eastern part of the application site;

        - Sea urchins around the western end of the application area;

        - Solitary ascidians in the shallower area to the east and northern part of the application site; and

        - A number of anemones throughout much of the application site.

    - No indications of biogenic reefs in the vicinity of the application site.

- Infauna analysis showed that while there were differences between sites and there were sites with higher infauna abundance and richness than others, abundance and diversity were low relative to elsewhere and that overall there was little difference among the sampling sites; and

- No other notable seabed features, such as large rocky outcrops were detected.

Overall the seabed in the application site is relatively homogeneous comprising sand, occasionally mixed with mud or shell hash. It has a sparse epi- and infauna and low ecological diversity. It does not contain any of the ecologically sensitive habitats that have been found in Foveaux Strait, such as bryozoan reefs or oyster reefs.

Importantly, despite being predicted as suitable habitat for bryozoan species by Wood *et al.* (2013, **Figure 14**), it appears that the application site does not actually contain such habitat.

2.6 Fish populations

2.6.1 Demersal fish

Information about fish distribution in Foveaux Strait is limited because there has been relatively little fish survey effort in this area (Middleton, 2019). However, recent work by Stephenson *et al.* (2019) classified demersal fish in order to capture fish distribution and spatial variation in New Zealand's continental shelf waters. Foveaux Strait was placed in group 24 and the application site is at the boundary of this group, group 25 and group 26. These classes extend up the east coast of the South Island and around the Chatham Islands (**Figure 19**). Groups 24 and 26 belong to a category referred to as "intermediate – shallow depth groups south of the Subtropical Front" and were characterised by "locally strong tidal currents, high seabed roughness and highly oxygenated but low productivity waters" (Stephenson *et al*. 2019). Key species likely to be found around the application site are spiny dogfish (*Squalus acanthias*) and barracouta (*Thyrsites atun*) and with relatively high occurrences[2] of terakihi (*Nemadactylus macropterus*), red cod (*Pseudophycis bachus*), elephantfish (*Callorhinchus milii*), red gurnard (*Chelidonichthys kumu*) and hāpuku[3] (*Polyprion oxygeneios*), as well as ling (*Genypterus blacodes*), hāpuku, red cod, witch (*Arnoglossus scapha*) and tarakihi in places (Stephenson *et al*. 2019).

Stephenson *et al*. (2019) described the species in these groups as follows:

> "Most of these species are predatory carnivores that feed on a range of prey including fish, squid and crustaceans. Tarakihi are an exception, feeding predominantly on benthic invertebrates that they obtain by foraging in soft sediments on the seabed. Spiny dogfish and barracouta rove widely through the water column, whereas hāpuku,

[2] Additional species listed in decreasing mean frequency of occurrence in demersal fish records.
[3] Referred to as Groper in the South Island

tarakihi and red cod are usually more demersal in behaviour, associating more strongly with the seabed."

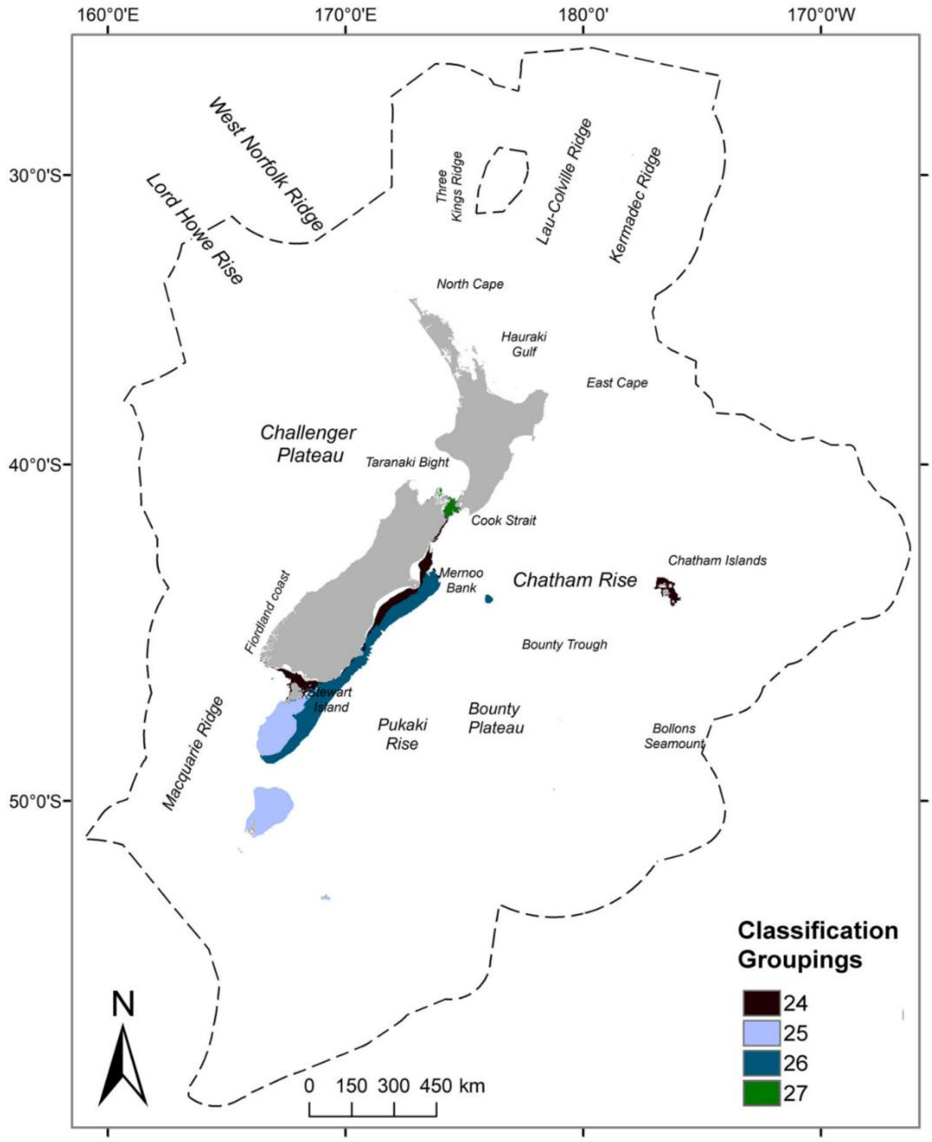


Figure 19. Geographic extent of groups 24 to 27 of the demersal fish classification of New Zealand continental shelf waters shallower than 2000 m. Source: Stephenson *et al.* (2019), Figure 7.

2.6.2 White sharks

White sharks were protected in New Zealand waters in 2007. Francis *et al*. (2015) surveyed white sharks in north eastern Stewart Island to identify their temporal and spatial patterns of occupancy. They found that white sharks were present in Foveaux Strait almost continuously from late summer to early winter, particularly from March to June, and for the remainder of the year were migrating to the tropics. The Titi Islands were identified as a focus of attention for white sharks in the north-eastern Stewart Island and Foveaux Strait region and Francis *et al*. (2015) also commented that it is possible that the abundance of white sharks at Ruapuke Island were underestimated because of the methods used. Overall, subadult and adult white sharks were found to aggregate in areas that provided feeding opportunities provided by fur seal rookeries and haul out areas (Middleton, 2019). Fur seal colonies were present in multiple parts of Ruapuke and adjacent small islands as well as other parts of Stewart Island, many of which were not investigated by Francis *et al*. (2015).

White sharks are susceptible to capture by set nets and a survey of bycatch data by Francis (2017) indicated that Foveaux Strait is one of three regions in New Zealand that accounted for 89% of white sharks reported caught by set net vessels. White shark captures are concentrated along the north-eastern side of Stewart Island and throughout Foveaux Strait, including one white shark caught south-east of Ruapuke Island (Francis, 2017; **Figure 20**).

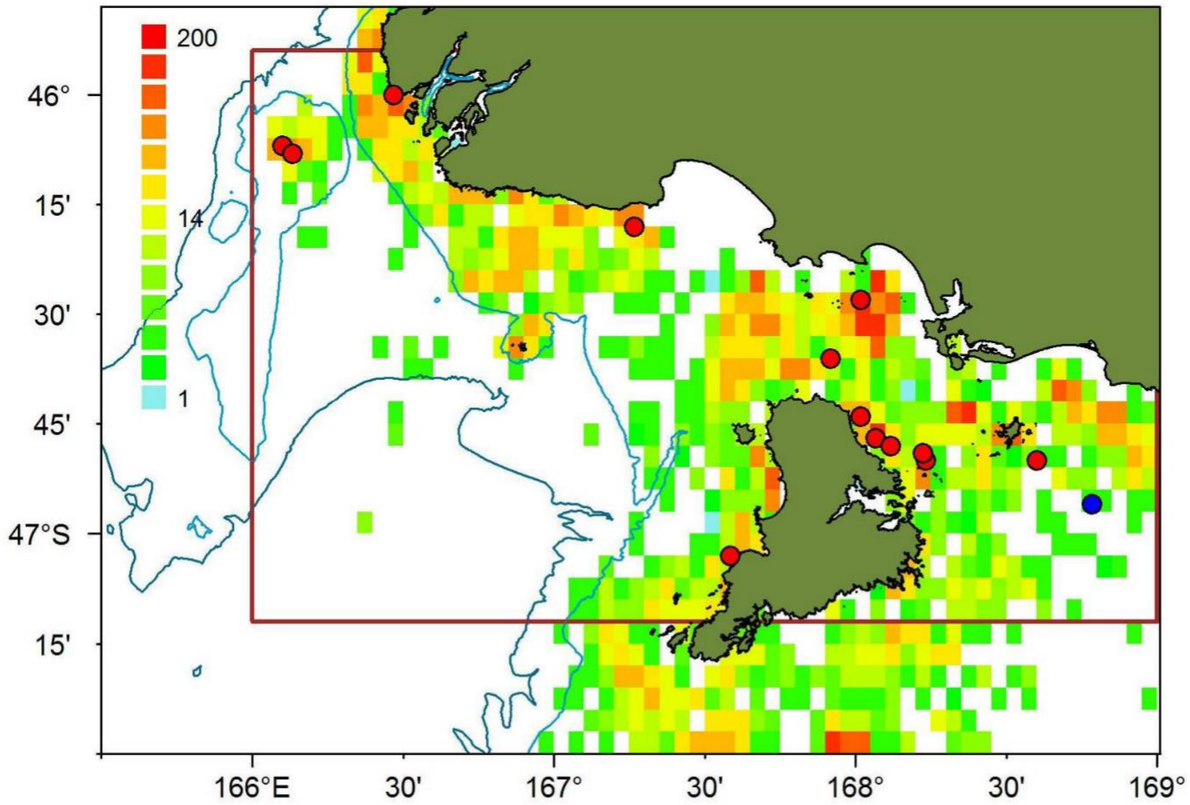


Figure 20. Fishing effort (colour scale, total length of net set from 2010 to 2016 in kilometres on a log scale) and locations of white shark captures by set net (red circles) and trawl (blue circle). Source: Francis (2017), Figure 3.

2.6.3 Commercial fisheries

The commercial fisheries in Foveaux Strait, including the application area, have been described in a report by Middleton (2019) prepared to inform this AEE. The findings of this report are summarised here.

2.6.3.1 Finfish fisheries

The application site is located in Ministry of Fisheries General Statistical Area 025 (**Figure 21**). Based on fishing effort, the most important fisheries in this area are cod potting, bottom trawling and set netting (**Figure 22**).

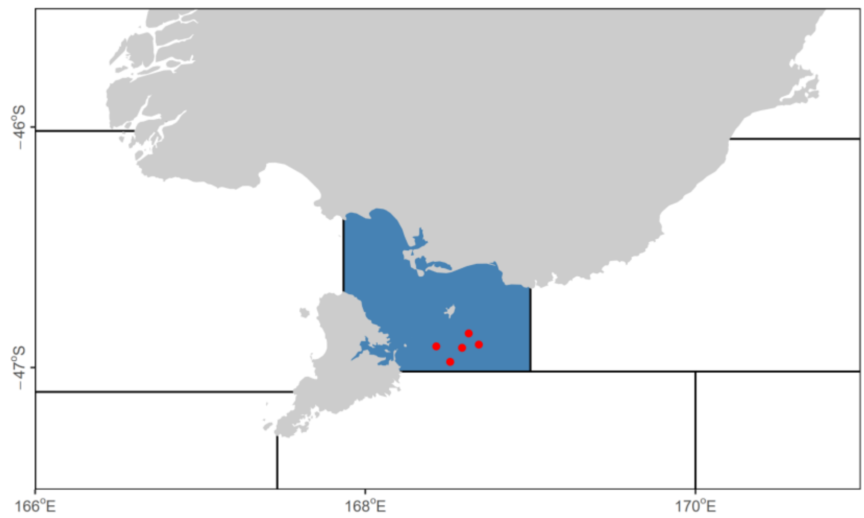


Figure 21. Foveaux Strait with Statistical Area 025 highlighted, and the location of the proposed five farms indicated by red points (note that these points indicate location only and are not to scale). Source: Middleton (2010).

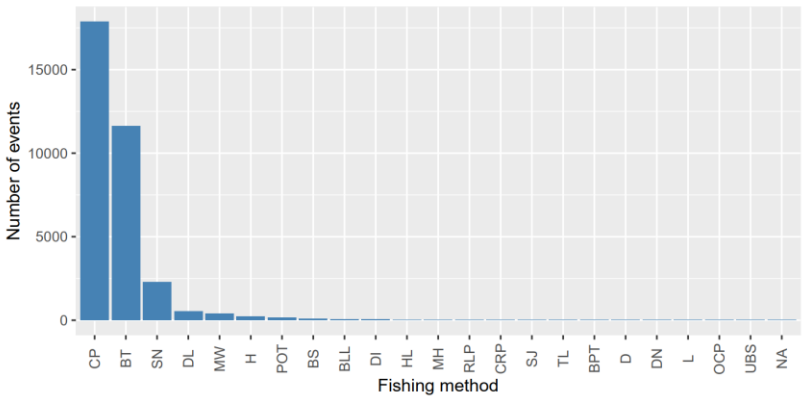


Figure 22. Fishing methods reported in area 025 from 2009/10 to 2018/19. Statutory reporting codes of the fisheries with greatest effort are: CP = cod potting, BT = bottom trawl – single and SN = set netting (including Gill nets). POT is a non-statutory code, assumed to indicate cod potting. Other codes are defined in Middleton (2010). Source: Middleton (2010).

Cod pot fishery

The cod pot fishery is a target blue cod fishery with only limited bycatch of other species. Blue cod catch and effort in the pot fishery have declined over the last decade. **Figure 23** shows the annual blue cod catch between 2009 (~700 t) and 2018 (~430 t).

No spatial resolution of fishing locations within Statistical Area 025 is available. However, effort location data are available from a subset of 18 vessels that participated in a diary programme from 2009 to 2011 (**Figure 24**). Although not necessarily representative of the whole cod fishery, they indicate that the application site is outside the main areas fished.

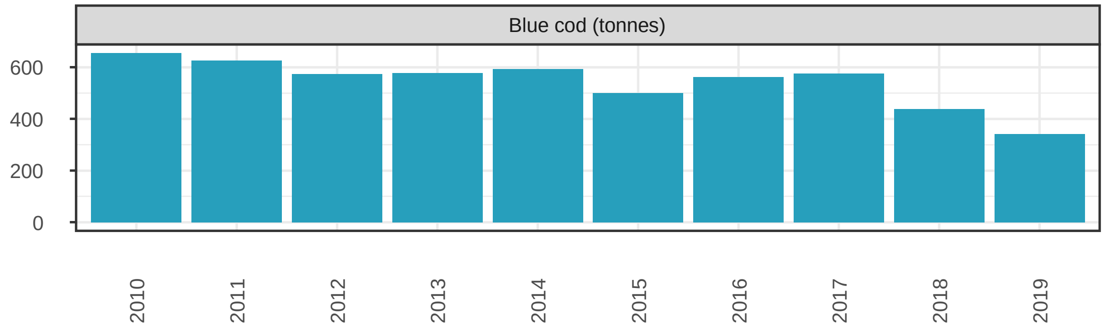


Figure 23. Annual blue cod catch by cod potting (method codes CP or POT) in statistical area 025 from 2009/10 to 2018/19. Fishing years are indicated by the later year; for example, 2010 represents the 2009/10 fishing year. Source: Middleton (2010).

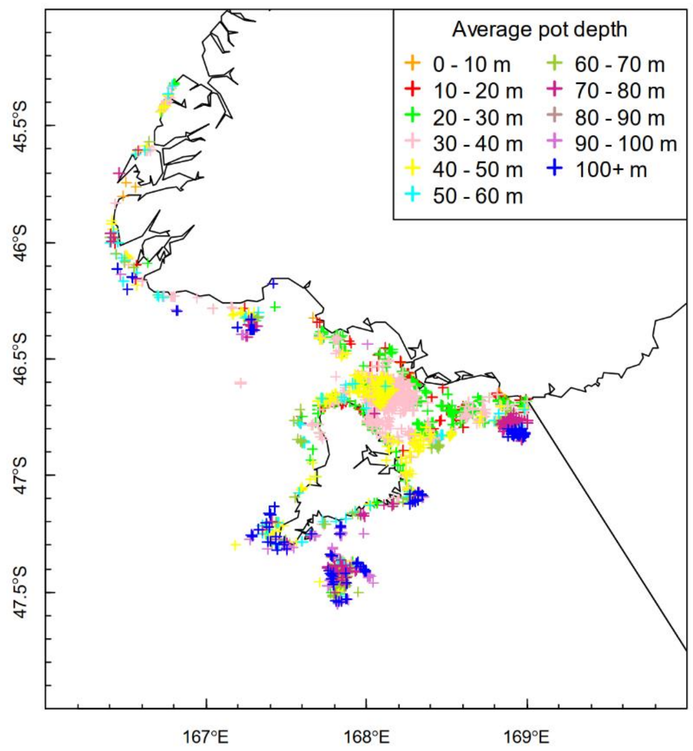


Figure 24. Fishing depth and location reported by 18 fishers from 2009 to 2011. Source: Middleton (2010).

Bottom trawling

Bottom trawling catches a range of species, with barracouta the dominant species landed, followed by flatfish, blue warehou, spiny dogfish, gurnard and stargazer (**Figure 25**). The trawl depth for the key target species is shown in **Figure 26**.

The start position of all bottom trawls has been recorded, so that they could be mapped within Statistical Area 25 (**Figure 27**). The highest catches of barracouta (BAR) and spiny dogfish (SPD) are taken to the south-east of the application site, while the greatest catches of elephant fish (ELE) are taken to the north of the proposed farms. The highest catches of flatfish (FLA) and gurnard (GUR) are also taken to the north of the application areas but moderate catches of both these stocks are taken in cells that overlap with the area. The greatest overlaps between standardised catch and the application site occur for red cod (RCO) and stargazer (STA). Catches of blue warehou (WAR) are patchier but the application site overlap with the area where the greatest catches of these species have been taken.

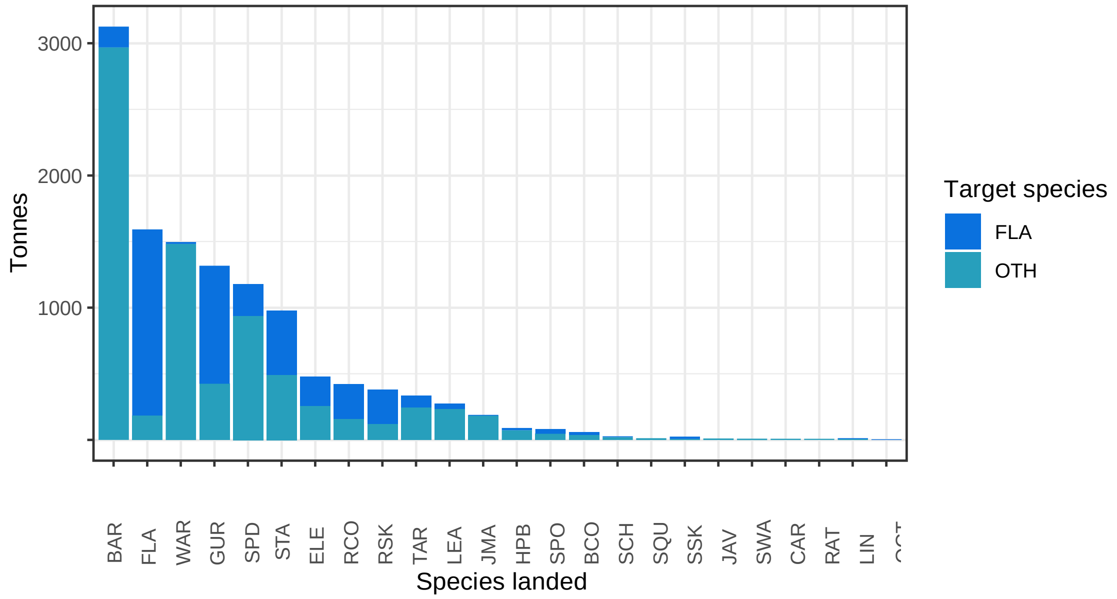


Figure 25. Catch by species by bottom trawling in statistical area 025 from 2009/10 to 2018/19, for species with aggregate landings of at least 5 tonnes in this period. Statutory reporting codes are defined in Middleton (2010). Catches are categorised according to whether the associated fishing event was targeting flatfish (FLA) or non-flatfish (OTH) species. Source: Middleton (2010).

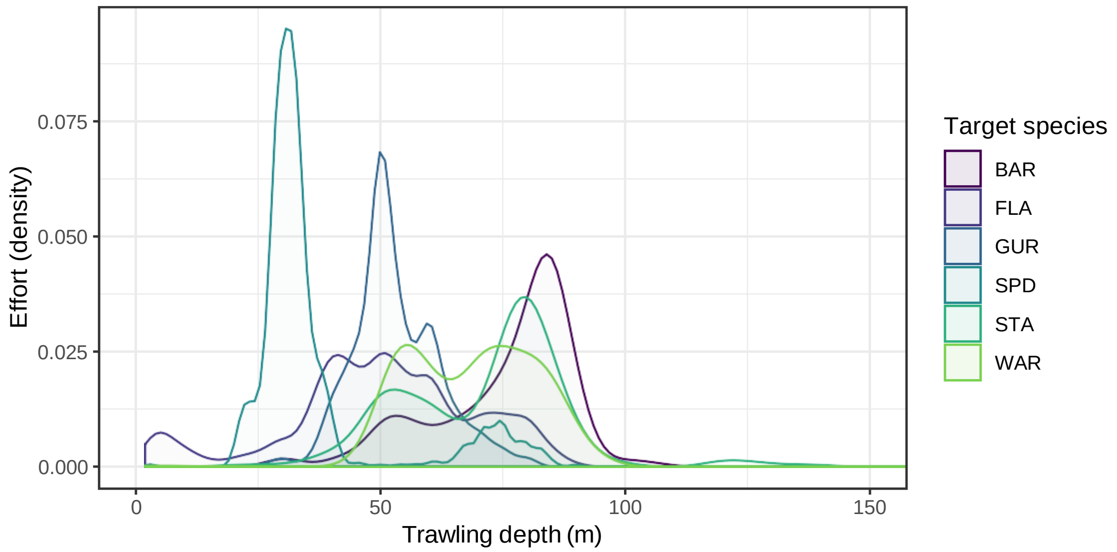


Figure 26. Trawl depth for key target species for bottom trawling in Statistical Area 025, from 2009/10 to 2018/19. BAR = barracoota, FLA = flatfish, GUR = gurnard, SPD = spiny dogfish, STA = stargazer, WAR = blue warehou. Source: Middleton (2010).

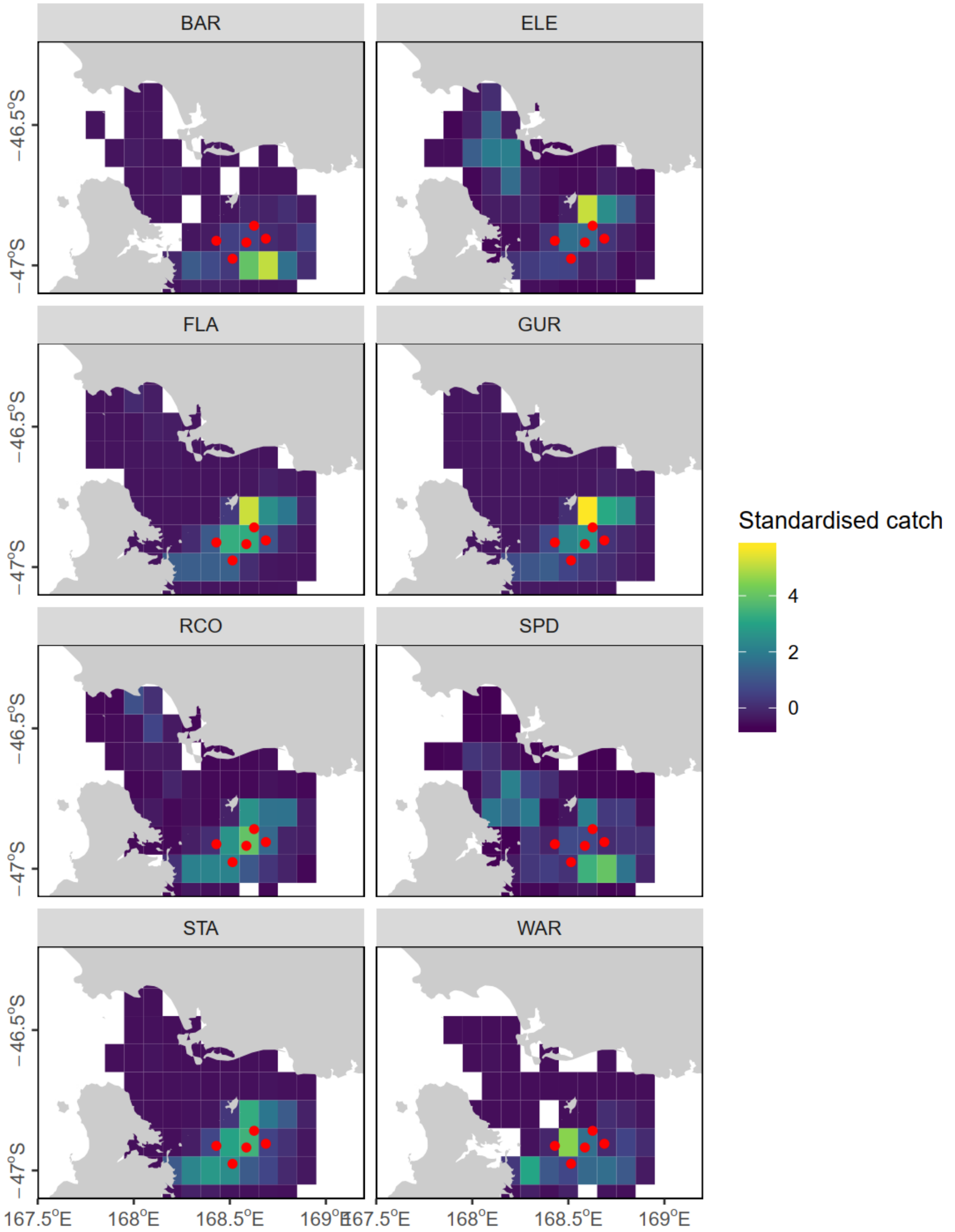


Figure 27. Standardised catch of key species taken by bottom trawl in Statistical Area 025, from 2009/10 to 2018/19. BAR = barracoota, ELE = elephant fish, FLA = flatfish, GUR = gurnard, RC = red cod, SPD = spiny dogfish, STA = stargazer, WAR = blue warehou. Source: Middleton (2010).

Set netting

Set net catches in Statistical Area 025 are dominated by inshore sharks (spiny dogfish, school shark and rig, **Figure 28**). Butterfish is the key non-shark species taken by net. Based on set net effort where fine scale spatial data are available, there is generally little overlap of set netting and the application site (**Figure 29**). Spiny dogfish and rig dominate catches in the north-west of Statistical Area 025 while the greatest catches of school shark occur east of the application area. Butterfish set net catches are localised in a small number of coastal areas.

Set net catches show little overlap with the farming areas.

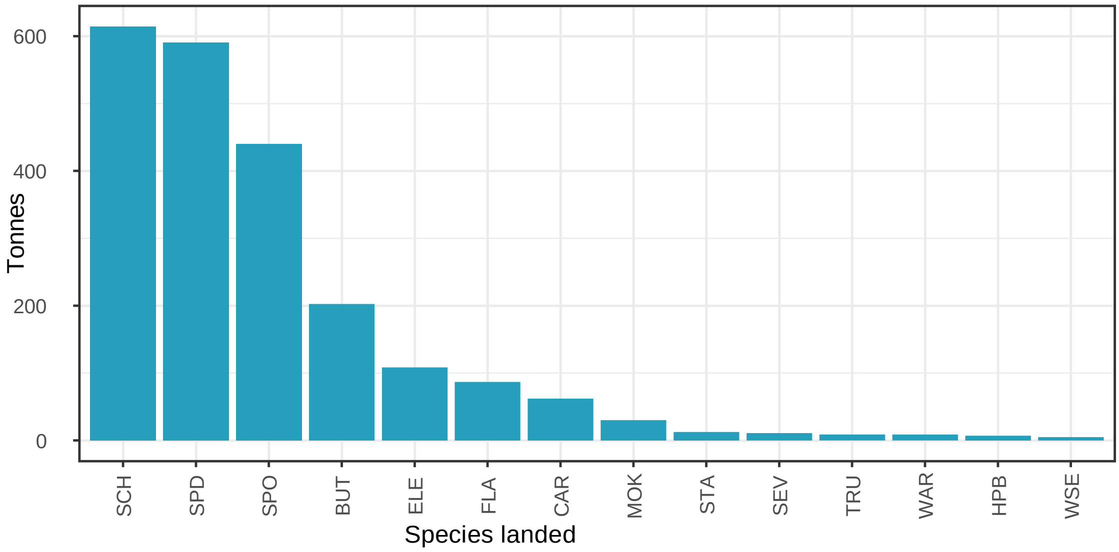


Figure 28. Catch by species by set netting in Statistical Area 025 from 2009/10 to 2018/19, for species with aggregate landings of at least 5 tonnes in this period. Most important species codes are SPD = spiny dogfish, SCH = school shark, SPO = rig, BUT = butterfish. Other statutory reporting codes are defined in Middleton (2010). Source: Middleton (2010).

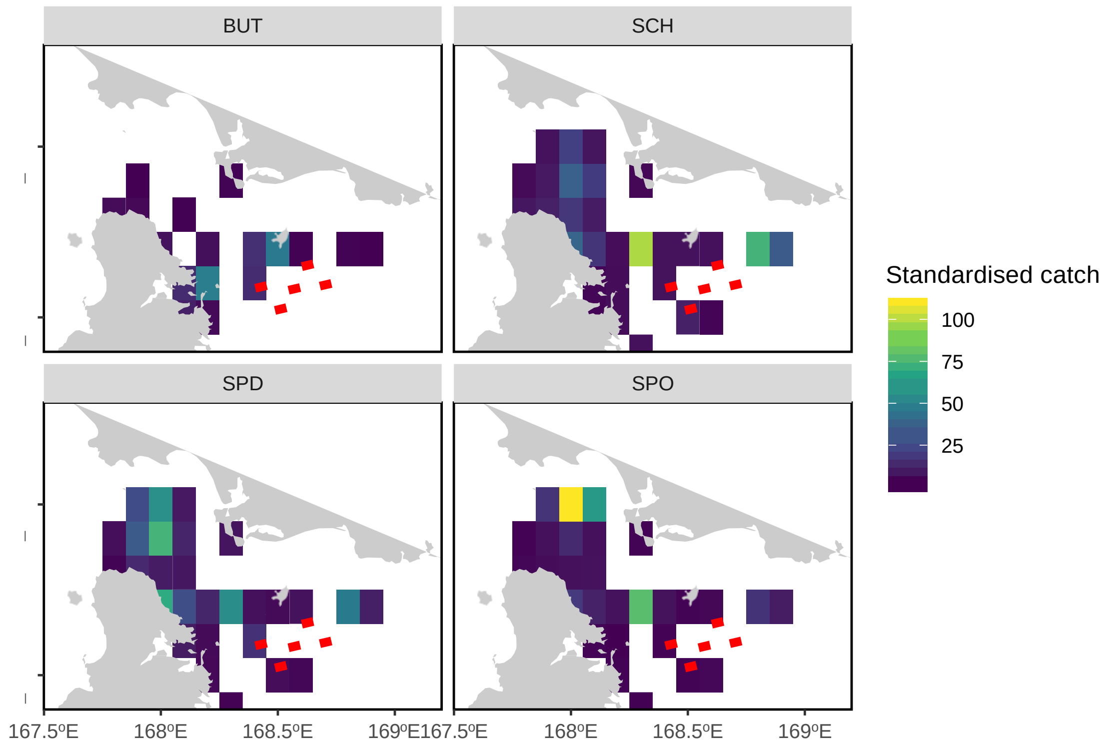


Figure 29. Standardised catch of key species taken by set net in Statistical Area 025 from 2009/10 to 2018/19. Species codes are SPD = spiny dogfish, SCH = school shark, SPO = rig, BUT = butterfish. Source: Middleton (2010).

2.6.3.2 Non-finfish fisheries

The major non-finfish fisheries (i.e. oysters, paua and rock lobster) have species-specific statistical areas.

Oyster fishery

Oyster catch has increased over the past decade (**Figure 30**). Foveaux Strait comprises several oyster statistical areas and the largest catches have come from the central part of the Strait between Steward Island and Ruapuke Island (**Figure 31**). The application site is entirely outside the area where the oyster fishery operates.

Paua fishery

Paua catch from statistical areas in Foveaux Strait has been reasonably stable over the past decade (**Figure 32**). The largest catches have come from the northern paua statistical area in the east and west of the Foveaux Strait, with catches fairly evenly spread along the paua statistical areas off the coast of Steward Island (**Figure 33**). While moderate catches of paua are reported from the statistical areas overlapping the application site, it is likely that these catches are actually taken from coastal areas only with no actual overlap between the paua fishery and the application site.

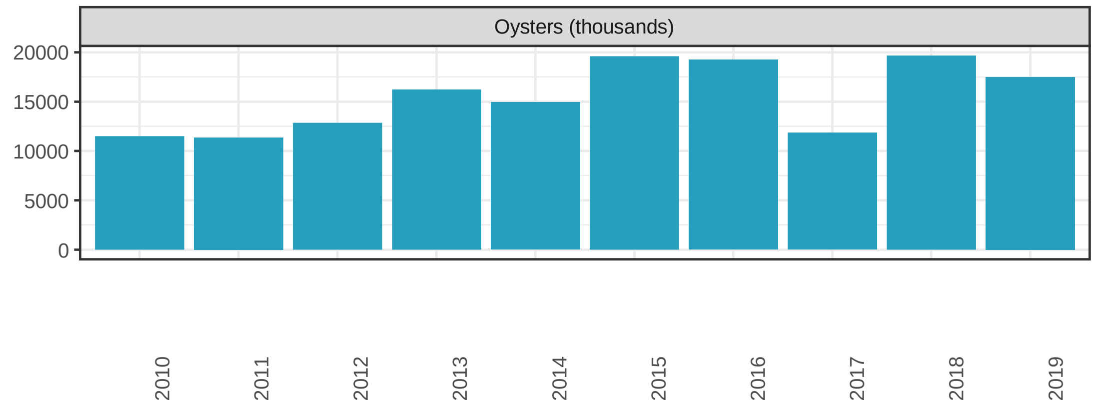


Figure 30. Annual oyster catch by dredging in Foveaux Strait from 2009/10 to 2018/19. Fishing years are indicated by the later year; for example, 2008 represents the 2007/08 fishing year. Source: Middleton (2010).

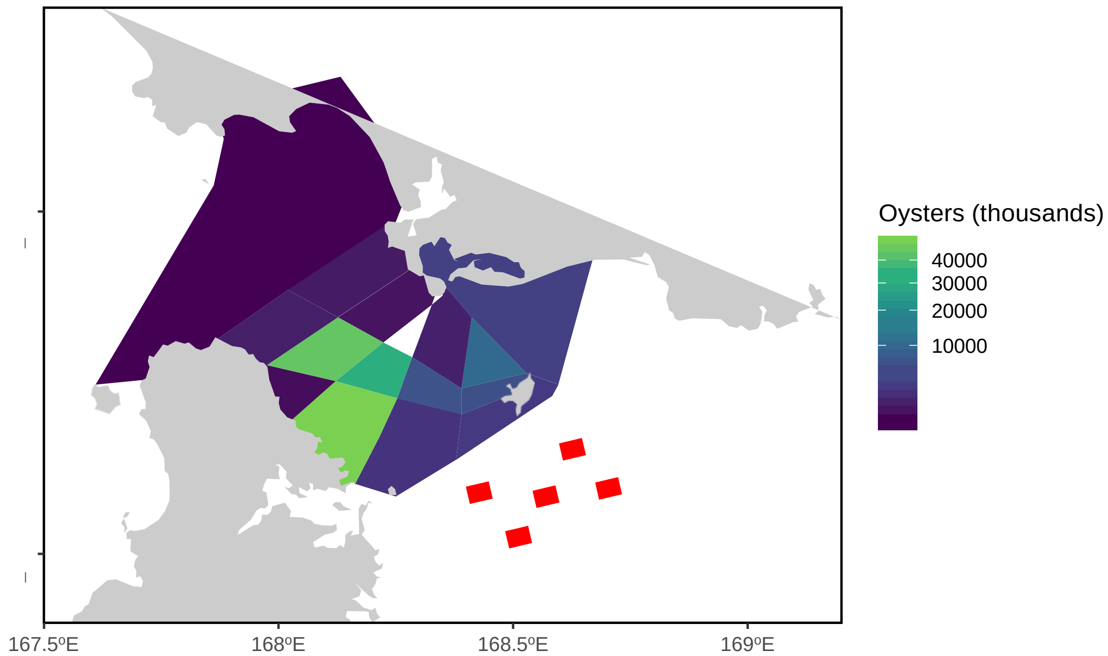


Figure 31. Oyster catch by statistical area in Foveaux Strait from 2009/10 to 2018/19.

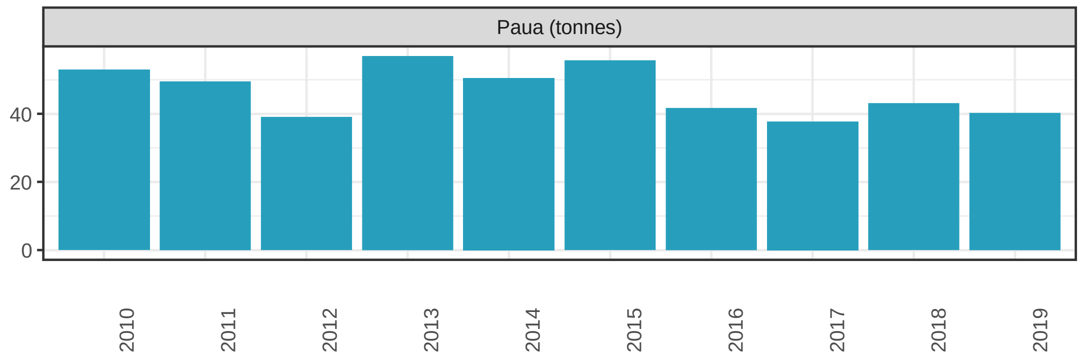


Figure 32. Annual paua catch by dredging in Foveaux Strait from 2009/10 to 2018/19. Fishing years are indicated by the later year; for example, 2008 represents the 2007/08 fishing year. Source: Middleton (2010).

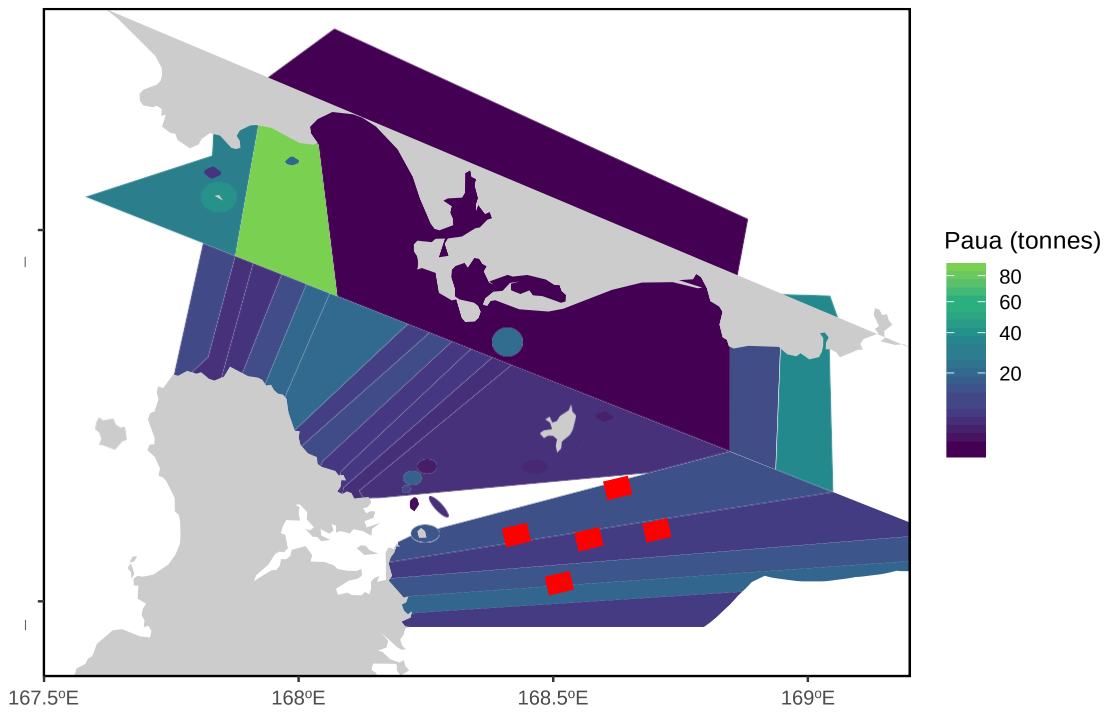


Figure 33. Paua catch by statistical area in Foveaux Strait from 2009/10 to 2018/19.

Lobster fishery

The lobster fishery has been quite stable over the last decade, although an increase in catch is evident in the last four years (**Figure 34**). Foveaux Strait falls in just three lobster statistical areas with the greatest catches coming from rock lobster statistical area 925, which is off the north-east coast of Steward Island (**Figure 35**). The application areas mostly lie within the lobster statistical area with intermediate catches but this area is large and it is unclear how much catch is actually taken in the application areas. Again, most of this catch is likely to be inshore close to islands and reefs and not in the application site.

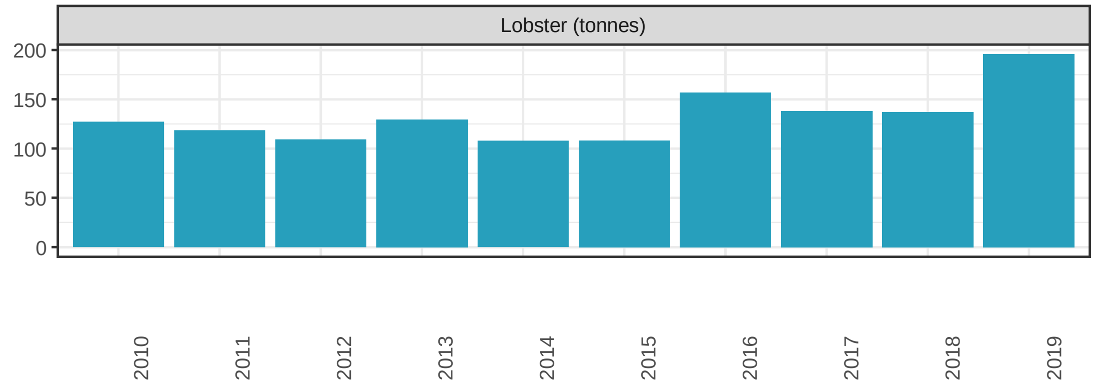


Figure 34. Annual lobster catch by dredging in Foveaux Strait from 2009/10 to 2018/19. Fishing years are indicated by the later year; for example, 2008 represents the 2007/08 fishing year.

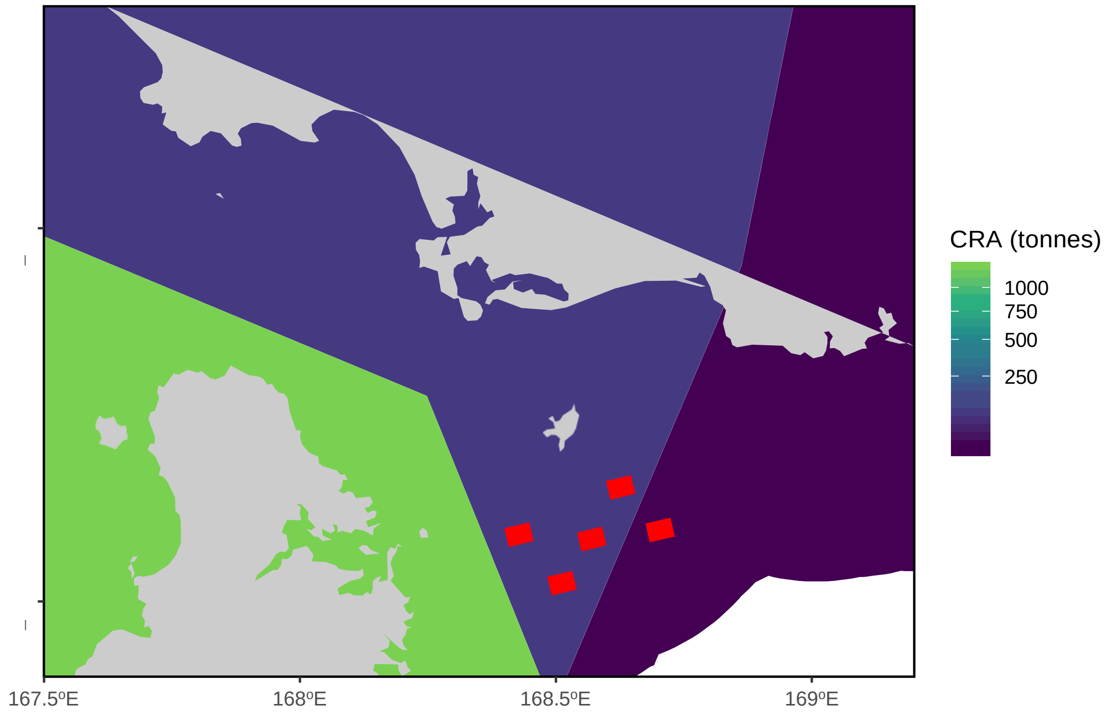


Figure 35. Lobster catch by statistical area in Foveaux Strait from 2009/10 to 2018/19.

2.6.4 Recreational fisheries

Foveaux Strait is within the Southland Fisheries Management Area, FMA 5. The 2017-18 National Panel Survey of Marine Recreational Fishers demonstrated that FMA 5 has the lowest number of fishers and recreational fishing trips of all the mainland New Zealand FMAs (FMA 4, the Chatham Islands, was no included in the survey), although it is one of only two areas where an increase in numbers of recreational fishers was estimated since the 2011-12 survey.

Key recreational fishing methods in FMA 5 are rod and line fishing and hand-gathering, especially by diving. While rod and line fishing are the dominant method used, net, pot and dredged fishing by recreational fishers are proportionally more important in FMA 5 than other areas. Of the finfish species harvested by recreational fishers, blue cod is the dominant species harvested (the 2017-18 estimate is 139,176 fish, or 66.86 tonnes), followed by sea perch (13.22 t) and trumpeter (over 27,000 fish), then flatfish, butterfish and blue moki (7,000-9,000 fish). Oysters and paua (approx. 30t) are the key non-finfish species harvested, followed by mussels and crayfish (40.96 t).

There is only limited information available on the spatial distribution of recreational fishing within FMA 5 and the information available does not provide any information about fishing in the application areas.

2.7 Seabirds

Foveaux Strait and the Ruapuke area supports a diverse, abundant seabird community with most inshore and offshore islands, and much of the Stewart Island coastline, supporting breeding colonies of numerous seabird species. The importance of the area is demonstrated by the identification of multiple Important Bird Areas for seabirds, both on land and at sea.

In a report prepared to inform this AEE (McClellan *et al*. 2019), the seabird community of the Foveaux Strait region was described from a combination of eBird (eBird global database, Cornell Lab of Ornithology) and fisheries observer (Ministry for Primary Industries) data, combined with breeding colony data compiled for the Important Bird Area (IBA) project (BirdLife International/Forest & Bird) and the National Aquatic Biodiversity Information System (NABIS) database (Ministry for Primary Industries). These data are described in this section, much of it taken directly from the report by McClellan *et al*. (2019) and general descriptions for birds from James *et al*. (2019).

2.7.1 Seabirds in the Foveaux Strait region

A map of the locations of eBird and fisheries observer records is shown in **Figure 36**. To select records most relevant for the application areas, a subset of the full area was identified (referred to as 'small extent' in **Figure 36**). Separate polygons were created to evaluate the records in Foveaux Strait ('Foveaux Strait'), two kilometres off the shore of the mainland ('Mainland coastal'), and two kilometres off the shore of Stewart Island ('Rakiura coastal').

Using observer records create some uncertainties in the data. Briefly, many observations only record the presence of a species rather than a count of numbers seen. In such cases, the observation was included as a single bird. As a consequence, actual numbers will be underestimates. Also, the two datasets show distinctly different populations of seabirds. eBird data include approximately 65 taxa, whereas the fisheries observer data is limited to only 18 taxa, which generally show strong attraction to commercial fishing vessels, mostly albatross taxa, sooty shearwater, and cape pigeon. While these aspects create some uncertainty about the number of birds, this was addressed by assessing a relatively large spatial area around the application areas. The resulting data set is considered robust enough to describe seabird distributions in the area of interest at an appropriate level of accuracy.

These data have been used to describe 'at sea' seabird diversity and abundance. They were also used to identify seabird breeding locations alongside a comprehensive collection of additional information sources (described in McClellan *et al.* 2019). Seabird colony maps indicative of the distribution of breeding locations are shown in **Figures 37** to **40**.

The seabird species recorded in the area shown as 'small extent' in **Figure 36** are described below. Each species' threat status is provided in parentheses. A summary of all at risk and threatened seabird species is provided in **Table 4**. Tables showing the number of species and a break-down by the three zones shown in **Figure 36** are provided in McClellan *et al*. (2019).

Penguins

Five species of penguin have been recorded in the Foveaux Strait region. Three species are commonly observed: blue penguin (At Risk-Declining), yellow-eyed penguin (Threatened-Nationally Endangered), and Fiordland crested penguin (Threatened-Nationally Vulnerable). All three species have extensive breeding distributions in the region, shown in **Figure 37**.

The little blue penguin is the smallest species of penguin, and populations are found around the New Zealand and the Chatham Islands coastlines. They nest along the coastline in burrows in banks. Their population is estimated to be 350,000 - 600,000 globally. They feed just above or on the seafloor on cod and squid.

Yellow-eyed penguins are equally dependant on marine and land habitats. Their population is estimated to be 6,000 - 7,000, however, the number of breeding pairs is estimated at 630. They breed along the eastern and south-eastern coastlines of the South Island, as well as Stewart Island, Auckland Islands, and Campbell Islands. Yellow-eyed penguins are predominantly pelagic feeders but forage close to the seabed (Marchant & Higgins 1990, Moore 1999). They feed mainly at depths of 40-80 m on sprat, red and blue cod but some will feed closer inshore.

The Fiordland crested penguin nests in colonies along the south-west of the South Island and on Stewart Island, preferring hollows under fallen trees, roots, boulders or rock crevices on inaccessible headlands and islets. Their current population is estimated to be 2,500 - 3,000 breeding pairs. The main prey species are cod and squid.

Albatross and mollymawks

A diverse population of albatross and mollymawks is present within Foveaux Strait, as identified by both the eBird and fisheries observer datasets. The actual number of taxa recorded is not clear given difficulties with identification of certain taxa at sea, and the differences in taxonomical systems. The most common species present are shy mollymawk (often called white-capped albatross; At Risk-Declining), southern Buller's mollymawk (At Risk-Naturally Uncommon), Salvin's mollymawk (Threatened-Nationally Critical), and royal albatross (two species, both At Risk-Naturally Uncommon; sightings most likely dominated by southern royal albatross).

Shearwater, petrel and prion

Approximately 27 shearwater, petrel and prion taxa were recorded within the eBird dataset. Species with more than 100 reports were: cape petrel (probably comprising two different subspecies, one a migrant, the other At Risk-Naturally Uncommon), sooty shearwater (At Risk-Declining), Cook's petrel (At Risk-Relict), common diving petrel (At Risk-Relict), northern giant petrel (At Risk-Recovering), and fairy prion (At Risk-Relict). Of these, sooty shearwater was clearly the most numerically dominant species - reports generally comprised hundreds of birds. The other particularly abundant species was common diving petrel. Many of these species breed in the region (**Figure 38**); others breed hundreds or thousands of kilometres distant, traveling to the region to forage, or passaging to other locations.

Sooty shearwater (Māori name tītī, muttonbird) breed on islands around New Zealand but all the large colonies are around Stewart Island or on The Snares. The sooty shearwater forages widely offshore where they dive to depths of over 40 m. They feed mainly on small fish, squid, krill and other crustaceans.

Shags

Five species of shag are regularly present in the region: black shag (At Risk-Naturally Uncommon), Foveaux shag (also known as Steward Island shag, Threatened-Nationally Vulnerable), little shag (Not Threatened), pied shag (At Risk-Recovering), and spotted shag (Not Threatened). Little black shag (At Risk-Naturally Uncommon) also appears in the eBird database and has been recorded as a vagrant on Stewart Island (Armitage 2013). Foveaux shag is endemic to Foveaux Strait, and is the most commonly reported shag species in the Strait and around Stewart Island. All five species are well reported; **Figure 39** is likely to significantly underestimate breeding locations of several species.

The Foveaux shag has an estimated population of 1,600 - 1,800 breeding pairs, and breeds and roosts on steep cliffs and rugged islets. They are found from southern Stewart Island as far north as the Waitaki River. Stewart Island shags feed up to 15 km offshore and are mainly demersal feeders on small fish such as cockabullies and flatfish (Lalas 1983).

Pied shag are found around New Zealand's coastline and typically breed in coastal evergreens overhanging the sea. A national population count has not been undertaken; however, the population is estimated to be 1,000 - 5,000 mature individuals. Pied shag feed mainly on small fish and crustaceans.

Spotted shag are a sub-species found on Stewart Island and nest in colonies of up to 700 pairs. The estimated population is up to 50,000 breeding pairs. Spotted shags are also demersal feeders, feeding mainly on deep water ahuru (small cod species), sprats, and red cod.

Skuas, gulls and terns

Seventeen species of skuas, gulls and terns have been recorded in eBird. Foveaux Strait records are dominated by red-billed gull (At Risk-Declining), southern black-backed gull (Not Threatened), and white-fronted tern (At Risk-Declining). South Island coastal records include large numbers of black-billed gull (Threatened-Nationally Critical), which breed in large colonies on Southland rivers, and at some coastal sites such as the Waiau River bar; lower numbers of individuals have been recorded out at sea and around Stewart Island. Other species of note recorded in significant numbers in Foveaux Strait include the braided river specialist black-fronted tern (Threatened-Nationally Endangered), and brown skua (At Risk-Naturally Uncommon). The breeding locations of several species, such as southern black-backed gull and white-fronted tern, are likely to be significantly underestimated (**Figure 40**).

The black-billed gull is endemic to New Zealand and the majority of the population nests in Southland, with approximately 5% in the North Island, and the remainder across the rest of the South Island. Most black-billed gulls breed in large colonies on inland river beds but some will breed in coastal habitats. Their population was estimated to be 90,000 individuals in 2008 with 70% occurring in the Southland region. Black-billed gulls feed mainly on land but can also feed in coastal areas on fish and invertebrates.

The red-billed gull is the most common gull in New Zealand and is found in coastal communities around the country. They breed in dense colonies mainly along the eastern coasts of the North and South Islands on stacks, cliffs, river mouths, and sandy and rocky shores. Red-billed gulls scavenge for a wide range of food including small fish and shellfish.

The southern black-backed gull is one of the most abundant and familiar large birds in New Zealand. They are found all around New Zealand except for in forest and scrub habitats and are abundant where there is a food source. They breed throughout New Zealand with the largest breeding colonies on islands, steep headlands, sand or shingle spits, or on islands in shingle riverbeds. They are very abundant with a number of colonies with more than 100 breeding pairs and a few with more than 1000. Black-backed gulls feed on a range of foods including marine invertebrates, fish and in some cases they predate on other birds.

Australasian gannet

Australasian gannet (Not Threatened) has one breeding colony in the region on Little Solander Island; relatively low numbers of this species have been reported.

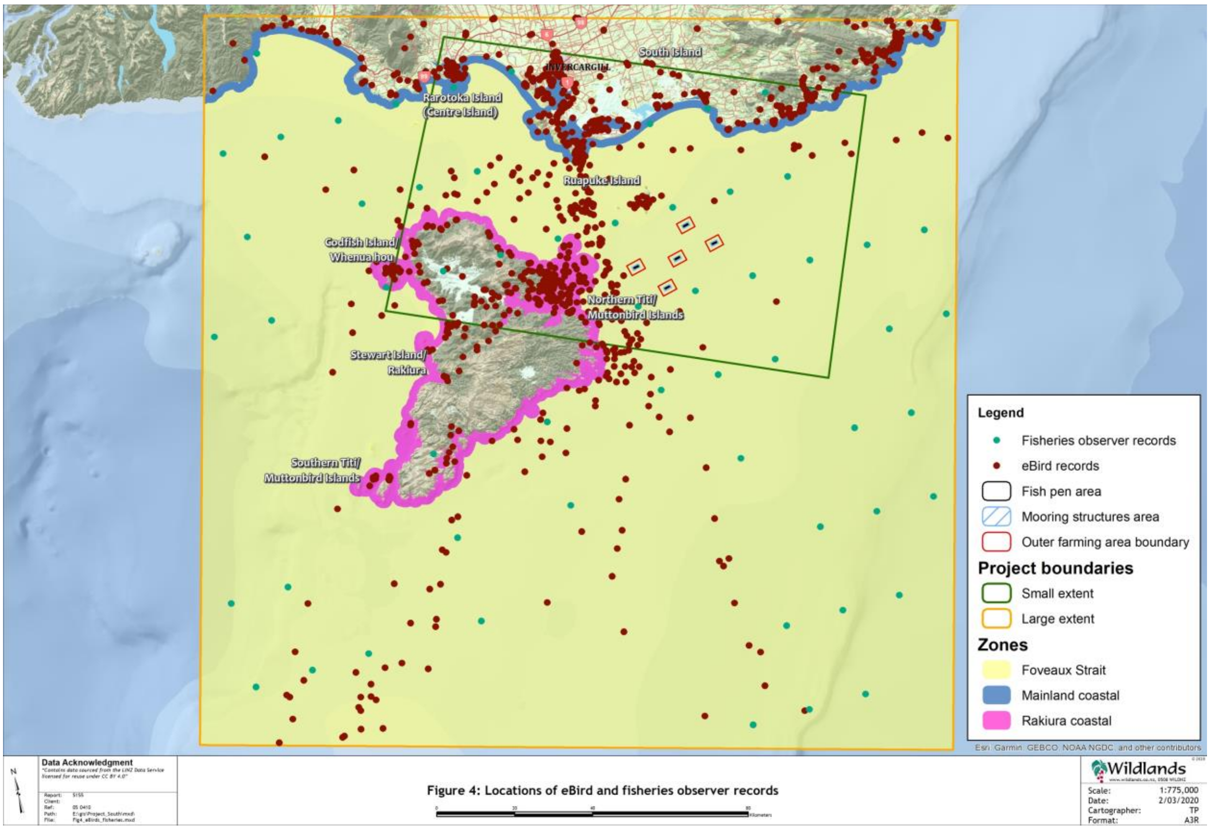


Figure 36. Location of eBird and fisheries observer records. For the description of seabirds in this AEE records were extracted from the area labelled ‘small extent’. Source: McClellan *et al*. (2019).

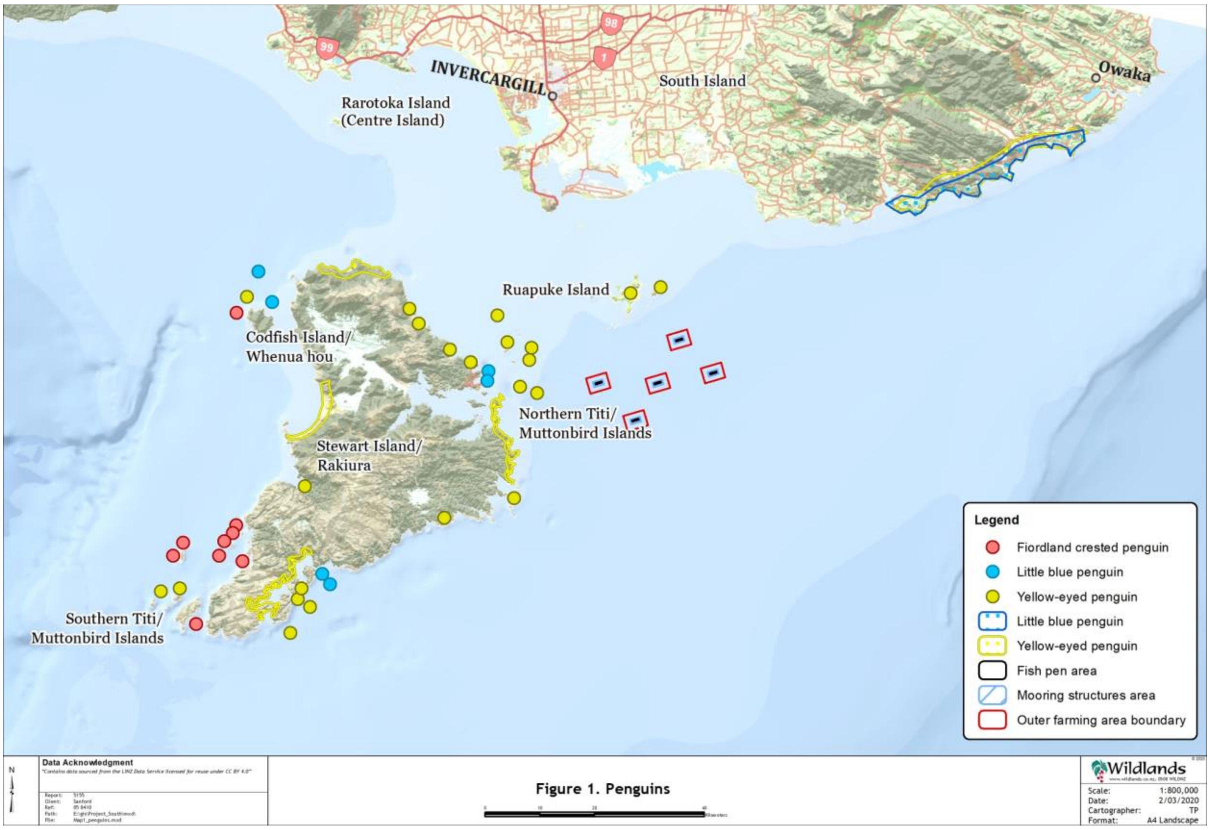


Figure 37. Penguin colonies showing indicative distribution of breeding locations. Source: McClellan *et al*. (2019).

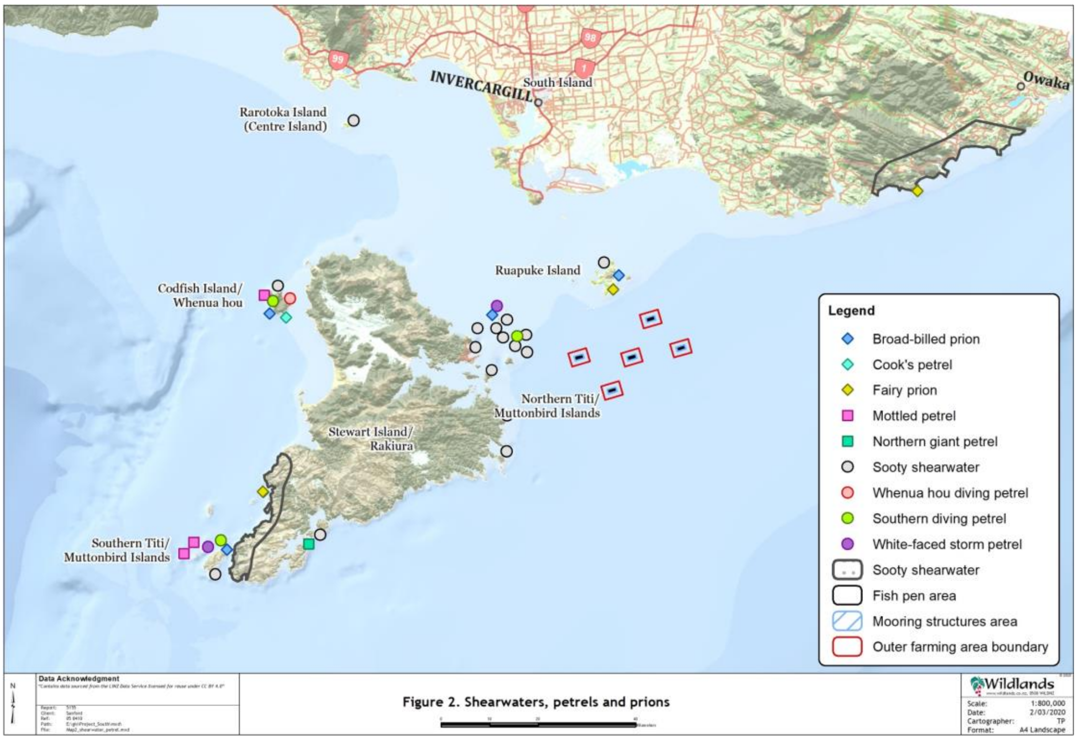


Figure 38. Shearwater, petrel and prion colonies showing indicative distribution of breeding locations. Source: McClellan *et al*. (2019).

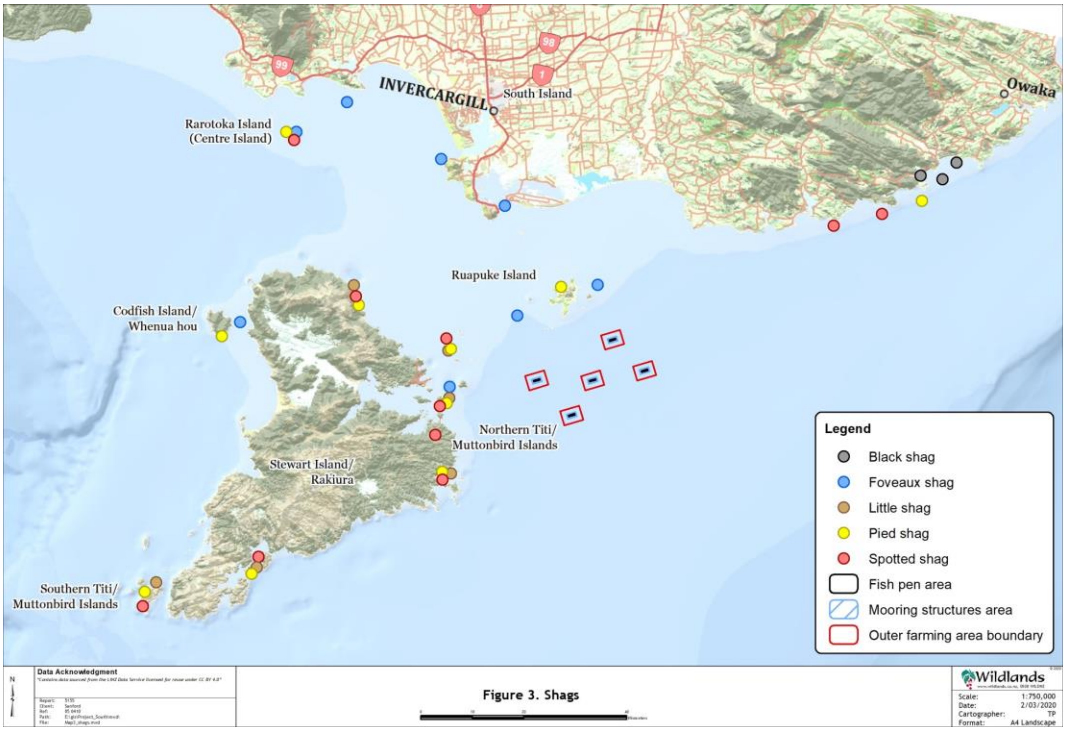


Figure 39. Shag colonies showing indicative distribution of breeding locations. Source: McClellan *et al.* (2019).

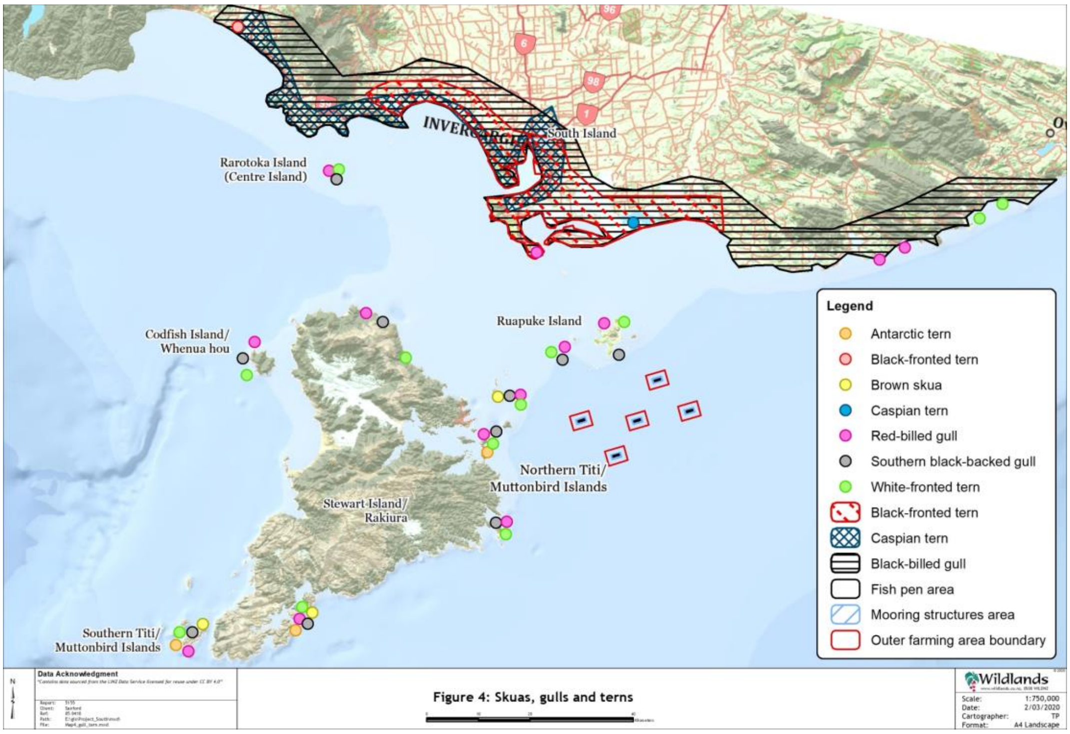


Figure 40. Skuas, gulls and tern colonies showing indicative distribution of breeding locations. Source: McClellan *et al.* (2019).

Table 4. At risk and threatened indigenous bird species in the Foveaux Strait region (in area shown as 'small extent' in **Figure B1**).

Species	**Threat status**
red-billed gull	At Risk-Declining
white-fronted tern	At Risk-Declining
Black-billed gull (*Chroicocephalus bulleri*)	Nationally critical
black-fronted tern	Threatened-Nationally Endangered
brown skua	At Risk-Naturally Uncommon
Southern blue penguin (*Eudyptula minor minor*)	At risk - Declining
Yellow-eyed penguin (*Megadyptes antipodes*)	Nationally vulnerable McClellan (2019): Threatened-Nationally Endangered
Fiordland crested penguin (*Eudyptes pachyrhynchus*)	Threatened-Nationally vulnerable
shy mollymawk (often called white-capped albatross)	At Risk-Declining
Salvin's mollymawk	Threatened-Nationally Critical
royal albatross (southern and northern)	At Risk-Naturally Uncommon
cape petrel	At Risk-Naturally Uncommon
Sooty shearwater (*Puffinus griseus*)	At risk-Declining
Cook's petrel	At Risk-Relict
common diving petrel	At Risk-Relict
northern giant petrel	At Risk-Recovering
fairy prion	At Risk-Relict
Black shag	At Risk-Naturally Uncommon
Foveaux shag (also known as Stewart Island shag) (*Leucocarbo chalconotus*)	Threatened-Nationally vulnerable
pied shag	At Risk-Recovering
Little black shag	At Risk-Naturally Uncommon

2.7.2 Important Bird Areas (IBAs)

The 'Important Bird Area' (IBA) concept was developed by BirdLife International and has been in use for over 30 years. The identification of an IBA is based on a relatively simple set of criteria[4] that can be applied both in terrestrial and marine environments. Over 12,000 IBAs have been identified worldwide. The two seabird IBA reports containing the information presented in this section are 'Sites at sea' (Forest and Bird 2014) and 'Coastal sites and islands' (Forest and Bird 2015).

Three 'Sites at sea' seabird IBAs (total of 26 in NZ) and 11 'Coastal sites and islands' seabird IBAs (140 in NZ) have been identified in the Foveaux Strait region, demonstrating the highly diverse community of seabird species in the area, as well as the abundance of seabirds.

Sites at sea seabird IBAs

The application area overlaps with two 'Sites at sea' seabird IBAs, M014 and M015 (**Figure 41, Figure 42**). The species present in the two IBAs that triggered the IBA criteria are shown in **Table 5**. These species are yellow-eyed penguin, Fiordland crested penguin, Foveaux shag, northern royal albatross, white-capped albatross, Salvin's albatross, Buller's albatross, Hutton's shearwater, sooty shearwater, Fiordland crested penguin, Southern royal albatross, Antipodean albatross, Cook's petrel and mottled petrel.

[4] Criteria are described in McClellan *et al.*. (2019)

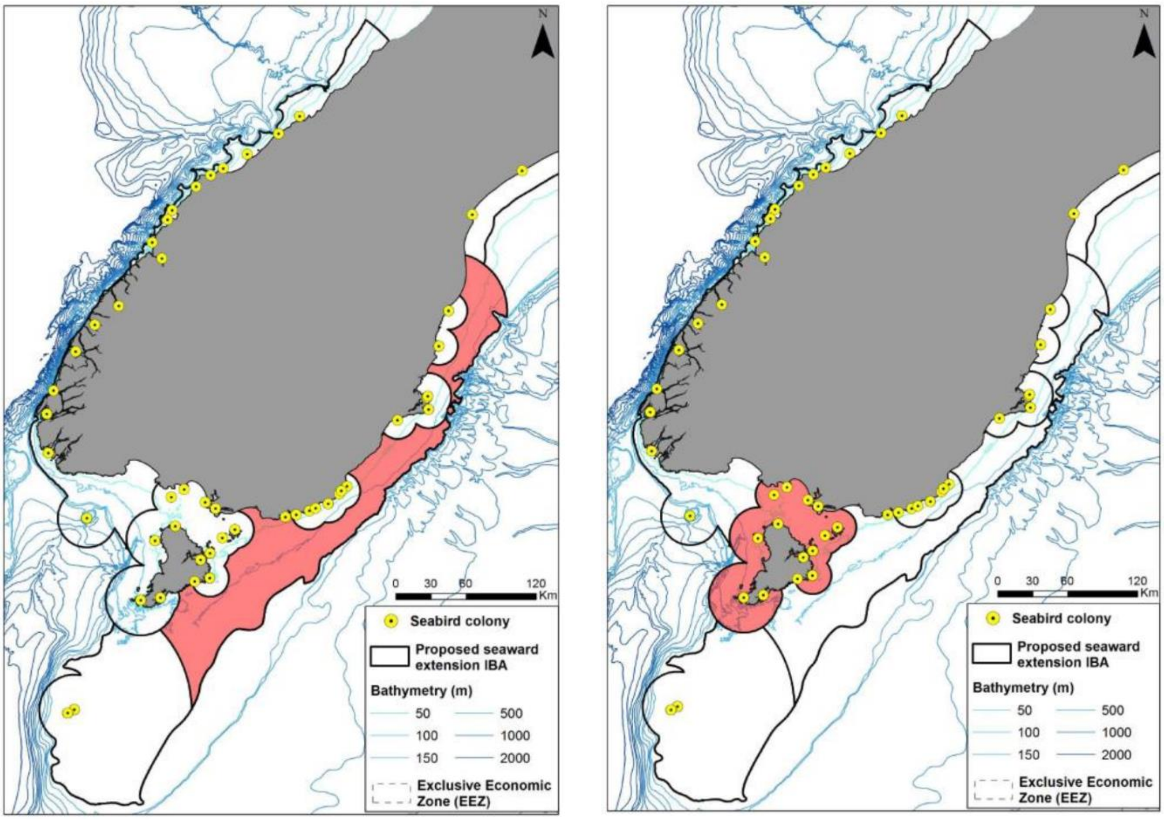


Figure 41. 'Sites at sea' seabird IBAs M014 (shaded red in the right panel) and M015 (shaded red in the left panel). Source: Forest & Bird (2014).

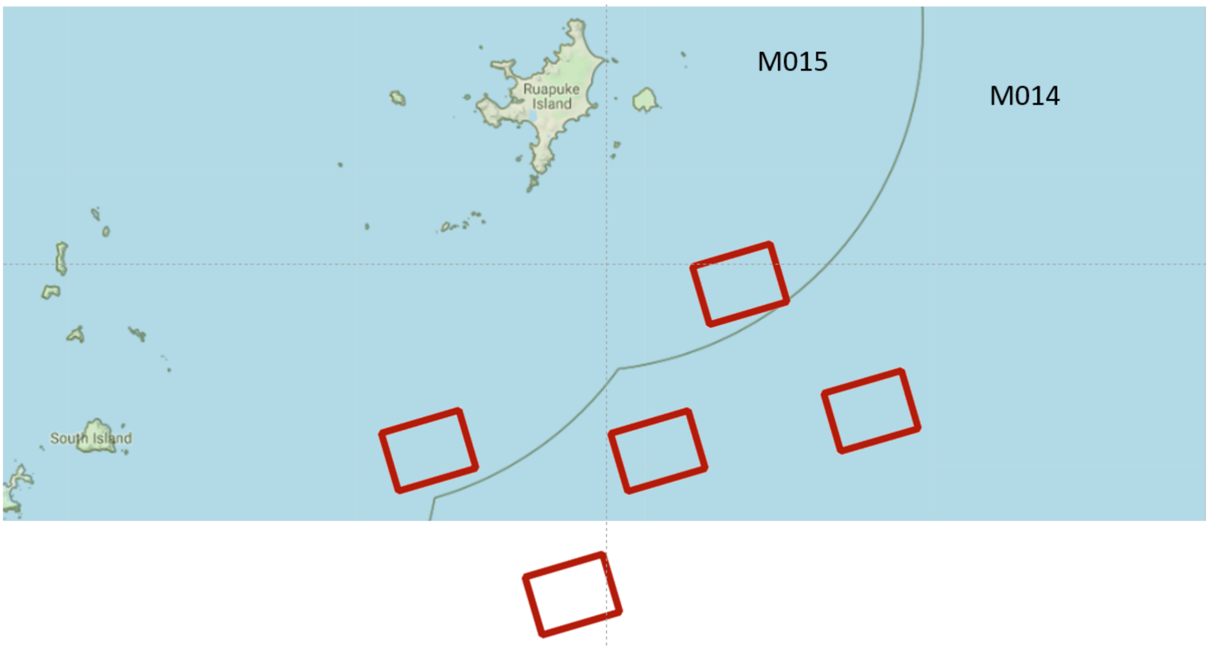


Figure 42. Indication of overlap of application area (red outline) and 'Sites at sea' seabird IBAs M014 and M015. The proposed farm areas are shown as red blocks.

Table 5. 'Sites at sea' IBAs relevant for the application are, along with a description of the species triggering IBA criteria, whether tracking data (for example, using GPS or GLS tags) support the identification of trigger species and what activities trigger species undertake in the IBA. Source: McClellan *et al*. (2019).

Important Bird Area (IBA)	**IBA Number**	**Area**	**Trigger Species**	**At Sea Tracking**	**Activity**
Southern South Island	NZ MO14	14,903 km^2	Yellow-eyed penguin	Yes	Foraging
			Fiordland crested penguin		Foraging
			Foveaux shag		Foraging, passage
			Northern royal albatross	Yes	Foraging, passage
			White-capped albatross	Yes	Foraging, passage
			Salvin's albatross		Foraging, passage
			Buller's albatross	Yes	Foraging, passage
			Hutton's shearwater	Yes	Foraging, passage
			Sooty shearwater	Yes	Foraging, passage
			Species group		
Rakiura	NZ MO15	7,811 km^2	Yellow-eyed penguin	Yes	Local foraging, passage
			Fiordland crested penguin		Foraging
			Foveaux shag		Foraging
			Northern royal albatross	Yes	Foraging, passage
			Southern royal albatross		Foraging, passage
			Antipodean albatross *	Yes	Foraging, passage
			White-capped albatross	Yes	Foraging, passage
			Salvin's albatross	Yes	Foraging, passage
			Buller's albatross	Yes	Foraging, passage

Important Bird Area (IBA)	IBA Number	Area	Trigger Species	At Sea Tracking	Activity
			Cook's petrel	Yes	Passage
			Mottled petrel	Yes	Passage
			Sooty shearwater	Yes	Foraging, passage
			Species group	Yes	

'Coastal sites and islands' seabird IBAs

The most relevant IBAs for this application are IBA NZ114 Ruapuke and NZ115 Fyfe Rock and nearby Northern Titi Muttonbird Islands (**Figure 43**). The species present in the two IBAs that triggered the IBA criteria are shown in **Table 6**. These species are yellow-eyed penguin and Foveaux shag.

The 'Coastal sites and islands' seabird IBAs are terrestrial and therefore do not overlap with the application area.

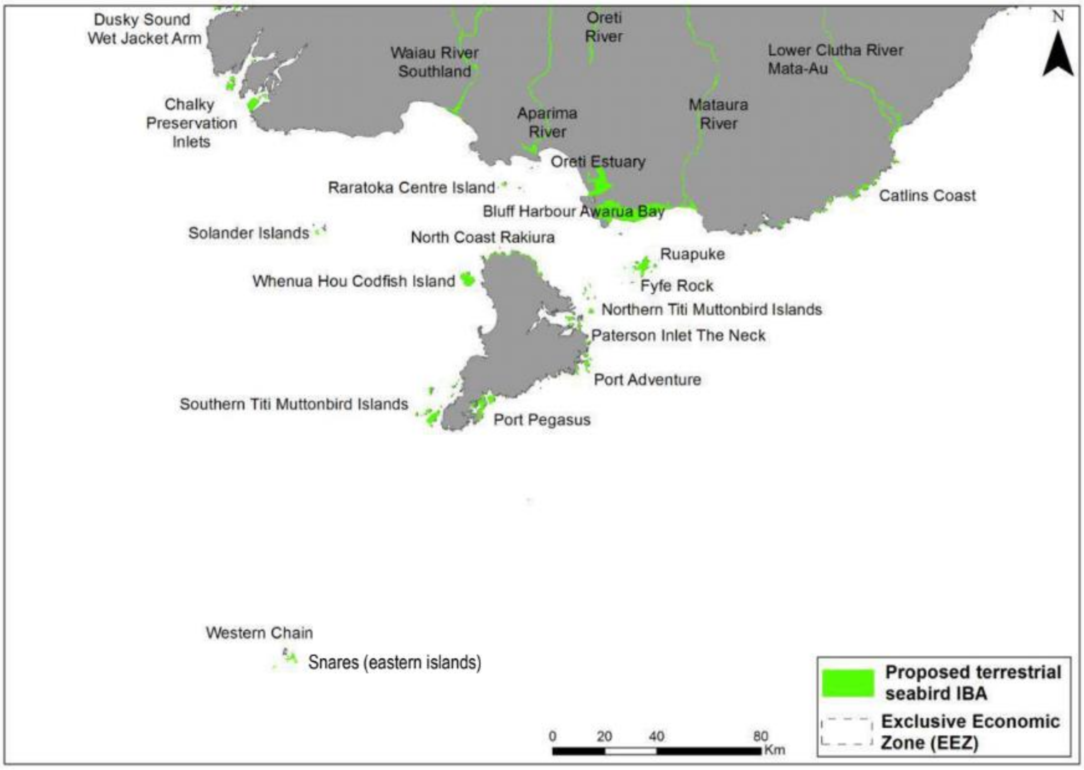


Figure 43. Coastal sites and islands' seabird IBAs in the Rakiura-Foveaux Strait region. Source: Forest & Bird (2015).

Table 6. 'Coastal sites and islands' IBAs near the application area listing the species that triggered IBA criteria and other seabird species confirmed, or likely, to be breeding in the IBA. Source: McClellan *et al*. (2019)

Important Bird Area (IBA)	IBA Number	Area (ha)	Trigger Species (globally threatened, or abundant) (pairs unless stated)	Other Seabird Species Confirmed or Likely to be Breeding (= Breeding), and Others Recorded
Ruapuke Island (includes multiple islands)	NZ114	1640	Yellow-eyed penguin: 43 adults Foveaux shag 83-94	Nine breeding: blue penguin, sooty shearwater, broad-billed prion, fairy prion, pied shag, spotted shag, southern black-backed gull, red-billed gull, white-fronted tern Others recorded: little shag, black-billed gull, black-fronted tern.
Fife Rock	NZ115	<1	Foveaux shag: 305-334	Three breeding: southern black-backed gull, red-billed gull, white-fronted tern. Further information required.
Northern titi muttonbird islands	NZ118	c.474	Yellow-eyed penguin: 40-66 Fiordland crested penguin: no counts Foveaux shag: 90-477 Sooty shearwater: no counts *Species group*: >10,000 pairs	Eleven breeding: blue penguin, broad-billed prion, common diving petrel, white-faced storm petrel, pied shag, little shag, spotted shag, brown skua, southern black-backed gull, red-billed gull, white-fronted tern. Others recorded: little tern.

In summary there are IBAs around and nearby Ruapuke Island that support breeding populations of yellow-eyed penguins, Fiordland crested penguin, Foveaux shags, blue penguins, pied shags, spotted shags, little shags, southern black-backed gulls, red-billed gulls and white-fronted terns. In most cases, the sizes of these populations are unknown, and regional and national importance cannot be assessed. However, of particular importance are the yellow-eyed penguin (Threatened-Nationally Endangered) and Foveaux shag (Threatened-Nationally Vulnerable). IBAs in the area are thought to support most of the regional population and 3.5-5.3% of the national population in the case of the yellow-eyed penguin and the majority of the national population of Foveaux shag. The foraging distributions of all the above species may overlap with the proposed location for the proposed salmon farm to varying degrees and will be discussed later in the effects section.

2.8 Mammals

Foveaux Strait is a known migration corridor for several species of whales. To describe marine mammal use of the application area and associated waters as well as the potential effects of salmon farming in the application area on marine mammals (discussed in section 3.9), a desktop study was undertaken by Cawthron Institute (Clement 2019). This section is largely taken directly from Clement (2019).

Clement (2019) summarises the occurrence of marine mammals in the application area as follows:

> The greater Southland and Foveaux Strait region, in association with Stewart Island waters, is considered an important area for a large number of New Zealand's cetacean and pinniped species. At least seven marine mammal species are considered year-round residents and / or seasonal visitors of these waters, with several baleen whale species migrating to and through Foveaux Strait each winter / spring, and more offshore species wandering into shallow regions over warmer months. The species with the highest potential to be affected by the proposal are New Zealand fur seals, New Zealand sea lions, bottlenose dolphins, southern right and humpback whales, and orca. While the proposed farming areas represent similar habitats to those available across the wider Foveaux Strait region, they also potentially constitute part of the winter habitat important for southern right whales and forms part of humpback whales' northern migration corridor through the Foveaux Strait area. Southland and Stewart Island waters also support sub-populations of nationally endangered bottlenose and Hector's dolphins, as well as a new breeding colony of nationally vulnerable sea lions, all of which need to be considered.

The remainder of this section provides more detailed information on the use of the waters around the application site by marine mammals.

For most marine mammals, normal home ranges can vary from hundreds to thousands of kilometres. Therefore, when considering potential implications of offshore developments on marine mammals, the appropriate spatial scale of consideration is considerably larger than the farming areas. The spatial extent of the area considered for this application, the ‘area of interest’ (AOI), is shown in **Figure 44** and in this case includes Foveaux Strait, Southland, Stewart Island waters and large areas of the open ocean.

For most marine mammals using the general Southland region and AOI, only broad-scale, regional information is available; however, a few studies have focused primarily on the wider Foveaux Strait region. A list of studies and databases used to inform this AEE is provided in Clement (2019, Appendix 1). All Department of Conservation (DOC) reported marine mammal strandings (1912–2015) and opportunistic sightings (1977–2018) within the AOI are shown in **Figure 44** and, at a more detailed spatial resolution, in **Figure 45**. It is important to note that most of these sightings are opportunistic rather than systematic. Consequently, the number of sightings in these figures does not necessarily represent unique animals (i.e. same animal may be reported by multiple members of the public or reported on two separate days or years). Also, as effort is not considered with opportunistic data, favourite fishing spots and tour boat tracks are likely to be over-represented, especially during periods of more favourable conditions (e.g. summer, daylight periods).

Out of the more than 50 species of cetaceans (whales, dolphins and porpoises) and pinnipeds (seal and sea lions) known to live or migrate through New Zealand waters, at least 24 cetacean and four pinniped species have been recorded passing through the AOI.

Of greatest relevance for this application are the presence and timing of the identified species in the wider region. The more prevalent species are listed in **Table 7** and divided into three general categories that describe the current knowledge about their distribution patterns within the AOI:

- Resident—a species that lives (either remaining to feed and / or breed) within the AOI and surrounding waters either permanently (year-round) or for regular time periods.
- Migrant—a species that regularly travels through part(s) of the AOI but remain only for temporary time periods that may be predictable seasonally.

- Visitor—a species that may wander into the AOI intermittently. Depending on the AOI's proximity to the species' normal distribution range, visits may occur seasonally, infrequently or rarely.

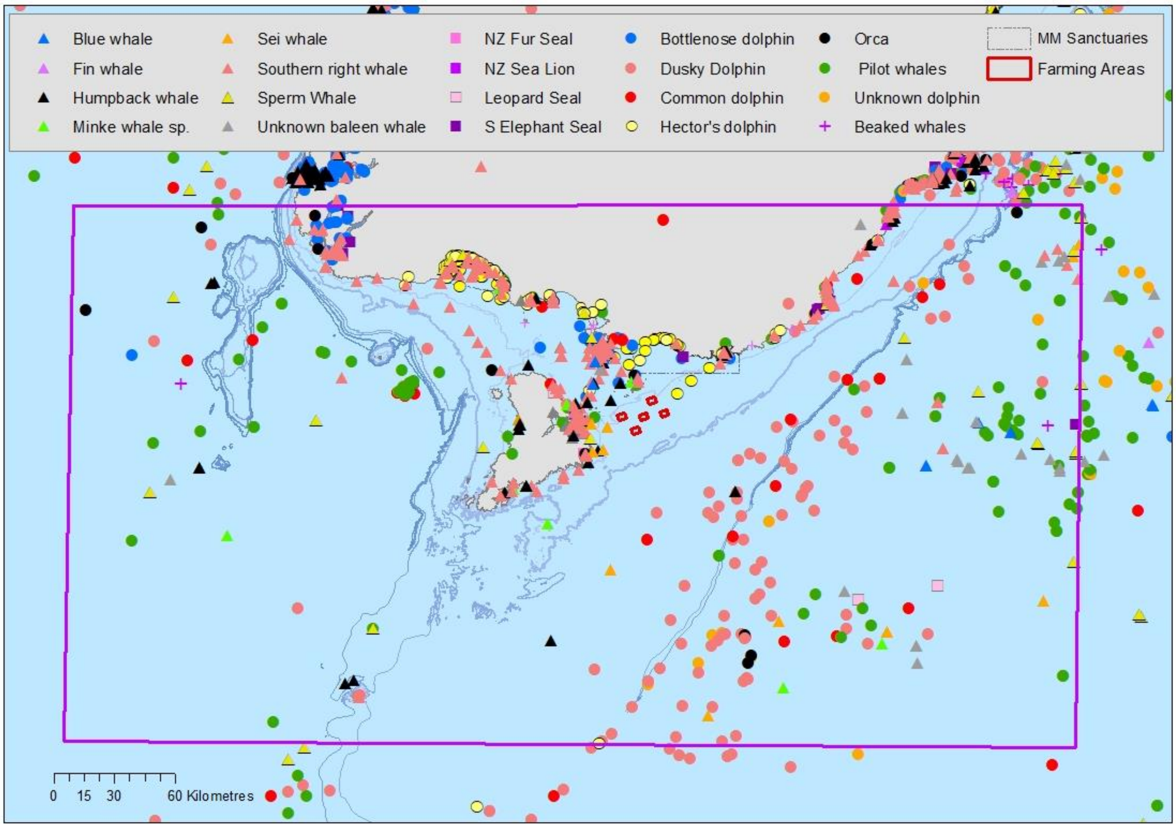
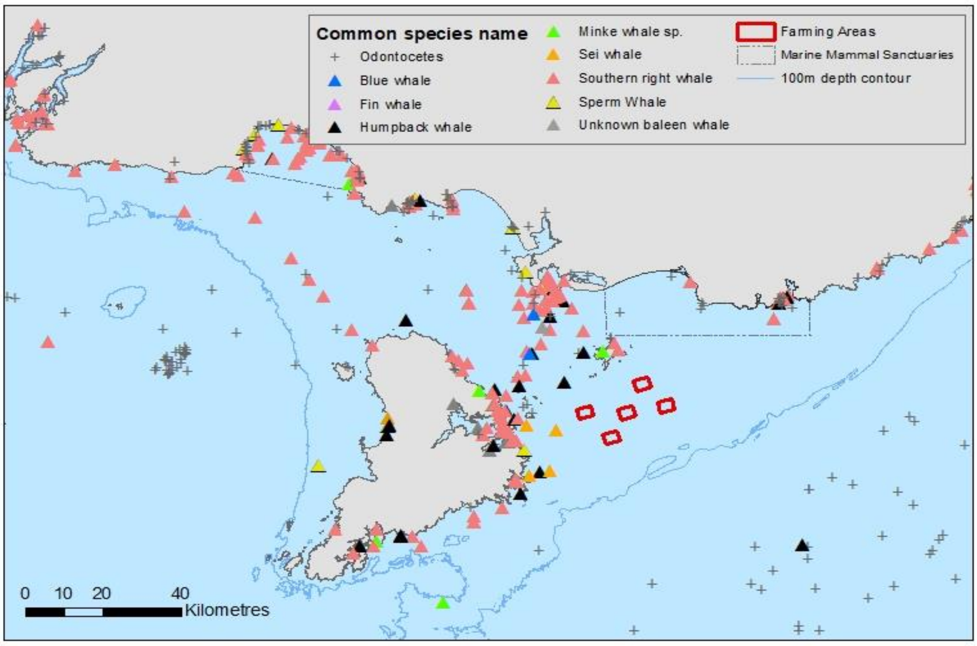


Figure 44. The spatial extent (purple polygon) of Southland and Stewart Island waters referred to as the area of interest (AOI). The relevant marine mammal sighting and stranding data are displayed in more detail in **Figure 45**. The proposal site is indicated in red.



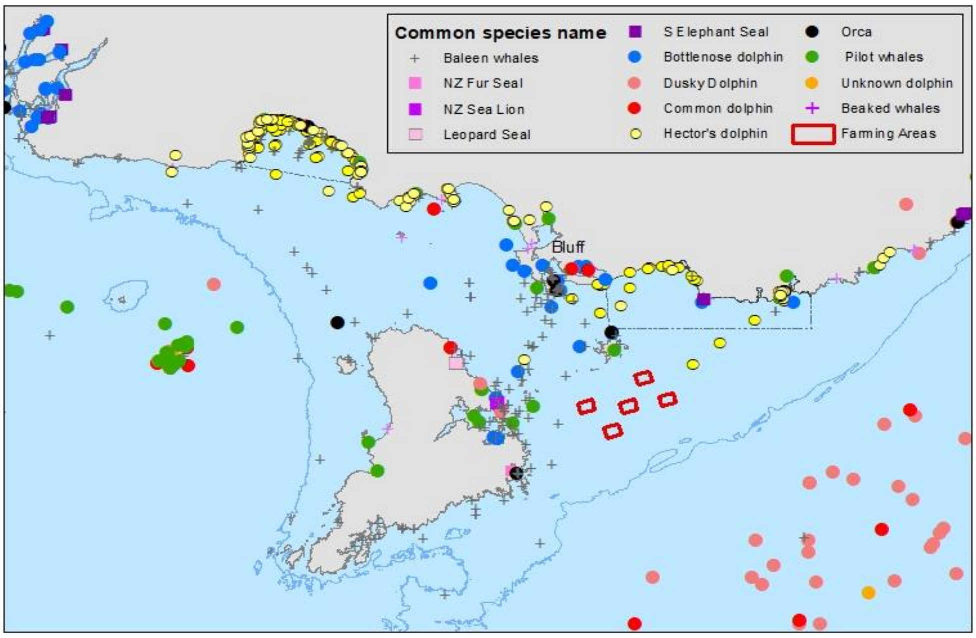


Figure 45. All Department of Conservation (DOC) reported marine mammal strandings (1912–2015) and opportunistic sightings (1977–2018) with in the AOI. Migrating baleen whale species (plus sperm whale) are shown in the top image and toothed whales, dolphins and pinnipeds (seals and sea lions) are in the bottom image. The proposal location is indicated as a red polygon.

Table 7. Residency patterns of the marine mammal species most relevant to the proposal and known to frequent the AOI. Species' conservation threat status is listed for both the New Zealand Threat Classification System (Baker *et al*. 2013) and international IUCN system (ver 3.1).

Common name	Species name	NZ threat classification		IUCN red listing	Residency category in AOI
RESIDENTS					
NZ fur seal	*Arctocephalus forsteri*	NZ native & resident, evaluated	Not Threatened	Least Concern	Year-Round Resident
NZ sea lion	*Phocarctos hookeri*	NZ native & resident, evaluated	Nationally Vulnerable	Endangered	Year-Round Resident
Hector's dolphin	*Cephalorhynchus hectori*	NZ native & resident, evaluated	Nationally Vulnerable	Endangered	Year-Round Resident
Bottlenose dolphin	*Tursiops truncatus*	NZ native & resident, evaluated	Nationally Endangered	Data Deficient	Seasonal to Semi-Resident
POTENTIAL OFFSHORE SPECIES					
Long-finned pilot whale	*Globicephala melas*	NZ native & resident, evaluated	Not Threatened	Data Deficient	Potential Offshore Semi-Resident
Sperm whale	*Physeter macrocephalus*	NZ native	Data Deficient	Vulnerable	Potential Offshore Visitor
Beaked whales	Ziphiidae species (7 species)	NZ native & resident, not evaluated	Data Deficient	Data Deficient to Least Concern	Potential Rare Offshore Visitors
MIGRANTS					
Southern right whale	*Eubalaena australis*	NZ native & resident, threatened	At Risk-Recovering	Least Concern	Seasonal Migrant
Humpback whale	*Megaptera novaeangliae*	NZ native, evaluated	Migrant	Endangered	Seasonal Migrant
VISITORS					
Dusky dolphins	*Lagenorhynchus obscurus*	NZ native & resident, evaluated	Not Threatened	Data Deficient	Seasonal Visitor
Common dolphin	*Delphinus delphis*	NZ native & resident, evaluated	Not Threatened	Least Concern	Seasonal Visitor
Orca (killer whale)	*Orcinus orca*	NZ native & resident, threatened	Nationally Critical	Data Deficient	Seasonal to Infrequent Visitor
Sei whale	*Balaenoptera borealis*	NZ native & non-resident, evaluated	Not Threatened	Not Threatened to Data Deficient	Seasonal to Infrequent Visitor
Blue whale	*Balaenoptera musculus (sub-spp.* brevicauda & intermedia*)*	NZ native	Data Deficient	Critically Endangered to Data Deficient	Seasonal to Infrequent Visitor

Several of the species highlighted in **Table 7** and **Figure 45** are known to be year-round or seasonal residents of New Zealand waters, including the wider Foveaux Strait and Stewart Island regions. The more common species occurring within the AOI, and those therefore potentially affected by the proposed project, include New Zealand fur seal (*Arctocephalus forsteri*), New Zealand sea lion (*Phocarctos hookeri*), bottlenose dolphin (*Tursiops truncatus*), southern right (*Eubalaena australis*) and humpback whales (*Megaptera novaeangliae*) and occasionally, orca (*Orcinus orca*). In addition to the species listed above other species that might potentially be affected by the application are southern elephant and leopard seals; Hector's, dusky and common dolphins; sei, blue, minke, and pygmy right whales; and pilot, sperm and beaked whales. Detailed descriptions of species and known interactions with finfish farms are provided in Clement (2019).

Based on the available data, there is no evidence indicating that any of these species have home ranges restricted solely to Foveaux Strait and associated regions. Hence, the proposal area is not considered ecologically more significant in terms of feeding, resting or breeding habitats for most of these species relative to other regions within the greater AOI based on current knowledge.

The possible exceptions are the use of Foveaux Strait as a main migration corridor for several species of whales and southern right whales' use of these waters as potentially important winter mating habitats. Whales' migration pathways through Strait waters are not well-known but increasing numbers of humpback, southern right and blue whales have been documented in recent years around New Zealand as populations continue to recover from whaling harvest impacts. As discussed above, Foveaux Strait waters also support potential sub-populations of endangered species, such as Hector's dolphins, bottlenose dolphins and orca, as well as local recovering colonies of the vulnerable NZ sea lions. The potential effects on these populations and wider context are discussed later in this report.

3 EFFECTS OF THE PROPOSED CHANGE TO SALMON FARMS ON THE RECEIVING ENVIRONMENT IN FOVEAUX STRAIT

3.1 Details of proposal

The proposed application site is to the south-east of Ruapuke Island with the nearest farming area (block of ten pens) approximately 10 km from the nearest point on the Island. Water depths in the area are between 50 and 85 m. The area is a high energy environment with currents up to 1.2 m s^{-1} and wave heights up to 10 m at least recorded (up to 1% of the time) in this region of Foveaux Strait.

The structures and layout have been drafted following extensive consultation with engineers and farm specialists with indicative features are shown in **Table 8.** The layout will be in a grid design of polar circle pens and an anchor system as shown in **Figure 46**. This will enable best international standards separation distance between the five farms to minimise environmental cumulative effects and between-farm effects for issues such as biosecurity.

Sanford propose to develop the marine farm with full development being five farming areas, each comprising 26 ha for pens and barge and 157 ha including anchor lines. The pens will be 25 m deep at their deepest point and 20 m side depth and submerged pens in severe weather events are being considered as an option (**Figure 47**).

Staging

Staged development of the farming areas will occur. At the completion of Stage 1 there will be two farming areas with 4-6 pens arranged in a grid of 2x2 or 2x3 pens with a maximum of 3,400 t/farming area/yr. Stage 2 will involve full development of the two farming areas. Stage 3 will be for partial development (4-6 pens) of the other three farming areas and Stage 4 will be full development of all five farming areas. At full development each farming area will have a maximum of 10 pens, arranged in a grid of 2x5 pens with a maximum stocking density of 20 kg/m^3, producing an estimated 5,400 GWT per year per farming area.

Before moving to another stage all relevant scientific and technical reports will be reviewed by suitably qualified and experienced persons on behalf of Sanford and the consent authority, and compared with specified standards and thresholds to confirm effects are no more than predicted. These standards and thresholds will be developed as part of an Environmental Monitoring Plan (EMP).

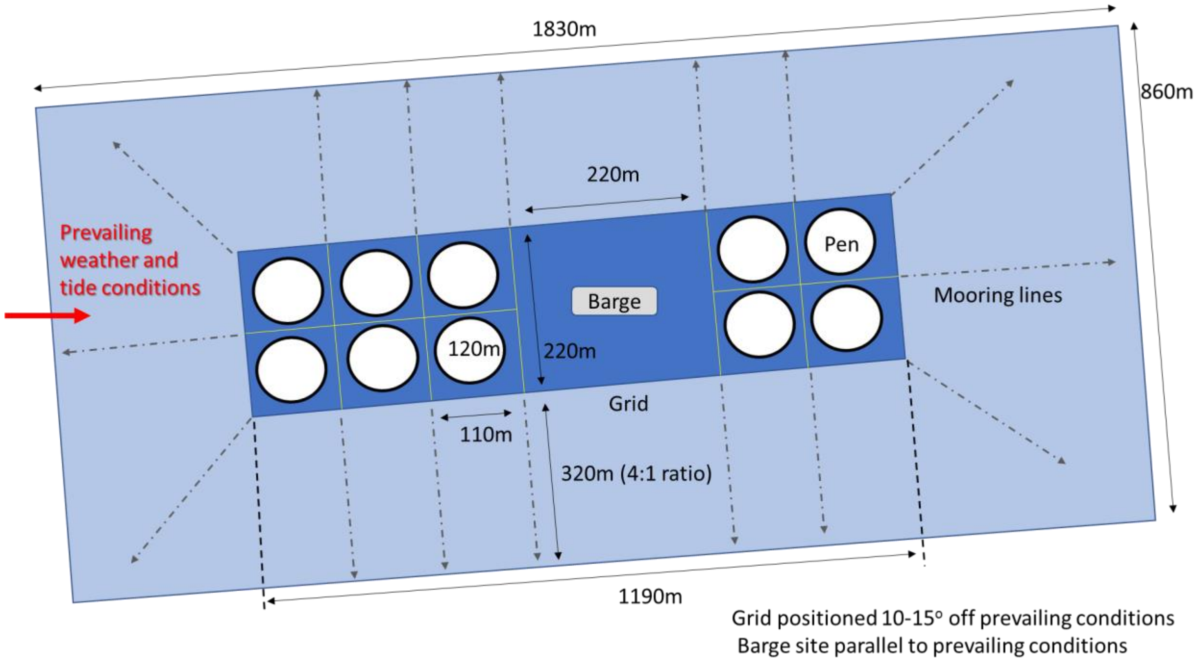
At full development each of the five farms will require up to 29 tonne of feed per day. The total nitrogen release per year for each farm will be 430.5 tonne/year at full development, 331 t of which will be soluble nitrogen. Each farm will be supported by its own resident barge.

Table 8. Farm layout and design

Parameter	
Water depth	52-80 m
Size of farming area	26 ha, 157 ha including anchor lines
Pens	10 pens per farming area at full development Circumference = 120 m, 38 m diameter Depth = 25 m in middle, 20 m side depth Pen volume = 27,000 m^3
Production	Production per 10 pens at full development 5,400t/yr Maximum density 20 kg/m^3
Vessel / barge for farm management	External contractor vessel for putting in anchors Each farm will have a resident barge that runs all feeding systems, and stores fish feed A supply vessel that moves between Bluff and the farms delivering feed A net cleaning vessel that moves between the farms on a fixed scheduled A harvest vessel that moves between Bluff and the farms used to harvest fish A maintenance vessel that moves between the farms and Oban - Stewart Island A staff ferry vessel that moves between Bluff and the farm, Oban – Stewart Island and the farm
Fish sources	Juveniles sourced from Sanford’s freshwater hatcheries, and smolt grown on farms in BGB (Big Glory Bay) On-growing at proposed site
Predator nets	At the start no, but may be required

Feed characteristics	refer top ADS (2019d)
Chemicals and therapeutants to be used	No antifoulants, low levels of zinc in feed, no anticipated use of therapeutic chemicals

(A)



(B)

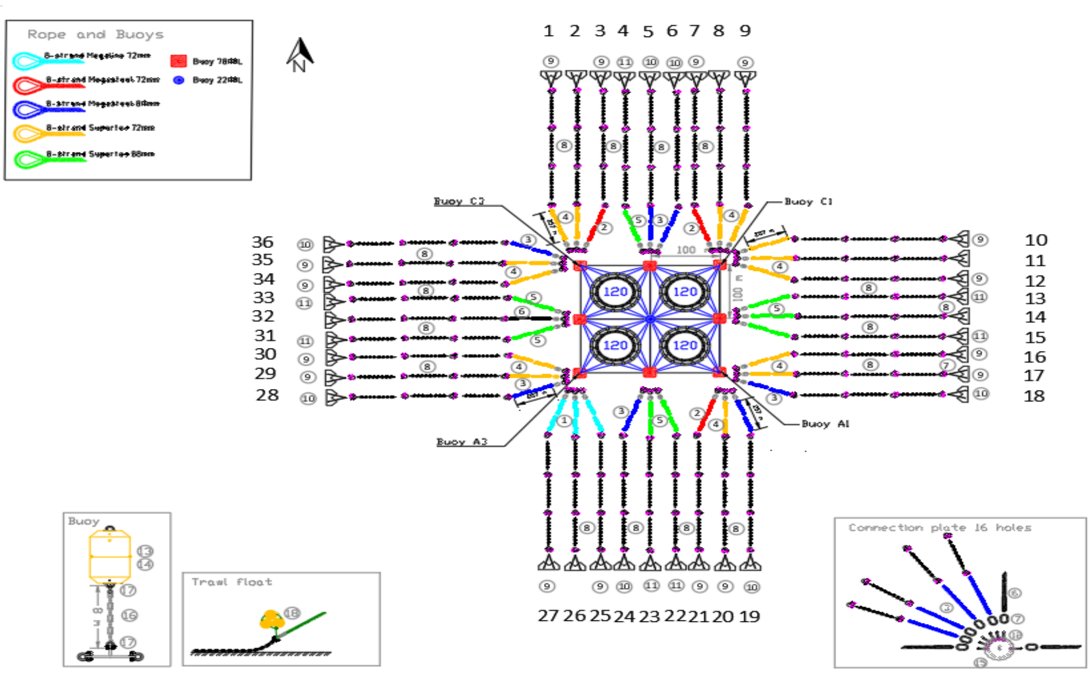


Figure 46. Layout of pens in each farming area (A) pen configuration for each farming area and (B) pens and anchors for 2x2 arrangement.

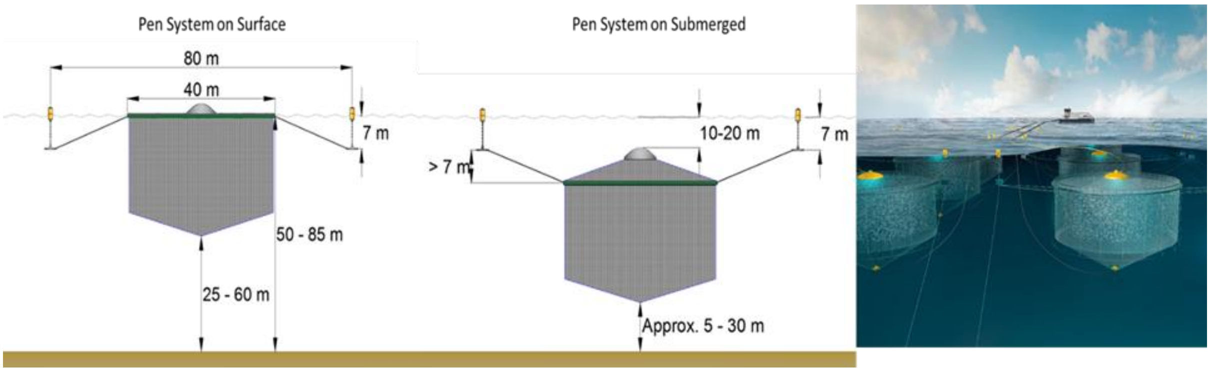


Figure 47. Example of pen likely to be used including submersible option

3.2 Introduction to effects

Farming of Chinook salmon has been undertaken on a commercial scale in BGB, Stewart Island, since the 1980s and Sanford has been farming salmon there since 1993. The ecological effects of salmon farming in the currently farmed coastal areas (the Marlborough Sounds, Akaroa Harbour and Big Glory Bay) are generally well known and have been summarised in recent review reports (Forrest *et al.* 2007; MPI 2013b).

The main considerations with finfish farming are the discharge of nutrients, deposition of faecal material, residual feed, and chemicals on the seafloor, addition of physical structures and operational activities. The general effects of finfish farming on ecology and the environment are illustrated in **Figure 48**. These effects are described and assessed in relation to this application in sections 3.3 to 3.10 in the following order:

- Hydrodynamics
- Water quality
- Seabed effects
- Biosecurity (marine pests and disease)
- Fisheries
- Seabirds
- Marine mammals

While the types of effects to be considered are fairly consistent among finfish farms, the relative importance differs among farms as a consequence of many factors, including farm location, breeding programmes, farming practices and the nature of the environment. Particularly relevant for this application is that the application site is in an offshore open ocean environment. Although applications have been made for two offshore farms, there are no offshore finfish farms operating in New Zealand at present.

The following sections provide an overview of potential effects and an assessment of the predicted ecological effects of this application and puts this into context of the application site and wider environment in this part of Foveaux Strait.

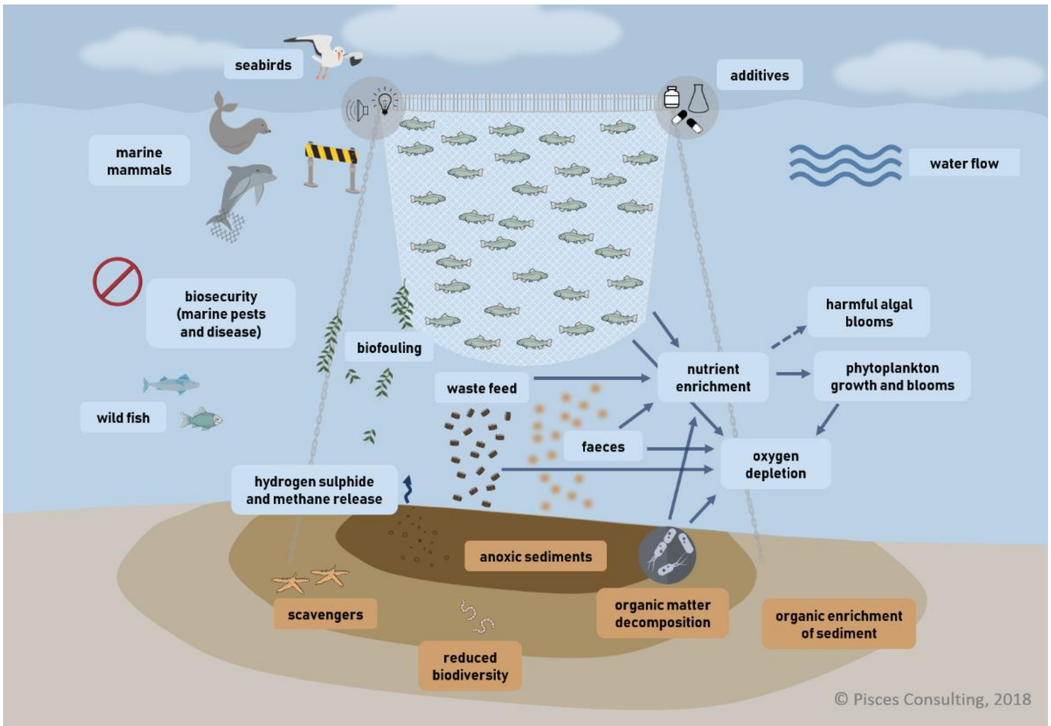


Figure 48: Illustration of the potential environmental effects of finfish aquaculture (provided by Hilke Giles).

3.3 Overview of the relative importance of effects

As outlined above, the potential forenvironmental effects from a specific finfish farm depends on a wide range of factors, including the species farmed, farm management practices, the scale and intensity of farming, the nature and resilience of the receiving environment, the level of knowledge of ecological issues, and the scope to manage effects (for example by implementation of best management practices).

The ecological context of this application differs somewhat from previous applications because of its setting in the offshore environment of Foveaux Strait. In offshore environments, most effects of finfish farming are predicted to be less than nearshore sites, as the dispersion and mixing of faecal material and residual feed and is increased as a result of greater water depths, stronger currents and winds (Holmer, 2013). Benthic communities; however, may be more sensitive to organic loading, as they may not be as well adapted to organic matter inputs as communities along the coastal fringe that are exposed to organic input, particularly from the land.

While the general effects of finfish farming in the application site are expected to be similar to those in nearshore environments, the following differences in the relative importance and intensity are predicted for this application and will be considered in subsequent sections on the potential effects of the proposal:

- The offshore farm location will be more dynamic and higher energy in terms of physical processes;
- Mixing and dispersion will be greater (in the water column and deposition on the seabed);
- The seabed in and near the application site may have a lower capacity to assimilate organic enrichment compared to nearshore benthic environments (this may be counterbalanced by reduced enrichment intensity as a result of greater dispersal);
- Interactions with mammals will potentially be more significant; and
- There is more overlap between the application site and commercial fisheries compared to existing finfish farming sites, including a nationally important oyster fishery in the case of this application. Thus, the risk of transfer of disease and pests is also potentially more important here.

The potential ecological effects of this application are described in the following sections. The assessments focus on the ‘typical’ effects of finfish farming as observed at existing finfish farming sites but the main focus is on the specific considerations related to farming finfish offshore and specific characteristics of the Foveaux Strait environment.

3.4 Effects on hydrodynamics

3.4.1 Potential effects

The potential changes to hydrodynamics are important because physical drivers interact strongly with pelagic and benthic processes. This is because hydrodynamic conditions influence dispersal of dissolved substances, such as nitrogen, as well as faecal material and residual feed.

Plew (2013) identified three potential effects for finfish farming on hydrodynamics:

- Reduction in currents and redirection of flow;
- Effects on stratification; and
- Wave dampening.

These three potential effects are described in this section, utilising information provided in Plew (2013).

3.4.1.1 Reduction in currents and redirection of flow

Reduction in currents and redirection of flow occurs when water speeds are reduced upstream, downstream and within finfish cages as a result of the physical obstruction the cages present. In addition, there can be local increases as a result of flow accelerations around or beneath cages. Increases in flow velocities beneath a farm may increase the shear stress on the seabed and thereby increase the likelihood of resuspension of deposited material from a farm. This has consequences on the depositional farm footprint (this is discussed further in the section on benthic effects).

Finfish pens placed in constricted areas, such as narrow portions of a bay, have a greater influence on flow than in wider areas as there is less room for flow to divert around the cages. In embayments current speed reduction may be noticeable on the embayment scales but in higher energy areas with relatively high current velocities, such as the application site, changes in circulation beyond the local scale of the cages are less likely.

Flows are also presumed to be altered by the presence of fish inside the pens; however, this is considered to be of less importance than the effects by farm structures as the fish will equate to less than 1% of the mass inside the pen, the rest being water.

The physical effects on currents persist for the duration that pens are in place but return to natural conditions nearly immediately once the pens are removed.

3.4.1.2 Stratification

Stratification is when a water body is layered due to differences in density as a consequence of temperature and salinity. Stratification naturally varies seasonally and in response to meteorological and climatic conditions. In strongly stratified waters vertical mixing is impeded, making them more susceptible to ecological issues, such as oxygen depletion and nutrient enrichment and reduction (through uptake in surface waters). Finfish pens can alter stratified water bodies through blocking or diversion of some water layers, generation of internal waves and possible enhancement of vertical mixing.

In theory finfish farming has the potential to increase water temperature through dissipation of turbulence generated by swimming, but this is expected to be insignificant. Furthermore, finfish are unlikely to have an effect on salinity as they neither consume nor produce salt.

The influence of finfish farming on stratification thus depends on how great the differences in water density are and on the strength of other physical process that drive water motion, such as tides and weather. The spatial scale of effects of finfish cages on stratification is unknown and will depend on the local hydrodynamic conditions.

Effects on stratification, if they occurred, will persist while finfish cages are in place but would generally be very localised in extent. How fast conditions will return to natural conditions will depend on the intensity of effects and length of time of operation but would be relatively rapid.

3.4.1.3 Wave dampening

Wave energy transmission in a water body is reduced as wave energy is reflected and attenuated by finfish pens. Wave dampening will manifest as a shadow of reduced wave heights extending down-wave from pens, and decreasing with distance from pens. This ‘pen-wave shadow’ is limited in size because wave energy will refract horizontally from regions not influenced by the pens. No guidance is available on the size of wave shadows, or how they relate to cage size, stocking density, cage design or water depth.

Some level of wave attenuation is expected to occur for any finfish pen structure with surface or near surface components. Effects may be undetectable for individual pens, small farms or in sheltered areas.

3.4.2 Predicted effects on hydrodynamics

The hydrodynamic conditions of the application site are characterised by currents from the east, north-east, south-west, and west with speeds of 0.2-0.4 m s^{-1} and peaks up to 0.7 m s^{-1}.

These high energy hydrodynamic conditions in the open waters of the application site create a low susceptibility to effects on hydrodynamics for the application site. Current flow can easily divert around the cages, reducing effects on flow in their vicinity. The open ocean environment makes it highly unlikely that regional effects will be detectable.

The water column in the application site is not usually stratified. The physical processes influencing stratification in the application site (i.e. current flow and mixing) are strong and it is therefore unlikely that the proposed finfish pens will influence stratification in and near the application site. Despite the low likelihood of effects, the proposed monitoring will include measurements of vertical salinity and temperature profiles to assess potential stratification.

Wave attenuation is expected to be limited because of the restricted area of the proposed finfish pen structures and would be even less likely if the pens are submerged.

Overall, the effects of the proposal on hydrodynamics are expected to be very small and localised. Furthermore, in the open ocean environment of and around the application site, the ecological consequences of potential alterations to the hydrodynamic regime as a result of the proposal are expected to be negligible.

3.5 Effects on water quality

The main considerations for the water column are the release of total ammonia-N (or TAN), potential enhancement of phytoplankton biomass, and consumption of oxygen.

3.5.1 Introduction

Finfish aquaculture can affect water quality in several ways and depending on environmental and hydrodynamic conditions, can potentially extend over large areas. Generally high flow sites may disperse material over a wider area but at lower concentrations and significant effects are less likely to occur than at low flow sites.

A particularly important consideration is nutrient enrichment. Farmed fish excrete dissolved inorganic nutrients such as TAN. Nutrients (primarily nitrogen and phosphorus) are also released from faecal material, residual feedand sediments (see benthic effects section).

Nutrient enrichment in the water column can stimulate phytoplankton growth (as a result of increased nutrient levels), change the composition of phytoplankton species (as a result of changes in the ratios of nutrients), and potentially stimulate phytoplankton blooms. If nutrient levels are very high, the water body can become eutrophic. Eutrophic waters have high primary productivity due to excessive nutrients and are characterised by low water quality and frequent algal blooms. If TAN concentrations are very high within or close to the fish pens, they can also become toxic to fish (see section below).

Another important consideration is the reduction of dissolved (DO) in the water column in or near finfish farms. DO depletion is a consequence of increased biomass (fish in pens) and microbial degradation that consume oxygen. Microbial degradation occurs in the water column (degradation of phytoplankton, faecal material and residual feed) and in the sediments (decomposition of deposited organic matter). Oxygen consumed in the sediments is replenished (if available) from the water column, thus leading to reduction of DO in the water column.

Poor water quality can detrimentally affect the health and growth of farmed fish, particularly oxygen depletion. Oxygenated waters are critical for the survival and performance of farmed fish. These concerns can be managed through appropriate farm location and management, and by protecting the farmed fish, so too fish species beyond the farm will be protected.

Another concern related to nutrient enrichment is the potential for increased occurrences of harmful algal blooms (HABs), including blooms of species that produce biotoxins (MPI 2013a, b). However, in New Zealand, no known HABs have been linked to the effects of finfish farming (MPI 2013a, b).

3.5.2 Nutrient enrichment and algal biomass

The existing state of the water column environment was described earlier in this report. The limited data available suggests nutrient concentrations will vary depending on the season, prevailing currents and source of water eg upwelled water from the Southern Ocean versus sub-tropical waters from the west coast.

Nitrogen is considered the main limiting nutrient for plant/phytoplankton growth in New Zealand coastal systems, including the coastal and offshore regions in Foveaux Strait. Chang (1990) attributed the naturally occurring bloom in 1989 that caused large scale mortality to salmon in BGB (see plankton section below) to a mixture of calm, warm weather (part of La Nina pattern) and relatively high levels of nutrients over summer from inputs of nutrient rich water from outside the Bay (DIN recorded as 0.048 g/m^3). A contributing factor was the ability of the *Heterosigma* species to migrate down to nutrient-rich waters lower in the water column. Although blooms may not occur very often in the open waters of Foveaux Strait episodic events and seasonal effects may result in higher phytoplankton biomass. The data collected in late spring 2019 indicates chl-*a* concentrations could be up to at least 1.5 µg/L but this may have been after the spring peak.

Increases in nitrogen, mostly in the form of TAN, that will be released from the proposed finfish farm has the potential to increase algal biomass and associated water quality and biological effects.

Predicted effects on water quality/water quality modelling

ADS (2019c) reports on the modelling aimed at simulating the release of farm-derived nitrogen (in the form of TAN) and its subsequent effects on chl-*a* (an indicator of phytoplankton biomass) as a result of the proposed development. ADS (2019c) also examined the potential changes in dissolved oxygen levels in the vicinity of the application site as a result of increased fish respiration (see next section). Readers are referred to ADS (2019c) for details of the modelling.

The enhancement of nitrogen from the proposed farm was assessed using the output from a hydrodynamic model run over 2017 (a year that had a comprehensive data set) to drive the water movement in the water quality module (see ADS 2019b for details). When TAN is released into the water it is available for uptake by phytoplankton and some will be nitrified to nitrate which is also available for phytoplankton production or can be denitrified to nitrous oxide and nitrogen gas which is released into the atmosphere.

The approach taken by ADS was very conservative (i.e. would over-estimate ecological effects) and assumed all the inorganic TAN is taken up directly by phytoplankton. In the model nitrogen was released within each pen and from under the pen where it was assumed that all deposited nitrogen (faecal material and residual feed) was also released back into the water column as TAN. Results of the model were presented for each season in 3-D for surface and bottom waters and increases in phytoplankton biomass were modelled using TAN:Carbon (C) and C:Chl-*a* relationships.

Key results from the modelling reported in ADS (2019c) were:

- Modelling showed little difference between increases in surface and bottom layer TAN, with TAN increases averaging 2-3 µg/L and chl-*a* 0.2 to 0.6 µg/L;
- The highest average increases near the surface are predicted to be at Farming Areas D and E to the south-east of Ruapuke Island where increases could exceed 4 µg/L but only right in the pen area and a plume of 2-3 µg/L could extend up to 8-9 km away from the pens (see **Figure 49** and **Figure 50** for examples). However, most of the

increased TAN would be restricted to within the pen areas. Increases will be lower in the bottom waters within and around the pens. Increases were lower and more confined to the pen areas showing more of a halo effect for Farming Areas A, B and C in the south and west of the application site;

- The modelled increases in chl-*a* followed the same pattern as for TAN with larger increases around pens in Farming Areas D and E. Generally, the average increases were less than 0.3 µg/L away from the pens and more dispersed in autumn than other seasons (see **Figure 50** for an example);
- The maximum seasonal increases (highest concentration for a single 10 min period) showed increases in concentrations in the order of 10-12 µg TAN/L, and maximum chl-*a* concentration of 1.2 to 1.4 µg/L. It should be noted that these are extremely short-lived, within the pen areas and unlikely to result in detectable increases in chl-*a*; and
- ADS concluded that:
    - The larger increases in TAN and chl-*a* were well to the south-east of Ruapuke Island and were all confined to less than 5 km from the pens; and
    - The increases in TAN and chl-*a* are predicted to be very low compared to those predicted and observed in other farming areas in New Zealand including in BGB, Stewart Island,, Marlborough Sounds and Storm Bay in Australia. This is due to the strong currents and mixing experienced at the site.

Considering the relatively high concentrations of nitrate-N measured at the site and in eastern Foveaux Strait (40-70 mg/m^3) then the increased availability of DIN due to release of TAN is small and unlikely to be detectable or ecologically meaningful in terms of enhancement of phytoplankton growth.

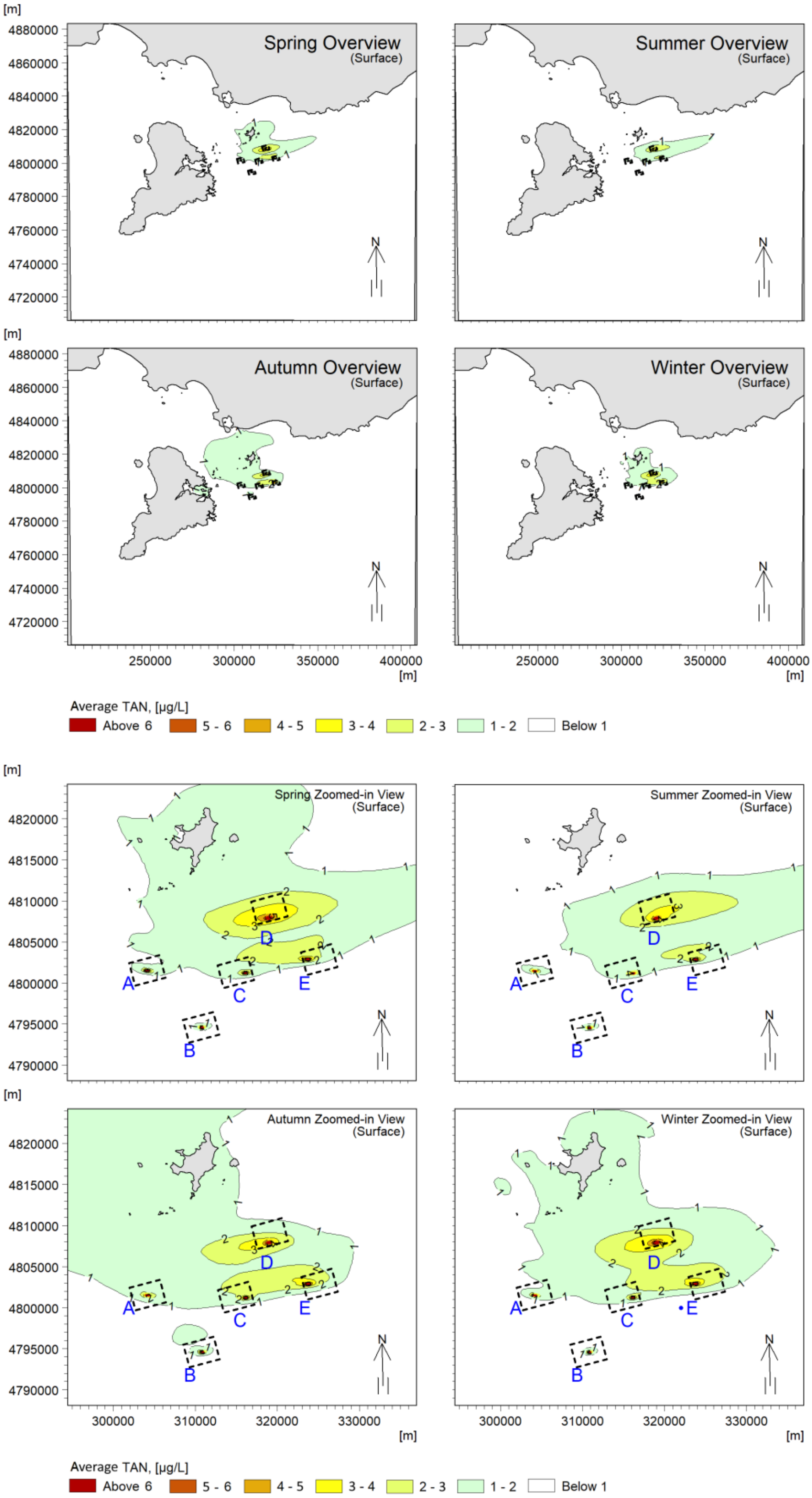


Figure 49. Seasonal average excess concentrations of total ammonia nitrogen (TAN) at the surface. (from ADS 2019c).

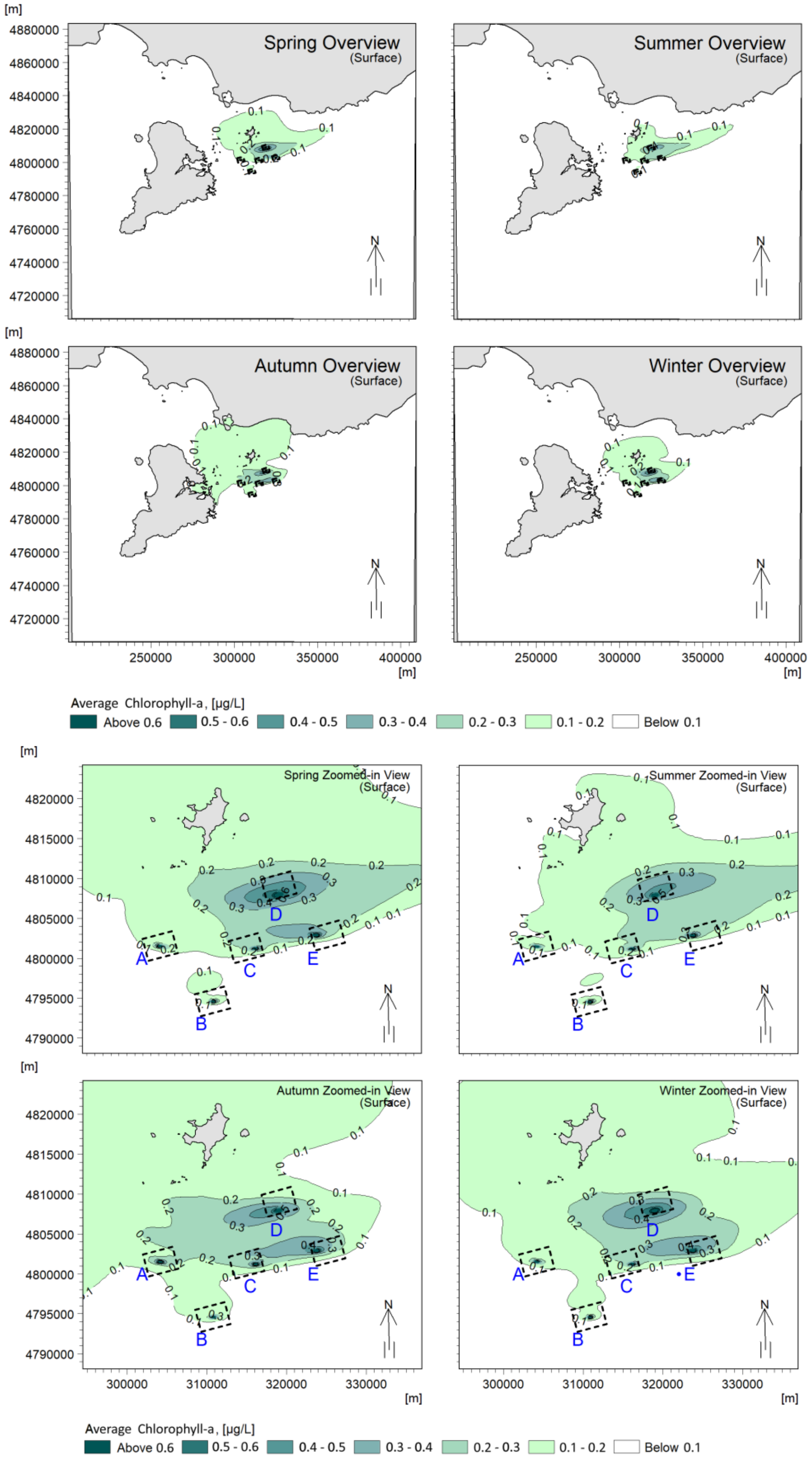


Figure 50. Seasonal average excess concentrations of chlorophyll-a at the surface. (from ADS 2019c)

ADS (ADS 2019c) have estimated that the total inputs of N released into the water column at full development would be 430.5 tonne per year per farming area or 2,152 tonne in total. To put this into context Gillespie *et al*. (2009) provide estimates of the total nitrogen load passing through Foveaux Strait. Based on an average nitrate concentration of 30 µg/L (concentrations tend to be higher to the east) they estimated that the annual load would be equal to 435,000 tonnes/year. The average N load coming from the proposed farm would be only 0.5% at full development noting that nitrate levels measured at the farm site were much higher than the 30 µg/L used by Gillespie *et al*. (2009).

3.5.3 Toxicity

Elevated nitrogen levels can potentially cause near-field toxicity effects in the immediate vicinity of fish cages, before any significant dilution of nitrogen has taken place.

Toxicity is based on a combination of two parameters: the duration of exposure and level of exposure. For example, “acute” toxicity levels are where pronounced effects occur over relatively short time frames (i.e hours to days), while “chronic” toxicity levels are those that relate to longer time frames (i.e. weeks to months). Chronic thresholds are generally set at much lower levels than acute toxicity values. Chronic toxicity can lead to a general decline in the health of farmed and natural biota, and ultimately increased levels of mortality in farmed and naturally occurring biological communities and populations. Elevated concentrations that only occur for very short durations may not necessarily cause harm to a particular organism. The actual processes involved in the toxicity relate to species assimilation and metabolic rates.

Ammonia exists in two forms in solution: the abundant ammonium ion or ionized ammonia (NH_4^+) and the un-ionized or free ammonia (NH_3). The sum of both added together is the parameter referred to as TAN. The ammonium ion is almost innocuous whereas the un-ionized ammonia is extremely toxic and poses a threat to health of farmed and naturally occurring biota even at relatively low levels.

The criteria for protection of aquatic life established by the US EPA agency are based on tables relating the concentrations of total ammonium nitrogen to pH and temperature. These can be used as guidelines for the maximum acute and chronic allowable concentrations. For seawater with salinity of 30 PSU, temperature of 15°C and pH of 8.4 (typical worst case observed in BGB), the maximum acute concentration allowed by EPA criteria is 4.2 g-TAN-N/ m^3 while the chronic concentration is 0.62 g-TAN-N/ m^3. Around the proposed farm in Foveaux Strait the predictions are that TAN would only reach a maximum of 0.010-0.012 g/m^3 which is well below the EPA chronic criterion.

3.5.4 Dissolved oxygen

Salmon farming is largely self-regulating with regard to DO in that farmers will lose stock or fish will lose condition if they are stressed by low oxygen levels in the pens. Similarly, if oxygen levels in the farm sustain the farmed fish, so too would oxygen levels in the wider environment be expected to be sufficient to sustain natural fish populations. Reduced levels of DO can affect the growth and survival of salmonids in different ways at different stages of life. Decreasing feeding activity in adult salmonids is usually observed under low DO concentrations (<6mg/L) and may also cause mortalities in "extreme" conditions (<3 mg/L) (Carter 2005). Bjornn & Reiser (1991) also stated that DO concentrations <5 mg/L can adversely affect growth, food conversion efficiency, and swimming performance in salmonids.

USEPA (1986) calculated the median percent reduction in growth rate (as a result of lowering the DO concentration) of Chinook salmon (based on a number of previous studies) fed with full rations and exposed to an average temperature of 15°C. The calculations indicate that the growth rates were reduced by 7% at 6 mg/L, 16% at 5 mg/L, 29% at 4 mg/L and 47% at 3 mg/L. A similar study on Coho salmon and Sockeye salmon by Brett & Blackburn (1981) also indicates strong dependence of growth on the DO concentrations where DO levels were below 5 mg/L.

Ultimately, it is temperature that controls metabolic rates and the value of the limiting oxygen saturation (LOS) shifts exponentially with temperatures (Barnes *et al. 2011*). Atlantic Salmon have been shown to position themselves vertically in the water column primarily in response to temperature, even if it positions them in a layer of relatively DO poor water (Dempster *et al.* 2016, Johansson *et al.* 2006). Both Dempster *et al.* (2016) and Johansson *et al.* (2006) have shown salmon to actively avoid temperatures greater than 18° - 19°C by swimming to deeper areas of the cage where there are cooler temperatures. Numerous personal observations by Aquadynamic Solutions corroborate these same phenomena at farm sites in New Zealand and Australia for both King/Chinook and Atlantic salmon.

Green and Cornelison (2016) have reviewed standards for DO in marine waters for a variety of biota, including ANZECC (2000) guidelines and various trigger values applied internationally and elsewhere in New Zealand. Triggers are based on percentage saturation or absolute DO concentrations and vary between 3-4 mg/L for instantaneous and up to 6 mg/L for 7–day measurements.

Predicted DO measurements near Farming Area A in November and December showed that the DO concentrations were between 9.0 and 9.4 in November and 8.1 and 8.5 mg/L in December increasing gradually from the surface down to 20 m depth while temperature did the reverse. This is consistent with lower DO as water warms. Modelling showed the reduction would be less than <0.1 mg/L and thus would not be ecologically meaningful or result in any effects on the farmed fish or natural biota.

3.6 Effects on the seabed

3.6.1 Description of potential effects on the seabed

The main consideration with finfish farming and the seabed is biodeposition, i.e. the deposition of faecal material and residual feed and biofouling material on the seabed. The area of seabed affected by biodeposition is referred to as the 'farm footprint'. Biodeposition can lead to changes in sediment chemistry, decreased bottom water DO concentrations, release of nutrients and hydrogen sulphide into the water column, and changes to biological communities. Another relevant consideration for the seabed is the deposition of contaminants such as heavy metals.

Biodeposition from finfish farms at highly dispersive farm sites, i.e. in locations where faecal material and residual feed is strongly dispersed by currents, such as with this application, is reduced under the farms but is distributed over a larger area beyond pens than at inshore sites. At such sites the general changes to sediment chemistry and ecology described in the following sections are expected to occur but at lower intensities than for inshore farms. Relevant for this application is that there is some uncertainty about the response of offshore sediments to organic enrichment. The reduced intensity of organic deposition is expected to mitigate the potentially reduced assimilative capacity of the sediments in and near the application site. This aspect will be further addressed through the proposed benthic monitoring.

3.6.1.1 Organic enrichment and subsequent changes to sediment chemistry and water quality

In the sediment, organic matter is decomposed (broken down) by complex microbial processes. The decomposition of organic matter releases nutrients, particularly ammonium (NH_4) and, to a lesser degree, phosphate (PO_4). These nutrients are released into the water column, potentially exacerbating nutrient enrichment.

Sediment microbes use different sources of energy, which, depending on the level of organic enrichment, results in sediment oxygen consumption and potential release of hydrogen sulphide and methane into the water column. The preferred source of energy for microbes is oxygen. Dissolved oxygen in the sediment is replenished with oxygen from the bottom water.

This generates a flux of oxygen into the sediment, contributing to oxygen depletion in the water column. When dissolved oxygen is depleted in the sediments, microbes use other sources of energy to decompose organic matter, following a well-defined sequence of diminishing energy gain for microbes. This can result in the release of hydrogen sulphide (H_2S) and methane (CH_4). If organic enrichment is severe, sediments can become anoxic (oxygen-depleted) under fish farms and, under extreme circumstances, even azoic (devoid of any living organism).

Microbial organic matter decomposition processes are called redox (oxidation-reduction) reactions. The redox conditions in the sediments depend on the prevalent microbial processes taking place and thus represent the degree of organic enrichment. Redox conditions can be assessed by measuring the sediment redox potential, Eh (expressed in mV). In the surface sediment (if oxygen is available), the redox potential is positive. It decreases with depth related to the decrease in the dissolved oxygen concentration. Negative Eh values are associated with anoxic conditions.

The redox potential discontinuity layer (RPD) is the point at which the redox potential drops abruptly from positive or slightly negative to highly negative values. This depth has been used as an indicator of the depth of the sediment where oxygen is depleted. However, while the depth of the RPD can be a good indicator of relative oxygen content in the sediment, it needs to be applied with caution because the relationship between oxygen and RPD depth is influenced by many factors that are situation-specific and vary greatly (for example, see Gerwing *et al*. 2015). Measurement of RPD will be an important component of benthic monitoring.

3.6.1.2 Seabed ecology

Sediment enrichment under fish farms can affect seabed ecology, through changes to infauna (organisms living in the sediment), epifauna (organisms living on the seabed) and biogenic habitats (habitat formed by the growth and structure of organisms).

Infauna communities under and near finfish farms typically have a reduced diversity with high abundances of common opportunistic taxa. In anoxic sediments species diversity can be reduced to levels at which only few infauna species can tolerate the degraded conditions. If deposition is very high (typically only directly under a farm and in low flow conditions), biodeposition can also lead to smothering of organisms. Two opportunistic species commonly used as key indicator species for enriched sediments are Capitellida and *Dorvelleid* polychaete worm species.

Changes in the seabed as a result of organic enrichment may make conditions unsuitable for some epifauna. Organic enrichment and deposition of biofouling organisms (see biosecurity section) can also attract scavenging epifauna such as sea cucumbers, sea stars and sea-lice (isopods), which often aggregate around the perimeter of the farm (MPI 2013a,b).

Biogenic habitats perform important roles in coastal ecosystems.[5] While some biogenic habitats have higher biodiversity values than others, all may increase overall diversity, abundance, and productivity of a range of species that associate with them, including small fish. Biogenic habitats may be adversely affected by biodeposition. The fine deposited material from farms may adversely affect filter-feeding animals that form biogenic habitat; these include horse mussels, green-lipped mussels, oysters, bryozoans, and sponges. Increased turbidity may reduce light levels and this may compromise photosynthesis in plants such as seagrass, kelps/seaweeds, and maerl/rhodoliths that may form biogenic habitats. Finally, physical changes to seafloor characteristics, such as increased 'muddiness', create difficulties for larvae of species forming biogenic habitats to settle and survive through to their adult forms.

A change in the quantity and quality of seston (*e.g.* farm derived organic material vs phytoplankton) has the potential to adversely affect bryozoan communities, and their associated fauna which generally prefer coarser sediments (Batson & Probert 2000).

3.6.1.3 Deposition of additives

Metals, such as zinc and copper, are found in finfish feed and antifoulant paints, respectively. They occur naturally in the water column at trace level concentrations and organisms require these essential elements for physiological processes and growth (Champeau, 2013). However, at high concentrations these metals can be detrimental and even toxic to organisms. Metals cannot be degraded and thus can accumulate in sediments.

Therapeutants (antibiotics and parasiticides) may be released into the marine environment if they are required to be used against bacterial diseases and parasites of farmed finfish. These additives can be stable and accumulate in the sediment (Champeau, 2013). Currently, the New Zealand finfish aquaculture industry uses minimal chemicals such as antibiotics, parasiticides and other therapeutants and the risk of ecological effects from therapeutants is therefore considered very low (MPI 2013a,b). None of these chemical interventions have ever been used by Sanford in Big Glory Bay, and are not proposed at the new farm (Ali Undorf-Lay, Sanford pers. Comm.).

[5] Information in this paragraph sourced from https://niwa.co.nz/publications/wa/vol16-no4-december-2008/biogenic-habitats-and-their-value-to-new-zealand-fisheries

3.6.2 Predicted effects of this proposal

The oyster dredge fishery has operated in Foveaux Strait for over 130 years and in that time has considerably modified the benthic habitat. The original habitat, particularly in the west was largely dominated by pebble-gravel sediments and biogenic structures supporting a diverse and productive community. This habitat is now dominated by relict pebble-gravel and is now much sandier in the west. The benthic habitat in the east of Foveaux Strait and in the area of the proposed farm has received less fishing pressure but as described earlier is dominated by coarse and very coarse sand, occasionally mixed with mud or shell hash with relatively sparse epifauna and low organic matter (1.6% from a sediment sample collected near proposed Farming Area A).

Benthic communities which are exposed to high levels of natural and dredging induced disturbance generally have high resilience to change. Foveaux Strait is a high energy dynamic environment, where large oceanic swells and tidal currents shift sediments and shape habitats and their benthic communities and produce gradients of natural disturbance, sediment stability, and composition (Michael *et al*. 2010).

To determine the expected farm footprints, i.e. the spatial extent and magnitude of biodeposition from the proposed five farming area, ADS carried out depositional modelling (ADS 2019d). Deposition from fish pens was modelled using the software New DEPOMOD, a widely used particle tracking model designed for predicting salmon farm deposition. The model simulates depositional farm footprints based on bathymetry, local currents and farming practices, such as pen layouts, feed input, and stocking density.

The shape, extent, and biodeposit concentration of the farm footprint are driven primarily by the local bathymetry and hydrodynamic regime. Bathymetry data was provided by NIWA and interpolated to 35m grid resolution. To identify appropriate hydrodynamic scenarios (representing average and high flow conditions), an acoustic doppler current profiler (ADCP) was deployed north-west of the proposed farming areas, between the proposed farming areas and Ruapuke Island, for 2 weeks from August to September 2019 (see ADS 2019b).

The ADCP deployment confirmed previous reports that there are generally two main tidal current flow directions in the region of the application site (to the east and west but with a northeast and south-west component). The average current flows are approximately 0.2 to 0.4 m/s and peak current speeds in the area of are up to 0.7 m/s. To the west currents can reach 1.2 m/s.

In the context of existing salmon farms, sites with mean mid-water current speeds ≥ 0.1 m/s are considered ‘high flow’ sites (MPI 2015). At these current speeds deposited material can be resuspended and redistributed on the seabed and sites experiencing those levels of flow can be characterised as ‘dispersive’ (as discussed in Keeley *et al*. 2012). Applying this to the hydrodynamic conditions at the five proposed farming area (based on the ADS hydrodynamic model and published current information), ADS demonstrates that the five sites are dispersive (ADS 2019d).

The pen set up and operational inputs for the deposition modelling are provided in ADS (2019d) and are based on full development with grids of 2x5 pens in each farming area, pens 120 m in circumference and 38 m in diameter, pen depth of 25 m (side walls 20 m depth), stocking levels of 20 kg/m^3 (maximum predicted), 28.8 tonnes feed per day for each farming area and final biomass of 5,400 tonnes of fish per farming area. For depositional modelling both a surface and submerged pen design is modelled.

The deposition model was run using one year of current data (2017) and simulates the deposition of organic carbon and total solid deposition on the seabed. Results are expressed in kilograms of carbon per meter squared per year (kg C m^{-2} yr^{-1}) and total mass of solid material in kilograms per meter squared per year (kg m^{-2} yr^{-1}). As described above, organic enrichment can lead to changes in sediment characteristics and ecology. Based on published carbon deposition thresholds observed to trigger infauna community responses, a contour of 0.73 kg m^{-2} yr^{-1} (2 g C m^{-2} day^{-1}) was identified as representing a conservative zone in which ecological effects are expected to occur (ADS, 2019d), noting that these thresholds were developed for low energy environments. While the lack of conspicuous fauna may suggest the contours are too conservative, offshore areas could also be regarded as more sensitive because they have lower levels of organic matter than inshore sites. Monitoring during development will help address this issue.

The total solids deposition threshold of 5.2 kg m^{-2} yr^{-1} approximates the enrichment scale (ES) index of 5, as developed by Keeley *et al.* (2012) for the Marlborough Sounds (ADS 2019d). Although the ES application was developed for the Marlborough Sounds and thresholds cannot be applied elsewhere at this stage the general principals remain the same. An ES of 5 is characterised by very high enrichment, very high abundance of opportunistic species, diversity usually significantly reduced, organic content slightly elevated, bacterial matsformation and out-gassing possible (Keeley *et al.* 2012). If such conditions were observed below farms then fallowing would be recommended to allow recovery.

The results of depositional modelling are provided in ADS (2019d) and can be summarised as:

- Current flows differed between sites but were predominantly in a west/south-west or north/north-east direction. The strongest and residual currents however, were in a north-west direction at Farming Area A, westward for Farming Area B, little dispersion from Farming Areas C and E, and easterly for Farming Area D;
- Deposition of faecal material and residual feed from Farming Area A is predicted to scatter up to at least 2.5 km to the north/north-west from the pens. Carbon deposition is predicted to reach 0.25 kg m^{-2} yr^{-1} for surface pens and 0.5 kg m^{-2} yr^{-1} for submerged pens and total solids is predicted to reach 1.0 and up to 2.0 kg m^{-2} yr^{-1} respectively, in small patches a few hundred meters from the pens, respectively (see **Figures 51 and 52**);
- Deposition of faecal material and residual feed from Farming Area B is predicted to scatter approximately 1.5 km west of the pens for surface and for submerged pens, carbon deposition could reach up to 1.25 kg m^{-2} yr^{-1} under the pens for surface pens and 3.0 kg m^{-2} yr^{-1} in isolated patches under the pens for submerged pens. Total solids are predicted to be up to 4.0 and up to 5.2 kg m^{-2} yr^{-1} under the pens and up to a few hundred meters to the west of the pens, respectively;
- Unlike Farming Areas A and B, at Farming Area C the deposition is predicted to scatter more in an eclipse up to 800 m away from the pens but within the wider farming area. Carbon deposition from surface pens is predicted to reach up to 1.0 kg m^{-2} yr^{-1}, and 2 kg m^{-2} yr^{-1} within a few hundred meters of the pens and in isolated patches for the submerged pens. Total solids deposition is predicted to reach 3.0 kg m^{-2} yr^{-1} under the pens for surface pens and over 5 kg m^{-2} yr^{-1} under submerged pens (see **Figures 53** and **54**);
- Deposition at Farming Area D is predicted to be to the east/north-east over 2.5 km from the pens. Carbon deposition from surface pens is predicted to reach up to 1.0 kg m^{-2} yr^{-1} and over 3.0 kg m^{-2} yr^{-1} in isolated patches under the pens for submerged pens. Total solids deposition is predicted to reach over 2.0 kg m^{-2} yr^{-1} in isolated patches for surface pens and over 5 kg m^{-2} yr^{-1} under submerged pens and up to a few hundred metres away;
- Like Farming Area C, the deposition at Farming Area E is predicted to scatter more in an eclipse. Carbon deposition from surface pens is predicted to reach up to 2 kg m^{-2} yr^{-1} and over 4 kg m^{-2} yr^{-1} under the pens in isolated patches for the submerged pens. Total solids deposition is predicted to reach 5.0 kg m^{-2} yr^{-1} in isolated patches only for surface pens and more concentrated patches under submerged pens;

- ADS (2019d) concluded that:
    - Deposited material is predicted to scatter more than 2 km from pens for some farming areas (up to 5 km for Farming Area A) but accumulations are likely to be very low. Thresholds may be exceeded outside the farming areas for a few of the farming areas but only in isolated patches close to the farming areas;
    - There is no evidence of biogenic reefs or communities at these sites and infaunal abundance is low due to the seabed being scoured by relatively strong currents and potentially dredging in the past;
    - Deposition and resuspension will be altered at times by stronger currents and waves;
    - The relatively high currents, low diversity and infaunal and epifaunal abundance mean that the effects of deposition is expected to be minimal and deposition above the thresholds will be concentrated under the pens or nearby.

Based on previous studies discussed above and the results of depositional modelling it is concluded that effects on the benthic environment that may cause some changes in the seabed characteristics, such as sediment grain size, chemistry and faunal communities (0.73 kg C m^{-2} yr^{-1} or 5.2 kg m^{-2} yr^{-1} of total solids), will be restricted to within the 26 ha pen area and in most cases to under the pens or within each farming area boundary. Outside the pen areas small patches may exceed these thresholds up to a few hundred metres away (Farming Area B to the west, Farming Area C mainly east or west, Farming Area D to the east/north-east). It should be noted that the model is for full development and takes account of resuspension but not the decay of faecal and excess feed material and thus can be considered conservative. The area affected at these levels is considered minimal and not ecologically significant outside the farming area boundaries and will not affect higher levels in the food web.

The development will take place in stages and it will be important that monitoring is put in place to confirm that the effects on the benthic environment are no more than predicted.

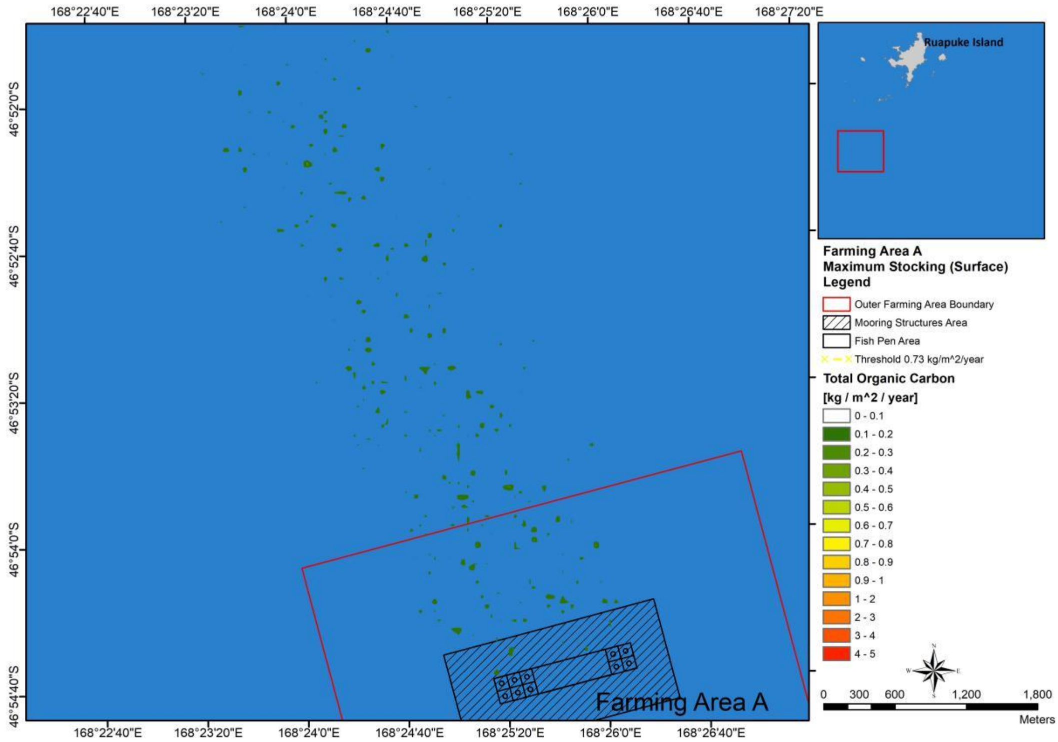


Figure 51. Farming Area A carbon deposition Surface Pen Scenario.

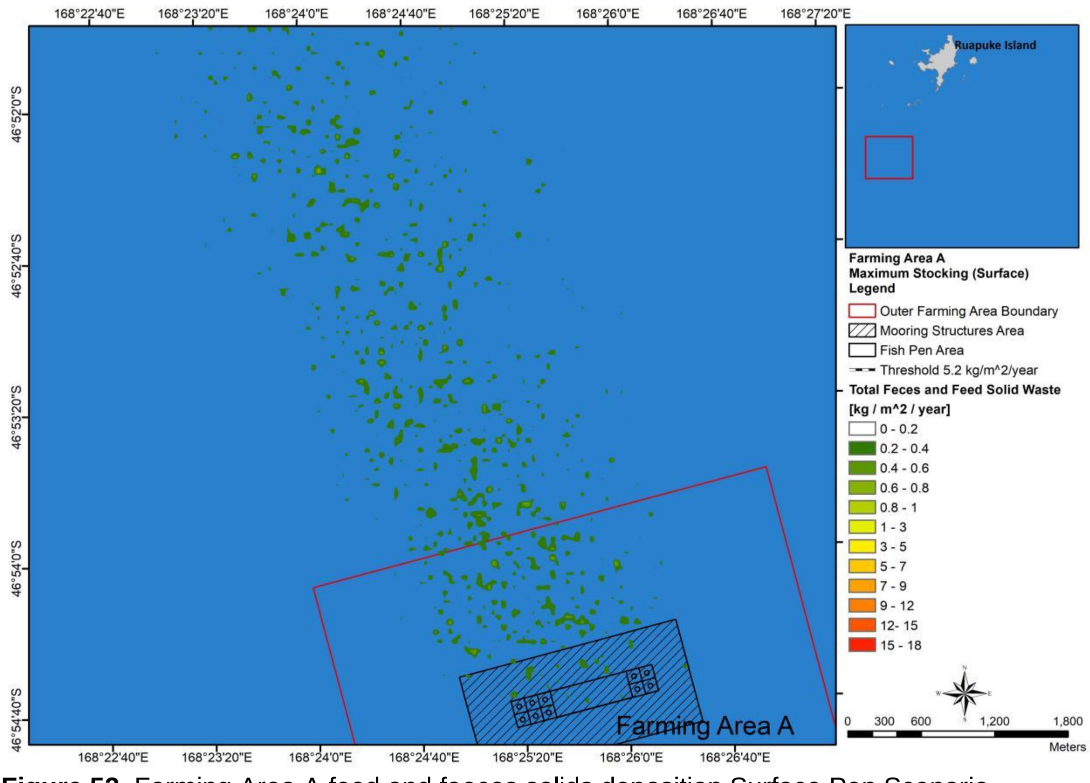


Figure 52. Farming Area A feed and faeces solids deposition Surface Pen Scenario.

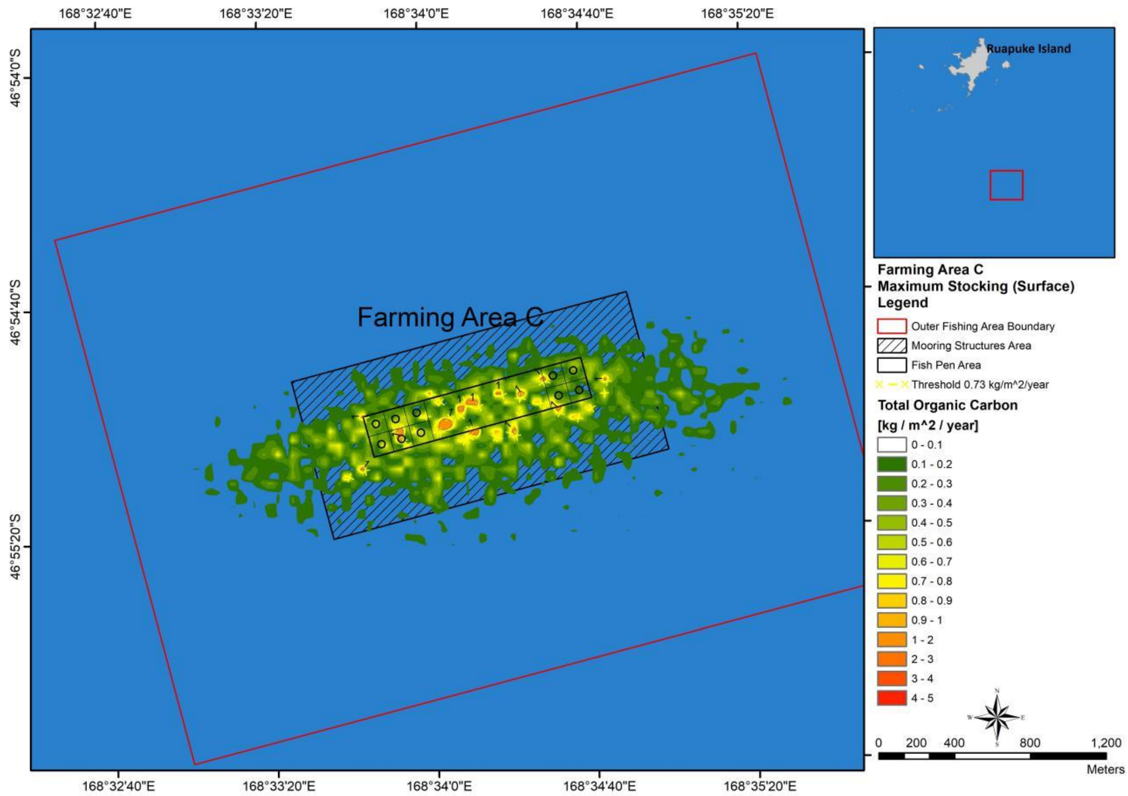


Figure 53. The depositional footprint for carbon deposition for the surface pen scenario at Farming Area C.

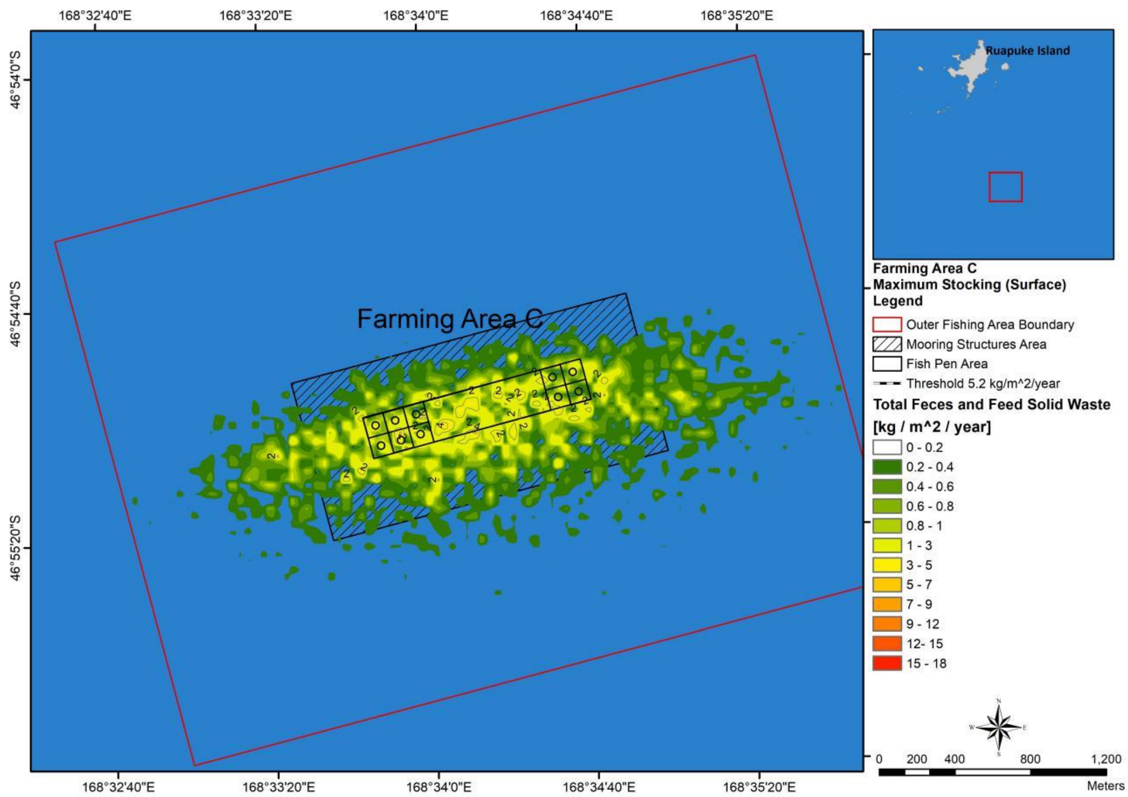


Figure 54. Farming Area C total feed and faeces solids deposition Surface Pen Scenario.

3.7 Biosecurity risk

Marine biosecurity refers to the management of risks posed by marine organisms that are potentially harmful to environmental, economic, social and cultural values (Forrest 2019). This section provides an assessment of biosecurity risks from marine pests (section 3.7.1). A risk assessment for diseases is being carried out separately and will be reported in the AEE.

3.7.1 Marine pests

3.7.1.1 Background to marine pests

Organisms that have adverse effects on the environment, including some biofouling organisms, are referred to as marine pests or harmful aquatic organisms[6]. Adverse effects on the environment include over-growing of high value biogenic habitats, and localised fouling of structures, including marine farms (Forrest *et al.* 2011). These effects are potentially irreversible depending on the species.

Some marine pests spread naturally, either via release of microscopic life stages (e.g. seaweed spores or animal larvae) to the water column (Forrest *et al.* 2007), or via release of viable fragments (Forrest *et al*. 2000; Bullard *et al*. 2007). Marine pests may also spread through anthropogenic pathways among farms, to other structures or to land and inshore areas, via transfer of aquaculture gear or vessel movement.

While finfish aquaculture may potentially exacerbate the spread of marine pests, it is unlikely to significantly increase the level of biosecurity risk because of the many other sources of biosecurity risk in the coastal marine area (Forrest *et al.* 2015). Finfish farms thus predominantly act as "stepping stones", enhancing spread of marine pests, even if they were not the original source of the marine pest in the region.

To support this application, an assessment of marine pest risks associated with the proposed activity was prepared by Salt Ecology (Forrest 2019). This section on marine pests summarises the findings of Forrest (2019). Parts of Forrest (2019) have been reproduced verbatim.

3.7.1.2

[6] The NZCPS 2010 defines harmful aquatic organisms as "Aquatic organisms which, if introduced into coastal water, may adversely affect the environment or biological diversity, pose a threat to human health, or interfere with legitimate use or protection of natural and physical resources in the coastal environment."

3.7.1.3 Existing biosecurity risk

Understanding the existing marine pest profile and risk is an important prerequisite for the assessment of the incremental risk posed by the proposed activity. This section describes existing marine pests in Foveaux Strait, their potential effects and management.

Around 214 marine non-indigenous species (NIS) have been introduced to and have established in New Zealand. Most entered the country at ports via shipping-related mechanisms, for example as ballast water discharge and hull biofouling. Once introduced, NIS can be spread in the coastal marine area via human activities, for example domestic boating, or by dispersal of microscopic life-stages in water currents. Established NIS are almost impossible to eradicate. NIS are considered a major threat to marine environments globally. Those NIS that become problematic are referred to as marine pests.

Despite the high number of introductions to New Zealand, only a few NIS have been designated as marine pests due to their actual or potential effects on areas of high conservation value, or on economically important sectors such as aquaculture. Environment Southland has listed seven marine organisms as pests in the Southland Regional Pest Management Plan (SRPMP 2019).

The only SRPMP-listed pest known to be present in the Southland region is the Asian kelp *Undaria pinnatifida*. *Undaria* is well-established in Big Glory Bay (BGB), an arm of Paterson Inlet, and also in Bluff Harbour and Half Moon Bay. *Undaria* is also described from a few other localities in Southland, including around Ruapuke Island immediately northwest of the proposal area (SRPMP 2019).

Undaria is listed as a 'progressive containment' species in the SRPMP, with an objective and associated rules that aim to progressively contain and reduce its geographic distribution and prevent further infestations. The rules include a requirement for vessels to be kept free of *Undaria*, unless they are operating exclusively within either of two designated exemption areas (maps shown in Forrest 2019, Appendix 3), of which the 'Southern Undaria Exemption Area' appears to encompass the farming areas.

There have been no comprehensive studies of marine pest effects in the Southland region, and few such studies nationally. Even for species with a prior history of invasiveness, and for which there is site-specific knowledge of effects, there are inherent uncertainties in predicting the magnitude of adverse effects in new habitats. The extent of invasion and related consequences can change from place to place, and also change over time at a given location, as documented by pest case studies in New Zealand (see references in Forrest 2019). Predicting the consequences of marine pest spread therefore remains a significant challenge.

The MPI (2015) marine pest guide describes a range of effects from the six high-profile pests already established in New Zealand. These effects are summarised in **Table 9**. Broadly, the types of effects attributed to the SRPMP pests, and other MPI-designated pests and nuisance NIS, include the following:

- Ecological effects on species or habitats in natural ecosystems, via direct or indirect (e.g. via food web changes) processes;
- Adverse effects on conservation values, or fishery resources of recreational, commercial or customary importance, as a result of changes to natural ecosystems.;
- Physical effects on commercial, recreational or amenity values; and
- Effects on the natural character of coastal ecosystems.

Although geographically isolated, the Southland region is reasonably well-connected domestically and internationally by vessel movements and other anthropogenic activities that could contribute to biosecurity risk.

The wider area of the proposed development is well-connected by vessel movements, including from potential source regions for marine pests. Beyond the immediate application site, there is considerable existing commercial vessel activity in BGB and Paterson Inlet. Much of this activity is related to mussel and salmon aquaculture in BGB, but additional vessel activity arises from movements of tourist charters, cruise ships, research vessels and private recreational vessels, sometimes arriving from out of the region. Additionally, there are many vessel pathways to and from Bluff, and its associated hub of domestic and international vessel activity.

Several biosecurity practices are in place for activities taking place in the Foveaux Strait and Steward Island area. These include consent requirements related to mussel spat source regions and transfer and practices arising from Controlled Area Notice (CAN) provisions (including restrictions on the movement of shellfish and hull inspections and cleaning) that have been implemented by MPI (MPI 2017) to minimise the risk of introducing the parasite *Bonamia ostreae* into southern New Zealand.

Table 9. Summary of habitats and potential effects of Southland Regional Pest Management Plan marine pests. Taken verbatim for the most part from information reported in MPI (2015) marine pest guide, except for *Didemnum vexillum*. Source: Forrest (2019), Table 2.

Species and habitat	Potential impacts
Charybdis japonica • Low tide to 15m depth • Sand and mud • Estuaries, harbours and most coastal habitats	• Highly detrimental to shellfish aquaculture • Aggressive predator • Displaces native and fisheries species • Can carry diseases that affect crab, lobster, shrimp and prawn fisheries
Didemnum vexillum • Low intertidal to up to 65m depth • Mainly on artificial structures in NZ including aquaculture, seagrass, and biogenic habitat suspended off seafloor • Estuaries, harbours and coasts, sheltered/semi-sheltered environments in NZ, but can invade deep open coastal habitat overseas	• Can form dense colonies • Fouls boats, aquaculture installations and other structures • Could displace important native New Zealand species, including Greenshell mussels • Described in one area overseas as smothering deep water gravel habitat across an area of 230km^2
Eudistoma elongatum • Intertidal to subtidal • Sand, mud, rock or seagrass beds • Aquaculture structures, wharves, pontoons and buoys • Estuaries, harbours and coasts, sheltered/semi-sheltered environments	• Can form dense colonies • Displaces native and fisheries species • Smothers beaches, rocks, tidepools • Fouls boats, aquaculture installations and other structures
Pyura doppelgangera • Rocky intertidal and shallow subtidal • Grows on hard surfaces in soft sediments	• Forms dense populations or mats, and can survive over a wide geographical range • Could displace important native New Zealand species, including Greenshell mussels
Sabella spallanzanii • Low tide to 30 m depth • Sheltered harbours to semi-exposed rocky coasts and reefs • Wharves, pontoons and aquaculture structures • Attaches to hard surfaces in soft sediments • Prefers polluted/nutrient-enriched waters	• Can form dense colonies (1000 individuals/m^2) • Displaces native and fisheries species • Highly effective filter-feeder • Preys on larvae of fisheries species • Disrupts natural ecological balance • Fouls boats, aquaculture installations and other structures
Styela clava • Low intertidal to 25 m depth • Rocky coast and reef • Wharves, pontoons and aquaculture structures • Grows on other organisms	• Can form dense colonies excluding other organisms • Highly effective filter-feeder • Preys on larvae of commercially important fisheries species • Displaces native and fisheries species • Fouls boats, aquaculture installations and other structures
Undaria pinnatifida • Intertidal to 40 m depth • Wharves, pontoons and buoys • Rocky coasts and reefs • Sheltered to exposed environments • Grows well in nutrient-enriched waters	• Very fast growing and can form dense colonies displacing native and fisheries species • Fouls boats, aquaculture installations and other structures

3.7.1.4 Potential effects of this proposal on marine pests

Aquaculture in New Zealand does not contribute to marine pest risk at the border but is vulnerable to the 'downstream' risk that arises from pest introductions from overseas and can itself become an exacerbator of risk when pests establish: (i) within marine farming areas; or (ii) in locations connected to marine farm regions by vessels and other pathways.

There are three main ways that finfish aquaculture can potentially contribute to marine pest risk, which are all relevant to the present proposal. Marine pests also have the potential to establish and spread due to factors and events unrelated to aquaculture activities; however, with respect to aquaculture itself, the three key processes are as follows:

1. *Risk pathways associated with aquaculture activities lead to marine pest introduction to farm sites or further spread*

   The movements of vessels associated with aquaculture, as well as transfers of equipment and stock, may lead to the unintentional introduction of marine pests to farm areas, or exacerbate pest spread within and among growing regions. The spread of pests as 'hitch hikers' within hull biofouling is a particular risk from such movements.

   Other vessel-related mechanisms also potentially exist, such as pests associated with debris on deck areas, sediments (e.g. on anchors), and in retained water such as bilge. However, for most of these additional mechanisms evidence is lacking as to their significance.

2. *Farms provide habitats and a reservoir for marine pests*

   Aquaculture structures provide a novel habitat for certain marine pests, in particular biofouling organisms. Certain species can become prolific on farm structures, without necessarily being equally invasive in natural habitats. The development of significant reservoirs of pests on marine farms can affect farming operations and exacerbate spread to the wider environment. The latter may be enabled by natural dispersal processes or through interactions between the pest reservoir and secondary transport vectors.

3. *Farm faecal material and residual feed may create environmental conditions suitable for marine pests*

   Marine farm deposited material can modify the local aquaculture environment, which has the potential to create environmental conditions suitable for the establishment or proliferation of certain marine pests. Relevant processes include nutrient and organic enrichment of the water column and seabed, and the effects of biofouling drop-off (e.g. as a food source).

3.7.1.5 Assessment of effects of proposed activity

The assessment provided by Forrest (2019) and summarised here considers incremental marine pest risk at two spatial scales. The first is to assess how the proposed operation could alter regional risk, in particular through the introduction or spread of SRPMP pests from other regions, or by enhancing the regional spread of established species like *Undaria*. The second is to consider the significance of the proposal at the local scale of the farms and their environs. At this local scale, farm development will establish a hub of activity and provide a surface area of structures for biofouling, which does not currently exist; the closest area of existing marine farming is BGB which is over 20km to the south. As such, part of the assessment involves addressing the extent to which risk to the local environment may be exacerbated by the proposal, considering not only the deep soft sediment habitats in the immediate vicinity of the farming areas, but also the high value habitats adjacent to those farming areas; in particular the shallow subtidal rocky habitats of Ruapuke and other small islands in the vicinity.

To address risks due to specific pests, it is necessary to consider the extent to which the general region and specific application site provide environments (e.g. temperature regime, benthic habitat) that are suitable. Simultaneously, it is also necessary to understand the connectivity among the proposed farming areas, and between the farming areas and adjacent natural marine habitats, with respect to the potential spread of pests that are introduced by anthropogenic pathways. Such an assessment requires an understanding of the interaction between the hydrodynamic environment (water currents) and the biological attributes of pests that facilitate their dispersal, e.g. duration of larval competency in the plankton.

A base assumption for the assessment is that, despite the vessel activity evident in the wider area, and given the distance to possible pest source populations in BGB, the application site is unlikely as yet to have been colonised by SRMPM marine pests; it is relatively isolated from significant anthropogenic reservoirs and, for many pest species, is unlikely to be vulnerable to natural dispersal, especially given the wave exposed nature of the area.

The risk and potential effects of the proposal, a subjective rating of their significance and the type of management required to reduce risk to a negligible level as reported by Forrest (2019) is summarised in **Table 10**. The summary in **Table 10** reflects that the most significant marine pest risk associated with the proposal arises from the movement of vessels and other vectors associated with salmon farming activities. Of particular importance are vessels or equipment that arrive from source regions having pests that have not been recorded in Southland.

Although the risk of introducing new pests to the region is already present due to existing activities, the proposal has the potential to introduce such species into a part of the region that is relatively isolated from current influences. Furthermore, the proposal will create a hub of activity in that area with the potential to contribute to the ongoing regional spread of pests. However, these are all risks that can be effectively managed to an extent where the level of residual risk is negligible and acceptable.

The other issues addressed by Forrest (2019) and summarised in **Table 10** relate to potential effects due to farm structures creating reservoirs for marine pests, and faecal material and residual feed modifying the environment in ways that facilitate pest establishment or proliferation. By contrast with the risk arising from vessels and other pathways, these are relatively minor considerations in the case of the proposal. The reservoir effect of the farms will be in part limited by the need to maintain fouling to low levels for operational reasons. Spread and establishment in the natural environment will be restricted or negated by the relatively isolated location of the farming areas, in a location with harsh environmental conditions that will limit pest establishment or proliferation. These conditions include water depths beyond the reported habitat range of most recognised pests, as well as a high energy wave/current environment and relatively featureless soft-sediment habitats in the farm environs.

Detailed recommendations for risk pathway management, surveillance and on-farm management and broader considerations to be included in a Biosecurity Management Plan (BMP) are provided in Forrest (2019). They are summarised in the Section 4 of this report and will be incorporated in the Biosecurity Management Plan prepared for the proposed activities.

Table 10. Summary of potential effects resulting from the proposal, their significance, and the type of management required to reduce risk to a negligible level.

Proposal risk	Potential effects	Incremental significance	Mitigation
PATHWAY RISK			
Farm-related vessels or other pathways from external source regions with pests not recorded in Southland	New pest introduced to farm location that could spread further and cause adverse effects	**Moderate:** Farm-related practices are a potential pathway for introduction and further spread of new pests to proposed farming area, although risk arises due to existing unmanaged activities	Effective management of external vessels and other pathways, especially of biofouling
Farm-related vessels and other pathways operating within-region only	Incremental spread of pests already established in the region	**Negligible to moderate:** Moderate potential for regional scale pest spread already exists due to other unmanaged activities. However, farm-related within-region activities potentially significant if farm area is first point of introduction	Effective management of within-region vessels and other pathways, especially of biofouling
RESERVOIR RISK			
Reservoir of pests establishes on farm and facilitates local spread	Surrounding natural habitats and associated values (e.g. fishery resources, natural character) adversely affected	**Minor:** Adjacent soft-sediment seabed habitats generally unfavourable for pests. More distant hard substratum habitats (e.g. rocky reef) may be susceptible, but some risk already exists due to anthropogenic pathways.	Maintain low level of fouling on farm structures that is consistent with operational needs for biofouling control
Reservoir of pests establishes on farm and facilitates regional spread	Regional scale spread of new or existing pests leading to adverse effects, including on aquaculture in Big Glory Bay	**Negligible to moderate:** Negligible risk of regional spread by natural dispersal. Moderate risk where there is potential for a new pest to be further spread by farm-related activities.	Operational control of biofouling on farm structures, combined with effective risk pathway management
PEST ENHANCEMENT			
Impact to seabed or water column from farm wastes facilitates pest establishment or proliferation	Pest abundance on farm structures or adjacent seabed enhanced, with potential for further spread and adverse effects	**Negligible:** Farms wastes unlikely to significantly modify local environment to the extent that overrides other conditions (e.g. unsuitable seabed habitats) that limit establishment	No specific measures required

3.8 Effects on wild fisheries

3.8.1 Potential effects

Fish farm structures and faecal material and residual feed may attract wild fish species seeking refuge and food sources (Cornelisen 2013). The consequences of attraction on wild fish could be positive (creating habitat and increasing food availability, both of which could enhance wild fish populations) or negative (potentially displacing regional fish populations from other habitats or making fish more vulnerable to recreational harvest; Cornelisen 2013). Larger farms located in shallow waters closer to the coast are expected to attract more wild fish species (Cornelisen 2013). Wild fish aggregations may attract other predators such as seals, dolphins or sharks. It may also increase or decrease fishing pressure on wild fish populations, depending on the extent of protection afforded to fish aggregating near farm structures (Cornelisen 2013).

The use of submerged artificial lighting at night can result in further attraction of wild fish species and enhance predation on organisms attracted to the lights (Cornelisen 2013). While small baitfish may enter salmon cages and have been observed to be predated upon by the farmed fish, the extent to which lights enhance the attraction of baitfish into farm structures is unknown.

Finfish farms can adversely affect wild fish if they are placed directly above or adjacent to benthic habitats (e.g. spawning areas or rocky reefs) and lead to degradation of these habitats, particularly through biodeposition from faecal material and residual feed (Cornelisen 2013). Assessment of such effects are closely aligned with the assessment of seabed effects.

There is a risk that farmed fish may escape (Ford 2013). Escapees may compete for resources with wild fish, predate on wild species and potentially alter the genetic structure of wild salmon fish populations (change in fitness, adaptability, diversity or reduced survival) although this is less likely with chinook salmon that face natural mortality post spawning. Escapees may also transfer pathogens to wild fish (also see section ‘Biosecurity risk – Diseases’).

3.8.2 Potential effects assessment of the proposed activity

The effects on the benthic community and food resources from the proposed farm will be very localised and decrease away from the farming areas thus flow-on effects on wild fish populations are not expected. The location in deep water and away from shallow water reefs and habitats will reduce the risk of fish aggregations compared with inshore farms but there is likely to be attraction of larger predatory pelagic fish around the farms.

The potential effect and risk of escapees and passing on pathogens is considered low in New Zealand because of the small size of the industry, the limited overlap of farmed and wild salmon populations, the limited salmon numbers in the wild populations within existing grow-out regions and the fact that the wild populations are non-indigenous. This is likely to be even more applicable to offshore farms, such as the application site.

The potential effect and risk of escapees depends on a range of factors, including the farmed species (especially whether fish are native or introduced), the number of escapees, the proximity of the farm to wild fish populations and the ability of escapees to survive and reproduce. At present, the likelihood of adverse escapee effects is considered low in New Zealand because of the small size of the industry, the limited overlap of farmed and wild salmon populations, the limited salmon numbers in the wild populations within existing grow-out regions and the fact that the wild populations are non-indigenous (Ford, 2013; Forrest *et al.* 2007). This is likely to be even more applicable to offshore farms such as that proposed in this application.

There is likely to be some overlap of the farming areas with commercial fisheries. The nationally important oyster fishery is based mostly to the west of Ruapuke Island but the farming areas and depths occupied do overlap with areas in Foveaux Strait for flatfish, gurnard, red cod, stargazer and warehou. These are small seasonal fisheries with 6 small boats mostly set-netting part of the year.

Middleton (2019) reports that overall 3.9% of bottom trawl tows in statistical area 025 started or ended within the overall farming areas. However, typical tow lengths are estimated to be 10-20 km long and because of the arrangement of the farming areas and the gently sloping bathymetry, trawling activity should be able to continue around the farms.

3.9 Effects on seabirds

Seabirds potentially affected by finfish farms are likely to include shags, gulls, terns and penguins.

The main matters requiring consideration for seabirds from the application are:

- Exclusion from foraging habitat by farm structure;
- Smothering of benthos affecting food sources;
- Alteration of water quality affecting food sources;

- Changes in abundances of prey (e.g. attraction of wild fish, enhancement of plankton populations);
- Provision of roosts;
- Disturbance by farming activities, including vessel movements to and from ports;
- Ingestion of foreign debris;
- Attraction by lights;
- Entanglement; and
- Collision with marine farm structures.

Of these exclusion, entanglement and collision with farm structures are considered to be the most important considerations. Overseas inshore fish farms report varying levels of mortality for a variety of seabird species, but notably species of gulls and cormorants/shags are often involved in interactions (see summary in McClennan 2019). No mortality has been reported from New Zealand fish farms (Buttler 2003, Lloyd 2003, Sagar 2012). Huon Aquaculture operates open ocean fish farms in two areas of Australia, and has reported c.50 deaths of seabirds, including several species of gulls and cormorants[7].

Shifting salmon farming operations into an open ocean situation is likely to reduce the potential effects on seabirds of exclusion from foraging habitat, as 'open ocean' seabird species generally have very large foraging ranges. The shift to open ocean farming is also expected to reduce the effects on benthos (see benthic effects section) and water quality, and possibly plankton enhancement, given the stronger currents present offshore. However, the shift exposes the farming operation to a much greater diversity of seabird species than is present in an inshore situation. The extent of potential interactions of these species with an open ocean farm are not known as there are none operational in New Zealand at present.

Potential effects assessment of the proposed activity

McClennan (2019) provides an assessment of the potential effects based on information available. McClennan's assessment can be summarised as:

- Because of a lack of effects on the benthic food resources, depth of feeding and wide foraging areas habitat exclusion is not considered to be an issue for bottom feeding birds pelagic feeding groups such as shearwaters (including titi or muttonbird), petrels and albatross;

[7] Information from, Huon website https://www.huonaqua.com.au/

- Exclusion will not be an issue for seabird groups such as gulls, terns, most shags, other penguins and gannets because of their wide foraging areas and small area affected;
- The threat status for yellow-eyed penguins and Foveaux shag is acknowledged and could potentially be a concern, however, the pens will comprise only a very small fraction of the available foraging area for these species;
- Reductions in benthic food for demersal feeding birds, including yellow-eyed penguin and Foveaux shag, are predicted to be very localised to within the farming areas and the area affected would be insignificant compared with their foraging ranges;
- Wild fish are likely to aggregate around open ocean farms attracting a number of bird species. This may have positive benefits through increasing food in a small area but may increase the risk of entanglement;
- Marine farm structures will increase roosting opportunities but again may increase the risk of entanglement;
- Vessel traffic past breeding or roosting locations is not an issue due to the offshore location of the farms. Marine farm vessels may disturb birds that are on the water resting or foraging, but this is likely to be only over short periods and will be insignificant;
- Best practice will be necessary to minimise the risk of foreign objects and debris;
- Entanglement in nets is probably the biggest single risk to seabirds and overseas open ocean farms have reported with gulls being the main group at risk. This risk can be minimised with the use of highly visible bird netting, reduced mesh size and stronger netting over the top of pens, no predator nets and no loose ropes. Some diving species such as shags and blue penguins will potentially still be at risk but this willbe minimised with the proposed pen netting. Larger species such as the Fiordland crested penguin and yellow-eyed penguin are less likely to be at risk than smaller species. The risk of entanglement and any significant effect on populations was assessed as low for petrels, mollymawks, gannets (can probably see the mesh netting), and albatrosses;
- There is a risk of collision with farm structures, depending on the level of lighting but again this risk can be minimised by downward facing lights; and
- To reduce the risk of effects on a number of species and in particular yellow-eyed penguins, Foveaux shag and red-billed gulls various management measures will be implemented by Sanford. Best practice with surface nets, and submerged pens without predator nets or stronger mesh could largely eliminate these risks.

In summary the area around the proposed salmon farm and Ruapuke and nearby islands provide foraging grounds and support breeding populations for a number of species some of which are threatened or where most of the New Zealand population is supported in this area. The main concerns are exclusion and entanglement and in particular for Foveaux shag and yellow-eyed penguin population because of their threat ranking and importance of this area. Exclusion effects will be limited due to the pens only comprising a very small fraction of the available foraging area for these species. Best practice management measures in respect of surface and submerged net design will be implemented to minimise the risk of entanglement.

3.10 Effects on mammals

3.10.1 Overview of effects

Most consequential interactions between marine mammals and aquaculture result from a direct overlap between the spatial location of the facilities and important habitats (i.e. feeding or nursing) and/or migration routes of the species (Clement 2013). Most existing New Zealand finfish farms are located in inshore waters with few resident populations of marine mammals. The movement of aquaculture to more offshore waters means that interactions with baleen whales and larger pods of dolphins (e.g. greater than 50 animals) are more likely (Clement 2019).

Clement (2019) summarises the potential effects of salmon farming in the application site on marine mammals as follows:

> The main potential effects of the proposal are possible habitat displacement or avoidance and entanglement risk. Other matters considered include underwater noise, artificial submerged lighting and trophic flow-on effects. The probabilities of effects occurring are highly dependent on the farm structures (e.g. types / material of pens, use of predator nets, warp line configurations), farm management (e.g. taut nets and no loose ropes) and pen layout (e.g. scale, intensity, spacing between pens) as well as the species involved and their demographics (e.g. calves present, age). While the overall likelihoods of these effects are considered low to moderate, the potential consequences of a rare event (such as the death of an endangered species) means best practice management measures are required. The development of a Marine Mammal Management Plan (MMMP) prior to commencing operations is recommended to ensure that the most appropriate protective measures are in place to reduce any residual effects.

The remainder of this section provides a summary of information (mostly verbatim) provided in the report by Clement (2019) for potential effects from:

- Habitat exclusion/displacement,
- Entanglement,
- Underwater noise disturbance,
- Artificial lighting,
- Possible flow-on effects due to alterations in trophic pathways, and
- Cumulative effects.

A summary of the potential effects identified by Clement (2019) is also provided in **Table 11**.

3.10.2 Habitat exclusion/displacement

As the proposed farms will consist of novel and stationary structures located within the open waters of Foveaux Strait, they may be perceived by marine mammals as physical, visual or acoustic obstructions that they may choose to ignore, investigate or avoid. As noted in the 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 more uncertainty around their possible responses.

Based on the limited evidence available, the likelihood for habitat displacement or avoidance behaviours associated with the proposed farm is considered low for pinnipeds, dolphins and most whale species. Some species, such as bottlenose dolphins, fur seals and orca, are more likely to be attracted to the farm structure as a food source, and thus the risk of attraction is considered moderate but with the proposed management measures put in place would be no more than minor. This assessment is based on the relevant factors listed in **Table 11**.

3.10.3 Entanglement

Within New Zealand, fatal entanglement of marine mammals in aquaculture structures has been a relatively minor issue to date (Clement, 2013), despite over 50 years of marine salmon farming and several decades of oyster and mussel farming. However, it is unclear how this record relates to the frequency of physical interactions (including non-fatal injuries) taking place between species and the industry. Without records of the absence of species near farms and/or the lack of interactions of animals with farms (also known as negative data), we cannot quantify the real level of risk or place it in context (i.e. paucity of entanglements because farms are relatively benign or density of farms and reporting is too low to detect potentially injurious interactions; Price *et al*. 2017).

However, records of previous New Zealand entanglements along with oversea data (particularly from Australia) inform which New Zealand marine mammal species may be more vulnerable to entanglement risk as well as which farm configurations or gear may increase or reduce the risk. Operational aspects can greatly influence the possible outcome (i.e. injury vs mortality) of any interactions and therefore, the overall risk (Clement, 2013).

Overall, the likelihood for a fatal entanglement is considered low for all species and evidence from overseas and within New Zealand demonstrates that entanglement risk can be reduced through proper siting, appropriate design and maintenance features, and standard operational procedures and protocols.

3.10.4 Underwater noise disturbance

Clement (2013) noted that the level and persistence of any underwater noises associated with a finfish farm are expected to be minimal relative to other underwater noise sources. However, underwater noises associated with farms will vary according to farm features (e.g. type, size), habitat characteristics (e.g. location, depth, types of bottom sediments, shape of coastline) and compounding factors, such as the number of farms and / or other noise sources in nearby regions.

In this case, any effects of anthropogenic noise generated from the proposed salmon farm and associated operations are expected to be nil to negligible on local marine mammal species with appropriate management (**Table 11**). Any additional noise from farm operations and vessels will likely attract species such as fur seals and bottlenose dolphins to the farms; the greater risk of any attraction to farm structures is potential entanglement issues. Southern right whales may also be attracted, given their curious nature, or may avoid the area depending on the scale of operations and resulting noise levels.

Table 11. Summary of potential effects of the proposal on relevant marine mammal species. Source: Clement (2019), Table 2.

Potential environmental effects	Spatial scale of effect on marine mammals	Persistence / duration of effect for marine mammals	Consequence(s) for marine mammals	Likelihood of effect	Avoidance Factors / Management Options (see Section 4 and Table 2)	Significance level of residual effect
Habitat / prey disturbance from farm structures and associated activities	**Medium to Large** Limited to immediate waters and habitats adjacent to the farm(s)	**Persistent** Farm structures will be permanent for the length of consent; most species only present in area for hours to days	**Individual to Regional Level** Local avoidance / abandonment by sensitive species / individuals; or age groups (e.g. mating groups	**Low-** Avoidance	• Record (visual, acoustic or both) and report the type and frequency of marine mammal interactions (including absences and effort) to build a local / regional picture	**Less than Minor to Minor**
			Individual Level: Pinnipeds / dolphins may approach site	**Moderate -** Attraction		**Nil to Negligible**
Entanglement in farm structure and / or debris	**Medium to Large** Limited to immediate area and habitats within and adjacent to the farm(s)	**Persistent** Farm nets and ropes will be permanent for the length of its consent; most species only present in area for hours to days	**Regional to Population Level** Death or injury of endangered or threatened species	**Low**	• Avoid or minimise operational changes (i.e. predator nets), installation or decommission during critical migration periods • Avoid loose ropes, no predator nets, keep all lines under some degree of tension • Make lines easily detectable and investigate methods to stiffen • Avoid overlap or crossing of warp lines between pens	**Less than Minor**
			Individual Level Death or injury of non-threatened pinniped or dolphin	**Low**		**Negligible**
Increase in underwater sound from farm structures / vessels	**Small to Large** Dependent on types of noise produced and frequencies	**Short to Persistent** Farm permanent; noise sporadic and potentially more seasonal	**Individual to Regional Level** Individual avoidance by whales or certain age groups; local attraction of pinnipeds and some dolphins	**Low -** Avoidance **to Moderate -** Attraction	• Minimise above-water and underwater noise to reduce the exclusion (or attraction) of wildlife	**Nil to Negligible**
Attraction to artificial submerged lighting	**Small to Medium** Dependent on types of lights and location within the farm	**Short to Persistent** Farms permanent; seasonal lighting at night-time only	**Individual** Local attraction of pinnipeds and some dolphins	**Low to Moderate**	• Minimum amounts of lighting and proper positioning to reduce the attraction of wildlife	**Nil to Negligible**
Flow-on trophic effects to marine mammals	**Medium to Large** Limited to immediate waters and habitats adjacent to the farm	**Short to Persistent** Dependent on trophic effect; potential seasonality	**Individual Level** Local avoidance; individuals may approach for foraging opportunities	**Not Applicable to Low**	• Ensure proper site placement	**Nil to Less than Minor**

Definition of terms used in table:

- Spatial scale of effect: Small (tens of metres), Medium (hundreds of metres), Large (> 1 km)
- Persistence of effect: Short (days to weeks), Moderate (weeks to months), Persistent (years or more)
- Consequence: Individual, Regional, Population level
- Likelihood of effect: Not Applicable (NA), Low (< 25%), Moderate (25–75%), High (> 75%)

- Significance level: Nil (no effects at all), Negligible (effect too small to be discernible or of concern), Less than Minor (discernible effect but too small to affect other animals), Minor (noticeable but will not cause any significant adverse effects), More than Minor (noticeable that may cause adverse effects but could be mitigated), Significant (noticeable and will have serious adverse effects but could be potential for mitigation).

3.10.5 Artificial lighting

To date, the few studies overseas or within New Zealand that have focused on the effects of submerged lights associated with finfish farms suggest they attract large aggregations of schooling baitfish to the pens that in turn may increase night-time predation by marine mammals and other species. As a result, marine mammals will more likely be attracted to any increase in noise and activity of caged or wild fish in response to the lights rather than the lights themselves. The effect of this attraction then becomes more of an entanglement issue (**Table 11**).

3.10.6 Possible flow-on effects due to alterations in trophic pathways

There is the potential for wider, more indirect ecosystem effects on marine mammals due to aquaculture in the form of food-web alterations. In general, the large-scale home ranges and generalist feeding-strategy of most marine mammals ensure that any localised effects to potential prey resources do not often have any substantial flow-on effects to the population. The only marine mammals expected to occur near the proposed farming areas with any regularity are NZ fur seals. However, this species likely forages throughout Foveaux Strait and off the nearby continental shelf edge. The lack of any marine mammal species foraging extensively within this region of Foveaux Strait means that even if there are some localised effects on prey resources (not predicted with this application), then this would likely to have a minimal effect on the relevant marine mammal species (**Table 11**).

3.10.7 Cumulative effects

The likelihood of most of the above effects occurring is dependent on the scale and intensity of the finfish farms within the proposed application site relative to the amount and types of habitats needed for the various functional requirements of the different marine mammal species, as discussed throughout this report. Other anthropogenic activities also affect the environment in which Southland marine mammals live including bycatch in fisheries; bottom disturbance (e.g. fishing dredges and trawls); commercial shipping to and from South Port, tourism and ferry boating impacts, and the underwater noise associated with most of the above activities.

Few studies to date have researched the potential cumulative effect of multiple anthropogenic activities on marine mammals. As a result, attempts to regulate any of these issues, individually or cumulatively, are currently extremely difficult as little is known about their biological significance for any species of marine mammal. The review by Price *et al.*. (2017)

indicated that there is a need globally for a formal risk analysis of potential aquaculture interactions in comparison to other marine activities such as fishing, shipping, and boating.

4 MONITORING AND MANAGEMENT OF EFFECTS

As discussed above the severity and spatial extent of water column and sediment effects depend on site-specific factors such as water depth, current speed and direction, and habitat characteristics. Environmental effects are to be managed by staging the development of the farms, managing stocking densities, minimising residual feed and optimising feed conversion ratios and implementing best practice for risks associated with biosecurity, birds and mammals. An outline of the recommended monitoring programme and measures for managing effects and are discussed in this section and summarised in **Table 12**.

4.1 Monitoring

Appropriate standards will need to be set to ensure the effects of the proposed development are no more than predicted and are appropriate for the area. There will need to be a comprehensive BMP and an environmental monitoring plan (EMP) developed that ensures these standards are met and sets out actions required if thresholds or limits are exceeded. Full baseline surveys would be carried out prior to any development.

As the proposed development is the first offshore finfish farm in the region (noting that an application has been made by Ngai Tahu off the northern coast of Stewart Island) it is recommended the following be monitored:

4.1.1 Benthic habitat monitoring

The main concerns for the seabed are the deposition of faecal material and residual feed on to the seabed and subsequent changes to the biochemistry and faunal and floral communities below the farms. Note that there is a relatively rapid improvement with increasing distance from the edge of the pens. The pens only occupy a very small area. In addition, as long as the effects do not reach a tipping point then they are largely reversible if pens are moved away.

The monitoring of benthic effects of salmon farms is mandatory in most countries and occurs at existing salmon farms in New Zealand, with standards set for a number of indicators, which if breached will lead to further investigations or eventually management actions if necessary. These standards or indicators are aimed at retaining a functional benthos around salmon pens. Potential indicators include benthic community diversity and number of taxa, observations on outgassing, presence of bacterial mats, and levels of copper and zinc.

The seabed (benthic habitat) should be monitored in accordance with the following programme:

- Benthic samples be taken within the application site (at the edge of pens and at various distances away from the pens in each farming area in the direction of the residual current to delineate the extent of effects), and at reference sites.

- Sampling to use the most appropriate technology at representative sites and to include:

    - Grabs for sediment characteristics (grain size, total organic matter (TOM), total organic carbon (TOC), depth of redox layer and hydrosulphide smell;

    - Grabs for infauna analysis including number of individuals, number and type of species/taxa and species diversity; and

    - Photoquadrats and/or video imagery (if conditions are suitable) for epifauna characterisation and qualitative analyses of any bacterial mats and observations of any outgassing.

- Baseline monitoring should be carried out prior to any development commencing to provide a robust and defensible baseline; and then monitoring after Stage 1, Stage 2, Stage 3, and Stage 4 are developed.

Reviews of the results at each stage will be used to refine and adaptively develop the monitoring programme.

A number of individual parameters and indicators have been applied to describing the effects of existing marine farms on the benthic environment. Triggers and standards to be met for this offshore farm will need to be developed and set out in the proposed conditions and will be included in the EMP to be submitted.

4.1.2 Water column

The main considerations for the water column will primarily be potential nutrient enrichment through excretion (primarily as ammonium-N) and breakdown of faecal material and residual feed which can stimulate phytoplankton growth, and reduction in DO through fish and benthic respiration.

The monitoring programme will set out the sites to be monitored, including sites near the pens, far-field sites and reference sites. Sampling would be monthly over 12 months as a baseline and at the end of each stage and would include:

- Integrated surface samples for nutrients: TAN, nitrate-N, nitrite-N, TN, DRP, TP, TSS;
- Profiles of temperature, salinity, DO;
- Chl-*a*, as an indicator of phytoplankton biomass; and
- Phytoplankton species composition with a focus on potential harmful species.

Standards and limits for the water column monitoring will need to be developed and included in the proposed conditions but are likely to include limits on increases in TAN and chl-*a* above those recorded in baseline surveys or compared with reference sites, and reductions in dissolved oxygen at a set distance from the pens (eg. 250 m). The data set to be used as a baseline should be clarified in the conditions.

4.1.3 Biosecurity

The BMP will include a requirement for regular surveillance of disease in salmon stock and invasive pests on infrastructure.

4.1.4 Seabirds

Monitoring and recording of any entanglement during the staged development of the farms will be critical to confirm the effects are as predicted.

4.1.5 Mammals

As recommended by Clement (2019) monitoring to improve knowledge of how marine mammals will perceive offshore farm structures visually and acoustically, and importantly, to confirm their reactions to farms and whether they use the application site. Monitoring should include the collection of baseline data on species' use of the proposal area and associated Foveaux Strait waters while commencing a database of marine mammal sightings (similar to overseas examples).

Baseline monitoring prior to development, and monitoring after full development, should include acoustic surveys to characterise species occurrence in the region.

4.2 Management of Effects

4.2.1 Pests and disease

Preventing or minimising the introduction of pest species and disease, ensuring early detection and having appropriate management strategies for control and containment in place is critical for sustainable operation of the proposed farm and protection of the wider marine environment in Foveaux Strait. Even though the risks might be assessed as relatively minor, there will always be some risk. A full biosecurity management plan (BMP) for pests and disease biosecurity incorporating the matters described below is to be developed by Sanford prior to any development.

4.2.1.1 Pests

Management considerations are described in detail in Forrest (2019) and can be summarised as:

- Effective management of external vessels and other pathways, especially of biofouling. Measures should be based on antifouling requirements and “clean hull” standard;
- Hull biofouling management measures for vessels operating outside the Southland region and within the Southland region;
- Maintenance of a low level of fouling on farm structures that is consistent with operational needs for biofouling control. This includes using new infrastructure or infrastructure treated to ensure it is pest-free, all marine gear used is free of fouling and clean, residual water is treated appropriately, and no long stay anchoring of vessels other than the barges within farming areas;
- On-farm surveillance for early detection and elimination/containment of incursions. This will include maintaining farms to be free of wanted organisms and any unwanted organisms are properly disposed of; and
- Development of the application site in stages to monitor risk and ensure appropriate distances between farming areas to prevent spread of unwanted organisms.

4.2.1.2 Disease

The risk assessment for diseases has been carried out as a separate exercise and reported in the AEE. It was concluded that none of the known diseases of chinook salmon require additional risk management measures for the proposed farm at this time. However, when the potential effects on the nearby Bluff oyster fishery in Foveaux Strait were examined, two diseases of concern were identified, including spread of infection by *Bonamia ostreae* via biofouling on sea pens, moorings and service boats and barges, and infection with *Bucephalus* *longicornutus*. As a result of the assessment these diseases will require risk mitigation to reduce the risks associated with the proposed development to acceptable levels.

A comprehensive biofouling control programme as part of the BMP discussed above, that manages biofouling risks originating from all service shipping from BGB and other parts of New Zealand (including the Marlborough Sounds), will be required to reduce the increased risk of introduction of *B. ostreae* into bluff oyster populations in Foveaux Strait to within an acceptable appropriate level of protection.

In order to confirm whether chinook salmon can act as a final host for *B. longicornutus*, experimental exposure trials are recommended, in order to better inform planning agencies of the potential risk to oyster survival and recruitment posed by *B. longicornutus* infections vectored by chinook salmon. This would also confirm if further management is required.

It must be noted that while the final pen design and operational plan will be refined the base case scenarios such as receiving smolt from Big Glory Bay, and use of both submersible and above water pens have been set out. There are options for managing year classes, which would allow spatial separation with at least 8 km buffer zones between some farming areas as is global best practice. It is recognised that an unquantifiable risk remains that biosecurity leaks could allow exotic diseases to be introduced, and/or new endemic diseases could emerge in salmon aquaculture in New Zealand at some time in the future. Because of this, it is important that planning arrangements emphasise biosecurity management that equates to world's best practice.

4.2.2 Marine mammals

As recommended by Clement (2019) a Marine Mammal Management Plan (MMMP) will be developed prior to commencing operations. This should be developed by an experienced marine mammal expert prior to commencing operations to ensure that the most appropriate protection measures are in place, as is required for Best Aquaculture Practices' (BAP) international certification requirements.

Sanford does not use predator nets around the outside of the pens to reduce or dissuade predator attacks in its BGB operations. If it is also able to do so here, the lack of predator nets, along with proper cage maintenance, will reduce the risk of possible marine mammal entanglement significantly (see Tanner 2007). This factor likely accounts for the zero marine mammal entanglement / mortality record of salmon farms in BGB to date (A. Undorf-Lay, Sanford pers.com.).

The current increase in marine mammal occurrences around the farms indicates that Sanford should prepare for the possibility of a marine mammal entanglement by developing and putting in place appropriate management practices, such as an entanglement avoidance protocol, along with a MMMP. This consideration is particularly important given the number of internationally recognised endangered or threatened marine mammal species within these waters.

There are a range of additional BMPs regarding the set-up and operation of marine farms that can reduce risks of entanglement and other adverse effects to marine mammals. Many of these practices are already reflected in the Finfish Aquaculture ECOP developed by the New Zealand Salmon Farmers Association (NZSFA 2007) and/or already being undertaken by the farms. The requirements of the additional conditions to be included in the MMMP include procedures and practices to be implemented to minimise, to the extent practicable, the interactions of marine mammals and seabirds with the farm site.

4.2.3 Seabirds

Effects on seabirds can be managed by avoiding placing fish farms near ecologically significant shorebird and wading bird habitats, as has been already done in the case of this application. The major concern with seabirds and the pens themselves is exclusion and entanglement.

Management options will be implemented to reduce the risks of entanglement including staged development of the farms in conjunction with robust monitoring, best practice with nets, and not installing predator nets if practical and using new tougher.

4.2.4 General considerations

Considerable advancements have been made over the last 40 years including improved feeds with better FCRs, use of physical net cleaning instead of antifoulants, improved netting and seabed management.

Further developments in feed and operations, such as net cleaning and types of nets and net material, should be assessed regularly as part of the technological review included in the recommended new conditions.

Table 12. Summary of Key Management and Monitoring Measures for Project South

Actual or Potential Effect	Recommended Management Approach	Recommended Monitoring Action	Additional Measures Proposed by Sanford
Hydrodynamics			
Changes to current speed and direction	None required as effects very localised and small. This matter has already been addressed by the location and design of the five farming areas.	None	None.
Water quality and plankton			
Potential for increased concentrations of TAN and chl-*a*	None required. This matter has already been addressed in the siting of the farming areas in a high flow environment. If monitoring during the staged development of the farming areas identifies unexpected adverse effects an adaptive management action may be required. This could include measures such as reducing or changing location/configuration of pens if required.	Monitoring at edge of pens, far-field and reference sites before development and at the end of each stage. Monitoring to include physical measurements, nutrients, chl-*a* as a proxy for phytoplankton biomass, phytoplankton species with focus on harmful algae.	None.
Reduction in dissolved oxygen concentrations	None required. This matter has already been addressed in the siting of the farming areas in a high flow environment.	Routine daily monitoring at edge of pens and as part of water quality monitoring	
Benthic environment			
Deposition of waste feed and faecal material	None required. This matter has already been addressed in the siting of the farming areas in a high flow environment.	Monitoring at edge of pens, various distances up to 500 m from pens and reference sites before development and at the	None

Actual or Potential Effect	Recommended Management Approach	Recommended Monitoring Action	Additional Measures Proposed by Sanford
	If monitoring during the staged development of the farming areas identifies unexpected adverse effects resting of sites may need to be considered	end of each stage. Monitoring to include physical and chemical characteristics of sediment, infauna, and epifauna	
Changes to benthic biota	As above	As above	
Biosecurity			
Increased risk of introduced pest species on structures	Preparation and implementation of a biosecurity management plan (BMP) based industry best.	Monitoring for early detection of potential pests	None.
Increased risk of disease in farmed salmon	BMP to include actions to eliminate or contain new incursions. Sanford plan to conduct exposure trials to assess potential for salmon to act as intermediary for *Bucephalus longcornutus*,.	Monitoring for early detection of disease	
Increased risk of structures acting as hub for spread of disease to natural biota and oyster beds nearby	Adherence to the Controlled Area Notice (CAN) for *Bonamia ostreae* and introduction of a comprehensive biofouling control programme as part of BMP Location >20 km from other existing salmon farms and buffer of > 8km between the proposed farming areas and the nearest shoreline.	Surveillance for introduced pests and disease as part of monitoring programme.	As above

Actual or Potential Effect	Recommended Management Approach	Recommended Monitoring Action	Additional Measures Proposed by Sanford
Fish and fisheries			
Exclusion in farming areas	None required. Avoidance of coastal paua and lobster fishery areas by moving offshore has already been considered. Ensuring an adequate buffer between the farming areas and the commercial oyster fishery.	None	None.
Mammals			
Exclusion	Preparation of a Marine Mammal Management Plan (MMMP) prior to commencing operations to ensure that the most appropriate protection measures are in place, as is required for Best Aquaculture Practices' (BAP) international certification requirements. Development will be staged with comprehensive monitoring and management responses in place.	Passive acoustic monitoring will be undertaken prior to development and after full development during the main whale migration period. Interactions with the farm will be monitored by local sightings recording.	None
Entanglement	The MMMP will include an outline of a dis-entanglement protocol in the unlikely event that there is an entanglement that is consistent with BAP standards and timelines and review procedures. Predator nets will be avoided if possible.	Recording of any entanglement incident regardless of outcome	None

Actual or Potential Effect	Recommended Management Approach	Recommended Monitoring Action	Additional Measures Proposed by Sanford
Noise	Noise will be minimised to reduce exclusion or attraction	None	None
Birds			
Entanglement	Implementation of best available practices for net design and staged development, monitoring and adaptive management of the farming areas.	Monitoring of any bird entanglement	None.
Attraction to structures and penned fish	As above	As above	None

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