Ministry for Primary Industries
Manatū Ahu Matua

Exploration of Finfish Farming Opportunities in Port Pegasus/Pikihatti, Stewart Island

Summary of Phase 2 Assessment of Environmental Effects Reports

Prepared by the Aquaculture Unit

11 October 2017

Purpose of Summary

The Southland Regional Development Strategy (SoRDS) has identified opportunities for economic and social development within the Southland region. The strategy identifies aquaculture, in particular finfish aquaculture, as a leading opportunity for regional development. The process to investigate this opportunity is being led by SoRDS in partnership with MPI, DOC, MFE, and Ngāi Tahu.

The focus of these investigations is centred on whether Port Pegasus (North Arm), Stewart Island/Pikihatiti provides a suitable location to develop a viable finfish farm industry. Five key Assessment of Environment Effects reports have been initially prepared to inform this investigation.

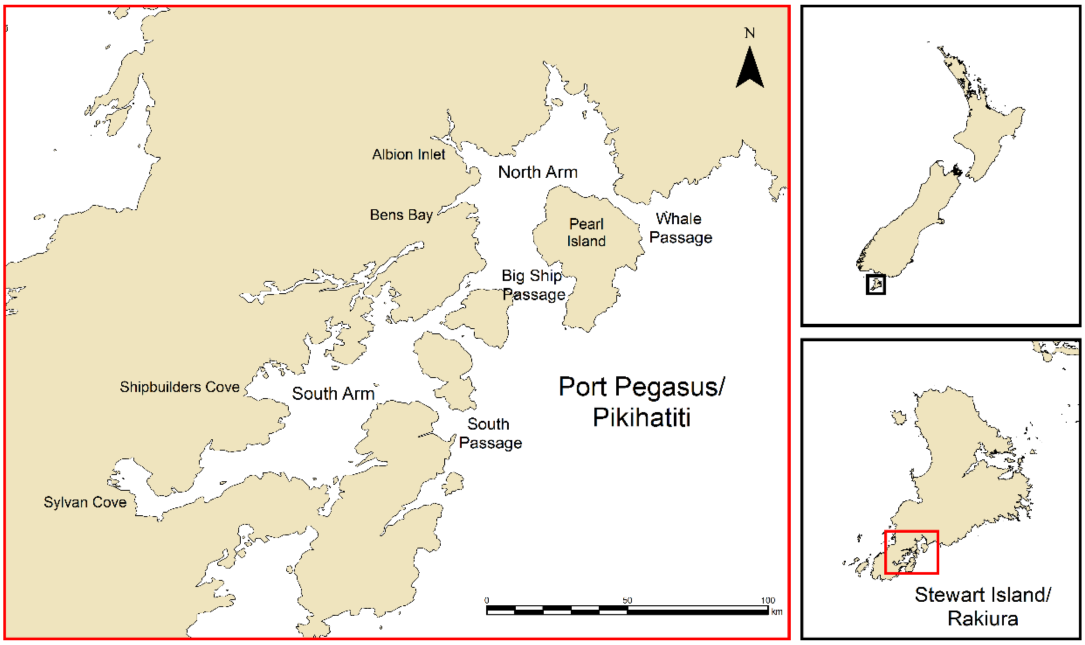
These are:

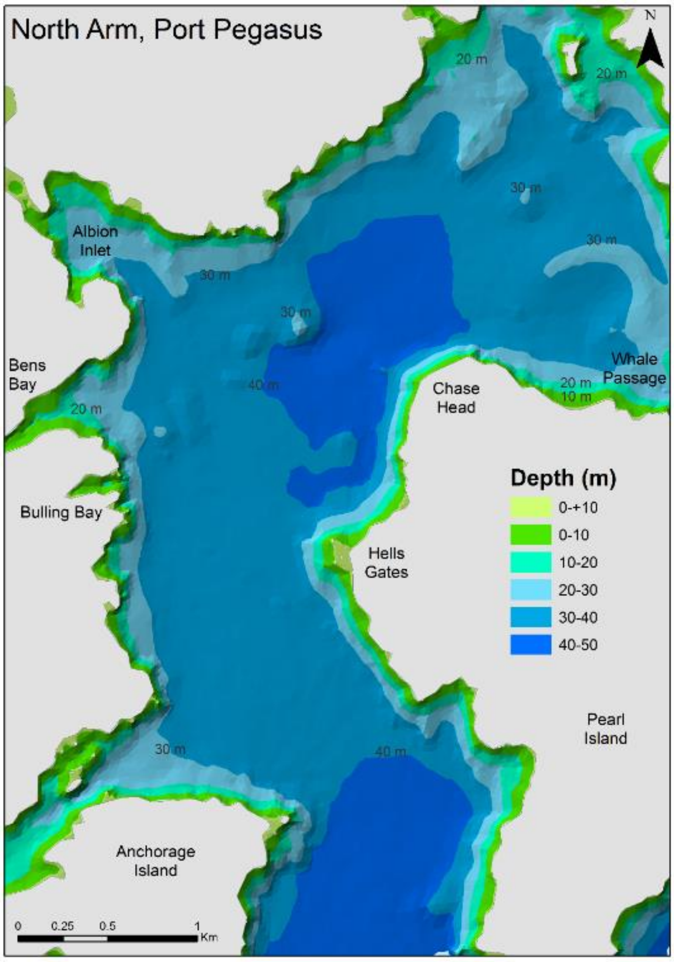
- *Benthic Habitat Assessment: North Arm, Port Pegasus/Pikihatiti* (6 October, 2017) – Cawthron Institute, Report No. 3047
- *Pelagic Biophysical Assessment: Port Pegasus/Pikihatiti* (10 October, 2017) – Cawthron Institute, Report No. 3076
- *Port Pegasus Salmon Farm: Indicative Business Case for new aquaculture in Southland* (12 September 2017) – New Zealand Institute of Economic Research
- *Port Pegasus/Pikihatiti Salmon Farms. Natural Character, Landscape and Visual Amenity Effects Assessment* (10 October 2017) – Boffa Miskell
- *Review of potential NZ sea lion interactions with aquaculture at Port Pegasus/Pikihatiti* (August 2017) - NIWA

This document presents the Executive Summaries of the five Assessment of Environment Effects reports in full. Note that the findings in each report relates only to the matters assessed in that relevant report. Each report should be considered within the context of all other reports.

Also included as Appendix 1 is an explanation of farm site selection and production scenarios used throughout the Assessment of Environment Effects reports. Appendix 2 shows the location of the four potential farm grow out areas (f1-f4) along with a smaller smolt growing area (s1).

This document does not provide any comment or recommendation on whether or not Port Pegasus, North Arm provides a viable finfish farming opportunity.





Map (top) and bathymetry in metres, relative to mean sea level (bottom) of North Arm, Port Pegasus/Pikihatiti.

Benthic Habitat Assessment: North Arm, Port Pegasus/Pikihatiti

Finfish aquaculture has been identified as a leading opportunity for economic and social development within the Southland region. The New Zealand government is committed to supporting well-planned and sustainable aquaculture growth, and are proceeding with a three-stage process to investigate this opportunity. Stage 1 assessments have identified the North Arm region of Port Pegasus/Pikihatiti (located at the southern end of Stewart Island/Rakiura) as potentially suitable area for development. Cawthron Institute was commissioned by the Ministry for Primary Industries and the Ministry of Business, Innovation and Employment to undertake further investigations on site suitability within the North Arm area to determine the suitability of the area for finfish farming operations. Stage 2 assessments included both benthic habitat and pelagic biophysical assessments (presented as separate reports).

The benthic habitat assessment focused on seabed areas that were likely to be of suitable depth for finfish farming. The survey aimed to determine the distribution of soft-sediment habitats, the location and size of offshore reefs identified, and the presence of habitats or taxa considered to have significant ecological, scientific or cultural value. Broad-scale habitat characterisation was achieved through a combination of sonar imagery, drop-camera and video sled footage and benthic grab sampling. Key findings regarding the benthic habitat assessment of the North Arm region are summarised below:

- Soft-sediment habitats within North Arm were separated broadly into two areas: an area to the north of Pearl Island, with sediments comprising higher proportions of mud particles and with mud-tolerant infaunal communities; and an area to the west of Pearl Island, with sediments having higher proportions of sand particles and infaunal communities more tolerant of the coarser substratum.
- Patch reefs with diverse invertebrate and fish assemblages extended into the mid-channel area from Bens Bay, as well as additional areas surrounding Chase Head.
- Soft-sediment habitats supported relatively sparse epifaunal assemblages (i.e. animals living on the seabed), when compared to similar semi-sheltered inshore environments around Stewart Island/Rakiura.
- Isolated areas of high epifaunal diversity were noted, in particular the coarse sand/cobble habitat identified near to the entrance to Whale Passage.
- Several taxa of ecological significance were identified within the surveyed area, including brachiopods, black coral, sea pens, tube-dwelling anemones and several large bivalve taxa.
- In general, taxa of ecological significance were sparsely distributed (< 1 per 10 m^2), and largely centred across areas of mud substrates to the north and northwest of Pearl Island. However, patches of greater abundance were found closer to patch reefs and within cobble habitats near to the entrance of Whale Passage.
- Macrofaunal communities present within North Arm are broadly representative of similar unimpacted environments elsewhere. Across the North Arm region, total abundance and species diversity was lower in sand substrates through Big Ship Passage, particularly when compared to mud substrates to the north of Pearl Island.
- Enrichment Stage (ES) scores were generally low across the North Arm region, reflecting natural conditions in the range of low-to-minor enrichment. In general, ES scores were slightly higher in the muddier sediments north of Hells Gates, possibly due to the close proximity of these sites to riverine inputs.

Results of the benthic habitat assessment outlined above were used to prioritise potential locations for finfish farming operations within the North Arm region. Circular exclusion ‘buffers’ were placed around areas of hard substrate or coarse-grained sediments and areas containing potentially sensitive taxa, as identified through sonar imagery and drop-camera transects. To provide additional guidance on suitable locations for potential farm sites, the Index of Suitable Location (ISL) for finfish farming was calculated for the entire North Arm area, based on depth and water current data. Results of the ISL analysis indicated that mid-channel areas in Big Ship Passage have the greatest potential for farming, when taking into account exclusion buffers and optimising water depth. Four potential farming areas (c. 10 ha each) were subsequently selected within Big Ship Passage, along with a smaller smolt growing area (c. 1.3 ha) at the northern coastline.

Depositional modelling, combining physical properties of water currents with farm configuration and production parameters, was used to predict the potential distribution and intensity of waste product (i.e. uneaten feed and faeces) deposition to nearby benthic habitats. In addition, depositional modelling provided an indication of the production capacity of the region, while staying within benthic guidelines with regards to associated seabed enrichment levels. Depositional modelling was carried out in isolation from any other considerations (e.g. water quality, natural character, landscape and visual amenity). Two sets of scenarios were modelled, based on the farming areas operating in a similar way to either low-flow or high-flow sites within the Marlborough Sounds region. This does not suggest that farm sites are 'high-flow', rather that some of the sites may be 'low-flow sites with episodic wave action' which may have a mitigating effect on benthic enrichment. The magnitude of that potential beneficial effect is currently unknown. The use of the high-flow assumption is for comparison purposes only, and does not suggest that the potential effect from waves would be of similar magnitude as high-flow tidal currents in the Marlborough Sounds. The 'high-flow' based scenarios and their associated potential production figures should therefore be interpreted with caution. For the depositional modelling, the total number of pens at each site was varied to achieve lower production levels, which were calculated using a feed conversion efficiency ratio of 1.7:1.

Under low-flow scenarios, production estimates of between 2,800 and 6,000 tonnes per year were possible, while adhering to benthic Best Management Practice (BMP) guidelines. Deposition beneath the pens, and beyond, was predicted to be at levels that are likely to be assimilated by the benthic communities in the lower feed-input scenarios. Higher rates of deposition were predicted assuming the seabed could assimilate farm waste similar to that observed at high-flow sites. The higher rates predicted were due to the slight overlap in depositional footprints from each pen, and the increased feed input per pen under high-flow scenarios. Seabed enrichment within these small patches was predicted to reach very high levels and would be at the upper limit of enrichment effect allowed under the BMP guidelines, provided the farms performed like high-flow sites. The low-flow nature of the smolt site resulted in relatively high rates of deposition, concentrated largely beneath the pens. Excessive enrichment was predicted directly beneath the pens in some scenarios; however, beyond the pens the deposition of farm wastes was at levels likely to be assimilated by benthic communities.

If finfish farming is deemed appropriate in North Arm, a staged approach to development is recommended. This is due to the low-flow nature of the area and uncertainty around the effects of wave action on the seabed beneath the proposed farming areas near the entrance to Big Ship Passage. Detailed, site-specific 'Stage 3' assessments are recommended once final farm locations are decided. These assessments would recommend initial and predicted sustainable feed inputs to each of the sites. The BMP guidelines are recommended as an initial framework for monitoring and managing seabed effects. Due to uncertainty around the role that wave action will play in seabed enrichment trajectories, some site-specific adjustments to the BMP may be necessary over time. However, several years of seabed monitoring would be needed to guide any site-specific adjustments to the BMP guidelines. Careful management of feed inputs would be necessary at all farming sites, to ensure benthic effects remained within BMP guidelines. The use of benthic management tools (e.g. fallowing, seabed remediation, waste capture) may be possible to mitigate benthic effects, with long-term environmentally sustainable outcomes the priority. However, most of these tools are in the early stages of development and have yet to be tested at commercial scales in New Zealand, and each has environmental costs that require consideration. Fallowing has been tested in Marlborough, but requires additional farm space that increases the area of seabed affected by deposition. Waste capture and seabed remediation have been tested at a research scale in New Zealand, but both require the regular transport and disposal of large amounts of farm wastes, either at sea or in landfill.

Pelagic Biophysical Assessment: Port Pegasus/Pikihatiti

The Southland Regional Development Strategy (SoRDS) has identified opportunities for economic and social development within the Southland region. The strategy identifies aquaculture, in particular finfish aquaculture, as a leading opportunity for regional development. This report constitutes a Stage 2 assessment of the pelagic environment for the North Arm of Port Pegasus, a region identified as a potential farming area based on initial scoping assessments. A combination of modelling exercises as well as instrument measurements, and sampling carried out within the period April to May 2017 have helped to provide further information on the area.

Analysis of measured and modelled currents within North Arm shows that it offers low current flows which are not ideal for finfish aquaculture due to the reduced capacity for dissolved and organic waste dispersion and subsequently, higher benthic accumulation. Frequent episodic wave energy in the southern entrance to North Arm (Big Ship Passage) could present operational constraints to the use of this area and also act to reduce benthic accumulation of organic waste under net pens placed here. However, there are key differences between midwater tidal currents (used to define 'low' and 'high' flow sites) and benthic wave-driven currents. Tidally-driven currents occur daily over long time periods of several hours, whereas peak wave-driven currents occur for short periods of time (seconds) and rapidly change direction. Consequently the magnitude of any benthic effect from wave-driven currents could not be determined for this assessment.

In terms of pelagic effects, the hydraulic residence time of dissolved wastes is an important consideration. Models simulating the release of dissolved nitrogen from potential aquaculture sites in North Arm suggest residence times to be about 18 days within the Arm. This result implies there is the potential for dissolved finfish wastes to be retained longer in comparison to a similar farmed area in Big Glory Bay (BGB), which also has low flows and an estimated residence time of 10–13 days under light winds. The BGB farm has a thirty-year salmon production history with recent production estimated at about 3,500 ton per annum (tpa) of salmon. Given this long farming history without record of significant pelagic effects in BGB, and considering the longer residence time of North Arm, we have suggested an initial production limit of 2,200 tpa for North Arm. The feasibility of an initial 2,200 tpa production level would be determined following Stage 3 aquaculture assessments. Subsequent increases would only follow stable and acceptable water quality results over a period of time.

The modelled increase in total nitrogen (TN) from an initial 'low' production level (2,200 tpa) show that mean summer increases in TN of about 10% over North Arm are possible. The effects from modelled higher production scenarios (> 2,200 tpa) show that larger increases (about 31% at 6,000 tpa) could occur. A phytoplankton bloom that occurred in 1989 in BGB led to large mortalities of salmon. Bloom events could also occur naturally in North Arm, and modelling shows waste nitrogen from salmon farming has the potential to exacerbate bloom intensity from 20% to 70% depending on the production scenario considered (i.e. 2,200 to 6,000 tpa, respectively). However it is difficult to assess the ecological relevance of these rare large bloom events, because in the case of the BGB bloom there were no reported wider-ranging ecological effects.

Although we recognise the potential for significant pelagic water quality effects at high production scenarios, we note that nutrient-induced effects in the pelagic environment are extremely complex. Without surety of effects it is difficult to translate a 'large' change in nitrogen or chlorophyll-*a* into a 'good', 'bad' or 'significant' ecological change. Consequently, if high production scenarios (i.e. up to 6,000 tpa) are considered for this area, staged development from initially low production levels (e.g. 2,200 tpa) should be implemented cautiously and in combination with appropriate monitoring, to manage potential risks to the environment.

Port Pegasus Salmon Farm: Indicative Business Case for new aquaculture in Southland

This report presents an Indicative Business Case for establishing new salmon farming at Port Pegasus on Stewart Island.

We find that under a variety of assumptions, such an initiative **would deliver a net benefit to the Southland regional economy**. However, constraints placed on the current configuration of the salmon farm for environmental reasons limit the size of that net benefit to a low level.

The farm would support regional, national and industry growth strategies …

The proposed salmon farm uses a modern innovative system based on circular fish pens that would have lower visual impact than conventional pen farming. Located in Port Pegasus North Arm, an area flanked by conservation land, the salmon farm would have no shore based infrastructure in Port Pegasus but be serviced out of Bluff, and send its produce there for processing and distribution.

There is a strong strategic case for new salmon farming in Southland, as it would align with objectives in the Southland Regional Development Strategy, the Government's Business Growth Agenda, and the aquaculture industry's Aquaculture Strategy.

It would also support diversification and resilience of the regional economy by harnessing the natural resource of marine space to create a stream of value.

… and deliver net economic benefits under various assumptions

In this Economic Case, we examine eight 'central' scenarios which vary with the size of annual output and the intensity of use of marine farming equipment, to estimate their economic viability and their impact on Southland's GDP and employment.

The scenarios are based on two levels of intensity, leading to low output and high output variants for each of four configurations of growing pens used.

We find:

- All scenarios look moderately positive on the figures and assumptions we use. Benefit cost ratios are greater than one but not greater than 2, with most in the range of 1.1 to 1.2 under our central assumptions.
- Larger output volumes are more net beneficial than smaller volumes, which partly reflects the way scenarios are defined with similar fixed costs of equipment used at lower intensity in the low output options.
- The new farm would add 0.2% to 0.5% to Southland's GDP in our central scenarios, peaking in year 8 and generate between 97 and 238 Full Time Equivalent jobs, depending on the size of output.

The results are robust to changes in salmon volumes or values

- Under more optimistic price assumptions, the new farm would add 0.9% to Southland's GDP.
- Lower salmon prices or volumes will push down the present value of benefits. Our break-even analysis indicates that targeted tonnage could drop by between 9% and 27% for low output scenarios, or between 32% and 45% for high output scenarios, and the project would still break-even. The smallest scenarios

(4a and 4b) would break even at about 2,540 tonnes annual production, and the largest (1a and 1b) at about 4,370 tonnes.

Further modelling could firm up estimates

Our positive economic results could be improved by more detailed assessment to resolve some of the uncertainties around cost items. They could also be improved with other configurations of growing pens which might improve the utilisation of the capital equipment employed.

Computable General Equilibrium modelling of selected scenarios could also broaden the impact analysis to examine the indirect flow-on effects through the economy of the new salmon farm, if established.

The latest changes to farm configuration and location to reduce environmental impacts have constrained the production of the salmon farm and reduced its potential contribution to economic and strategic aims. These contributions would increase with larger production than is currently provided by the current configuration.

Port Pegasus / Pikihatiti Salmon Farms. Natural Character, Landscape and Visual Amenity Effects Assessment

The Ministry for Primary Industries (MPI) along with The Southland Regional Development Strategy (SoRDS) have identified opportunities for fin fish farming within the Southland Region. Investigations into this have identified the North Arm of Port Pegasus, Stewart Island/ Rakiura as being an area where fin fish farming could occur. Boffa Miskell was commissioned by MPI and Environment Southland to undertake a Natural Character, Landscape and Visual Amenity Assessment for investigations for various scenarios of fin fish farming, assisted by ecological data provided by Cawthron, the Department of Conservation and Environment Southland.

The North Arm of Port Pegasus is located in a part of the remote and isolated east coast of southern Stewart Island. Stewart Island is renowned for its wild and remote landscape values, containing very high levels of naturalness and very high heritage values. Human modification is limited to discrete parts of the island.

Being remote and isolated from much of mainland New Zealand has resulted in the island holding a relatively diverse number of terrestrial habitats, ranging from indigenous forests and shrublands to wetlands, sand/ dune communities and alpine ecosystems. There is a wide diversity of indigenous species on and around Stewart Island, including rare and endemic lizards and invertebrates, and birds such as the Stewart Island brown kiwi/tokoeka.

Within the seascape or the marine environment, Stewart Island/ Rakiura is located within the Southern Ocean, at one of the world's great oceanic boundaries – the subtropical convergence, where the prevailing westerly wind and currents from the Tasman Sea moderate the temperatures protecting the island from the cooler subantartic waters further south. An array of marine wildlife lives within the sheltered and more exposed waters off Stewart Island/Rakiura including fur seals, sea lions and yellow-eyed penguins. The marine environment of Stewart Island is one of the largest areas of highly natural marine habitats in New Zealand. It is the southern extreme of many mainland species and communities.

In terms of cultural and heritage aspects, Stewart Island is extremely important to Maori where numerous middens, burial areas and waka-landing sites have been identified that support this. European adventurers have also explored this island, setting up sealing and whaling related activities.

Based on the above, Stewart Island, and the North Arm of Port Pegasus, holds special landscape values and has been assessed as being an Outstanding Natural Landscape, under Section 6(b) of the RMA and under Policy 15 of the NZCPS.

Furthermore, due to North Arm's limited modifications holding almost intact indigenous marine and terrestrial habitats, it is concluded that this area retains Outstanding levels of Natural Character under Section 6(a) of the RMA and under Policy 13 of the NZCPS.

Allied to this, the Island, including North Arm, also holds very high levels of amenity values.

The introduction of structures and modifications will affect many of the values that make this part of Stewart Island outstanding. For landscape, it is considered that the insertion of salmon farming would adversely affect the landscape and natural qualities of North Arm of Port Pegasus and of Big Ship Passage to such a degree that the area, or part of the area, could no longer be considered outstanding, irrespective of a chosen scenario. Part of North Arm and Big Ship Passage would then be aligned with the non-outstanding rating of Big Glory Bay and parts of Half Moon Bay, where a relatively high level of development has occurred. As a result, it is considered that the scenarios assessed here would be contrary to the RMA and the direction of the objectives and policies of Policy 15 (1) of the New Zealand Coastal Policy Statement, as well as the regional and district plans. The effects would be significant within the North Arm of Port Pegasus.

For natural character, and with the natural elements, patterns and processes evident within North Arm being amongst the highest in the country, these enclosed waters will be adversely affected by the development scenarios, both at a broad scale and at a more local scale. The farm scenario would interrupt and be discordant with the natural elements, patterns and processes that are currently present and would affect the scale and natural cohesiveness of the area, directly impacting on experiential aspects. It is concluded that all scenarios will have very high adverse natural character effects both at the broad and more local scales. The scenarios would also be inconsistent with the RMA and the direction of Policy 13 (1) (a) of the New Zealand Coastal Policy Statement.

With visual amenity values, irrespective of which scenario is chosen, the grow out farms in Big Ship Passage would be very visible for up to 2km and when travelling south from North Arm, may appear partly against the horizon, amplifying their visual presence. They would affect the visual cohesion of the area and with their central presence within Big Ship Passage, their visual presence would be amplified.

The location of any semi-industrial style activity within an area retaining outstanding landscape and natural character values, with no or very little existing modification, will create significant adverse effects on those values that underpin the landscape and natural character overlays. Irrespective of where the farms are located and which scenario is selected, the effects cannot be avoided, remedied or mitigated. The key visual effects relate principally to the insertion of human elements within a wholly natural environment.

The significance of landscape, natural character and visual amenity effects is considered to be in the highest category on the scale of effects outlined in the methodology. The scenarios constitute a substantial change to an area holding some of the most sensitive and valued landscape, natural character and visual amenity values in the country, leading to highly adverse effects, irrespective of which scenario is chosen.

Review of potential NZ sea lion interactions with aquaculture at Port Pegasus/Pikihatiti

Port Pegasus supports a small but growing breeding population of New Zealand (NZ) sea lions (*Phocarctos hookeri*), designated as 'Nationally Critical' by the NZ Classification System and 'Endangered' by the International Union of Conservation of Nature. The Stewart Island population was deemed by the 2017 Threat Management Plan to be of special conservation importance due to: its future growth potential; its proximity to pre-human breeding habitat on the mainland; and because it is close to achieving breeding colony status (41 pups counted in 2017, compared with the requirement for 35 pups born annually in 5 consecutive years).

The Southland Regional Development Strategy has identified Port Pegasus as a potential area for salmon (*Salmonidae*) aquaculture. DOC and MPI requested a review of existing observations of NZ sea lions at Stewart Island and global experiences with aquaculture-otariid (fur seal and sea lion) interactions to inform an assessment of the potential impacts of the proposed fish farm at Port Pegasus on NZ sea lions.

Annual surveys of pup numbers and distribution confirm that Port Pegasus is the main breeding location of the Stewart Island population. An analysis of tracking data found that reproductive females forage almost entirely within 50 km of Port Pegasus and that the North Arm of Port Pegasus was well-used. A female haul-out site was identified within 1 km of proposed salmon grow-out pens. A non-linear increase in interactions has been observed for fish farms located within 20 km of existing haul-out sites of other otariid species. As such, the potential for interactions between NZ sea lions and the proposed salmon farms at Port Pegasus is extremely high.

The global review identified potential direct interactions that were consistent across otariids, including: entanglement mortality in nets and intentional harm to 'problem' individuals. Also, some potential indirect effects, including: habitat loss or degradation, visual or noise disturbance and the spread of parasites and disease.

Some consistently effective measures were identified for minimising direct interactions, including: the use of steel cages, or well-tensioned and maintained predator nets. However, the nature of interactions varied by otariid species and prior experience of NZ sea lion interactions with fish farms is extremely limited. Following best-practise, fish farm operators would need to demonstrate that management systems can be developed to effectively manage all potential direct and indirect interactions with NZ sea lions. Potential interactions with resident females and pups at Port Pegasus that disturb breeding sites or disrupt breeding behaviour are of particular concern.

The Stewart Island NZ sea lion population is thought to be growing and have ample resources for this growth to continue. Otariids are capable of rapid population growth (10-fold increase over 20 years assuming an Rmax of 0.12—used as a default for otariids) and rapid growth has already been observed in other NZ sea lion populations. An eventual switch to colonial breeding is expected, though the locations of future breeding colonies are difficult to predict. Aquaculture planning at Port Pegasus should consider the implications of a major increase in NZ sea lion numbers and associated changes to demographic composition and behaviour that could dramatically alter the frequency and nature of interactions in future years.

Appendix 1: Explanation of farm site selection and production scenarios

Selection of potential farm areas:

Results of the benthic habitat assessment were used to prioritise potential locations for finfish farming operations within the Port Pegasus North Arm area. Circular exclusion ‘buffers’ were placed around areas of hard substrate or coarse-grained sediments (100 m radius) and areas containing potentially sensitive taxa (250 m radius), identified through sonar imagery and drop-camera transects. Larger exclusion zones were used for potentially sensitive taxa as their exact densities and distributions are unknown.

To provide additional guidance on suitable locations for potential farm sites, an Index of Suitable Location (ISL) for finfish farming was calculated for the entire North Arm area, based on depth and water current data. Results of the ISL analysis indicated that mid-channel areas in Big Ship Passage have the greatest potential for farming, when taking into account exclusion buffers and water depth.

Four potential farming (grow out) areas (c. 10 ha each) were subsequently selected within Big Ship Passage (f1, f2, f3 and f4), along with a smaller smolt growing area (c. 1.3 ha) at the northern coastline. The smolt farm location was selected as it provided some separation from grow-out areas, a feature that was requested during discussions with industry. A maximum of 16 x 160 m circumference pens (two rows of eight pens, c. 20 m spacing between pens) was considered at each of the four potential farming areas. A maximum of 8 x 100 m circumference pens (two rows of four pens, c. 15 m spacing between pens) was considered for the smolt growing area.

Depositional modelling and feed inputs:

As an indicator of likely finfish production capacity within the North Arm area, varying feed input and cage configuration scenarios (a, b, c and d) were modelled across the four farming areas using DEPOMOD v 2.2. Two sets of scenarios were modelled (1 and 2), based on the farming areas operating in a similar way to either low-flow or more dispersive (high-flow[1]) sites within the Marlborough Sounds. This modelling was undertaken to test two very different biophysical response regimes to varying feed inputs.

Maximum feed inputs per pen for each farm area were based on preliminary DEPOMOD assessments for a range of feed inputs for a single pen at each farm area (131–400 t). Feed inputs that resulted in maximum depositional rates of ~6 kg m^{-2} yr^{-1} at the net pen edge were used for DEPOMOD assessments for the low-flow farm scenarios. Feed inputs that resulted in maximum depositional rates of ~13 kg m^{-2} yr^{-1} at the net pen edge were used for DEPOMOD assessments for the high-flow farm scenarios. These levels of deposition are predicted to result in c. ES 5 conditions if the effects of the farm are similar to low-flow or high-flow farm sites in the Marlborough Sounds region, respectively.

A maximum of 64 grow-out pens (16 pens per area) across the four farm areas were assessed in the modelling, so maximum production was associated with all pens operating at all farms (Table A9.1). Scenarios with lower levels of production were achieved by reducing the number of pens at each of the farm areas. Across the two sets of scenarios (low-flow/high-flow), feed input per pen over a 1-year period varied depending on whether the effects of the farms were modelled as behaving like low-flow or high-flow sites.

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[1] This does not suggest that farm sites are ‘high-flow’, rather that some of the sites may be ‘low-flow sites with episodic wave action’ which may have a mitigating effect on benthic enrichment. The magnitude of that potential beneficial effect is currently unknown. The use of the high-flow assumption is for comparison purposes only, and does not suggest that the potential effect from waves would be of similar magnitude as high-flow tidal currents in the Marlborough Sounds. The ‘high-flow’ based scenarios and their associated potential production figures should therefore be interpreted with caution.

As the total number of pens varied across scenarios, the total feed input at each farm area also varied. The feed inputs resulted in scenarios with a range of production levels at each site (~2,800 to 8,000 t production, per annum; Table A9.1). The likely production from each scenario was estimated using a feed conversion efficiency (FCE) ratio of 1.7:1.

For the smolt farm, a feed level of 5% of the total feed input across the four grow-out farms was used across the two sets of scenarios (238 to 680 t per annum; Table 1). Smolt feed was spread evenly across 4, 6 or 8 smolt pens in each scenario, which resulted in feed inputs of 60 to102 t per pen (per annum).

Table A9.1. Farm scenarios and parameters, including feed input per pen (tonnes per annum), number of pens (160 m circumference for grow-out and 100 m circumference for smolt), total feed input and estimated production (tonnes per annum) for the four grow-out areas (f1-f4) and the smolt growing area (s1).

Scenario	Input parameters	Farming area				Grow-out totals	Smolt totals
		f1	f2	f3	f4		
1a	Feed per pen (tonne)	**131**	**131**	**150**	**225**		64
	Number pens	16	16	16	16	64	8
	Total feed (tonne)	2,100	2,100	2,400	3,600	10,200	510
	Total production (FCE 1.7)	1,235	1,235	1,412	2,118	6,000	
2a	Feed per pen (tonne)	**131**	**131**	**150**	**225**		63
	Number pens	8	10	14	14	46	6
	Total feed (tonne)	1,050	1,312.5	2,100	3,150	7,613	381
	Total production (FCE 1.7)	618	772	1,235	1,853	4,478	
3a	Feed per pen (tonne)	**131**	**131**	**150**	**225**		79
	Number pens	6	8	12	12	38	4
	Total feed (tonne)	787.5	1,050	1,800	2,700	6,338	317
	Total production (FCE 1.7)	463	618	1,059	1,588	3,728	
4a	Feed per pen (tonne)	**131**	**131**	**150**	**225**		60
	Number pens	4	6	8	10	28	4
	Total feed (tonne)	525	787.5	1,200	2,250	4,763	238
	Total production (FCE 1.7)	309	463	706	1,324	2,801	
1b	Feed per pen (tonne)	**175**	**175**	**200**	300		85
	Number pens	16	16	16	16	64	8
	Total feed (tonne)	2,800	2,800	3,200	4,800	13,600	680
	Total production (FCE 1.7)	1,647	1,647	1,882	2,824	8,000	
2b	Feed per pen (tonne)	**175**	**175**	**200**	300		85
	Number pens	8	10	14	14	46	6
	Total feed (tonne)	1,400	1,750	2,800	4,200	10,150	508
	Total production (FCE 1.7)	824	1,029	1,647	2,471	5,971	
3b	Feed per pen (tonne)	**175**	**175**	**200**	300		102
	Number pens	6	8	12	12	38	4
	Total feed (tonne)	1,050	1,400	2,400	3,600	8,450	407
	Total production (FCE 1.7)	618	824	1,412	2,118	4,971	
4b	Feed per pen (tonne)	**175**	**175**	**200**	300		79
	Number pens	4	6	8	10	28	4
	Total feed (tonne)	700	1,050	1,600	3,000	6,350	317
	Total production (FCE 1.7)	412	618	941	1,765	3,735	

Appendix 2: Location of potential farming (f1-f4) and smolt (s1) growing areas